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STATUS OF CORAL REEF AFFECTED BY DIFFERENT IMPACTS IN SOME SITES OF THE RED SEA

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ABSTRACT

Using Using SCUBA diving, surveying the coral reef communities at four sites, Red Sea Egypt was done. These sites are: Ras El Behar (polluted by petroleum oil), El-Hamraween (impacted by phosphate shipping), Shabrour Umm Gam'ar (harmed by recreational activities and has been suffering from the outbreak of *Acanthaster planci* during 1998) and Kalawy (a control site). The skeletal growth of the coral *Stylophora pistillata* was promoted greatly at the expense of other corals, in presence of chronic oil pollution (Ras El-Behar). In contrast, this species was completely suppressed in presence of phosphate and sulphur enrichment. Petroleum oil led to coral scarcity, space monopolization by one coral and increased sea urchins and algae. Coral reefs enriched with phosphate in the field, surprisingly was accompanied by extraordinary well flourishing corals. El-Hamraween was the only site having as higher number and abundance of *Acropora* as the control site. The abundance of *Porites* and *Pocillopora* was higher than the control site. Shabrour Umm Gam'ar, the site suffering from *Acanthaster planci* outbreak during 1998, was characterized by soft corals which were more abundant than stony corals, indicating that soft corals have higher rate of growth and recovery than stony corals after *Acanthaster planci* attack. Hydrocorals were abundant in the control site (kalawy).

1. INTRODUCTION

The Red Sea is a unique and outstanding environment with high biodiversity compared to other aquatic environments in Egypt. It is also rich of coral reefs which are considered among the best underwater parks in the world beside their scientific, touristic, economic and medical value which make them worth studying and monitoring the effect of different impacts. These coral reef environments have faced a lot of impacts throughout the last few decades, like petroleum oil pollution, mining especially phosphate and recreational activities (diving and snorkeling). Informations about the effect of these impacts on the Red Sea coral reefs are still few. The Red Sea, especially at the Gulf of Suez is rapidly developing as one of the world's largest offshore oil production areas (Dicks, 1984). The frequency of oil spills in tropical seas may threaten coral reef survival and some of the past research has indicated that oil alone as well as oil dispersed with chemical dispersants is toxic to corals (Knap, 1987). Negri and Heywards (2000) showed that petroleum products cause the inhibition of Fertilization and larval metamorphosis of the coral *Acropora millepora*. Hawkins *et al*. (1991), on their study of the effect of phosphate ship grounding on a Red Sea coral reef, found coral smothering. Corals in the areas polluted by phosphate may be under stress because of reduced light intensity, inhibition of calcification by excess phosphate, and increased sediment load (Walker and Ormond, 1982). Abu-Helal (1994) discussed the effects of the exported raw phosphate powder as the main source of pollution on the concentration of uranium in four hard and two soft corals from the Gulf of Aqaba, Red Sea. The attraction of tropical seas, convenient transportation and the popularity of SCUBA diving usually bring increasing numbers of tourists in close proximity to coral reef ecosystems (Rogers, 1988). Tourism has been implicated in the degradation of many reef areas (Rashid, 1980).

The aim of the present study is to quantify coral reef status in terms of abundance at four Red Sea sites, the first one is polluted by petroleum oil (Ras El-Behar), the second is polluted by phosphate and sulphur enrichment during their shipping (El-Hamraween), the third is impacted by recreational activities (Shabrour Umm Gam'ar) and the fourth is a control site representing the unpolluted area (Kalawy area).

2. MATERIAL AND METHODS

The study areas include 4 sites extending along the western coast of the Gulf of Suez and the Red Sea proper (Fig .1). Site 1 (Ras El-Behar), at the southern end of the Gulf and polluted by petroleum oil coming from the nearby oil fields and oil tankers. Site 2 (Shabrour Umm Gam’ar reef) is an offshore site, about 12 km south Hurghada City. The seaward side of the reef, having high waves and currents, is at the north-eastern direction while the leeward side, which is considerably sheltered, lies at the southwestern side. This site is impacted by recreational activities and has been suffering from the outbreak of the crown-off-thorns starfish *Acanthaster planci* during 1998. Site 3 (Kalaway area) lies about 30km south safaga City and is considered as a control site. Site 4 (El-Hamraween harbour) lies about 20 km north to Quseir City and is considered as one of the old phosphate harbours on the Egyptian Red Sea coast. The site is a coastal area in the form of coral reef patches which up to 4m depth.

SCUBA diving and 1m^2 quadrat, with a quadrat grid, were used for surveying the benthic coral reef communities. Twenty-five quadrats, 1m intervals, per depth zone were positioned parallel to the shore at each of the depths 1m, 3m, 5m, 8m, 12m, 15m and 20m in each of Shabrour Umm Gam’ar and Kalawy. However, only 25 quadrats were used at each of the two depths 3m and 4m in the two sites Ras El Behar and El Hamraween because of the shallowness of the two sites. Series of underwater photos were taken at each site, close up photos were also taken in order to help identification of species. Sea life Reef Master Digital Camera, with external flash attachment, was used for photography, close up photography was carried out using 16x and 32x magnifying lenses.

Corals and other groups were quantified in terms of abundance relative to the total number of individuals. Relative abundance of a given taxon was calculated as carried out by Bouchon (1980) as follow:

Where the dominance of a given taxon = (number of individuals of that taxon / total umber of individuals) × 100

3. RESULTS AND DISCUSSIONS

Four ranges of abundance were categorized in the studied sites. The first range was less than 1 (1-21 individuals per whole site) and categorized as scarce, the second range was 1-4 (22-64 individuals per the whole site) and categorized as frequent, the third range was from more than 4-8 (65-170 individuals per whole site) and categorized as common and the fourth range was more than 8 (171-837 individuals per whole site) and categorized as abundant.

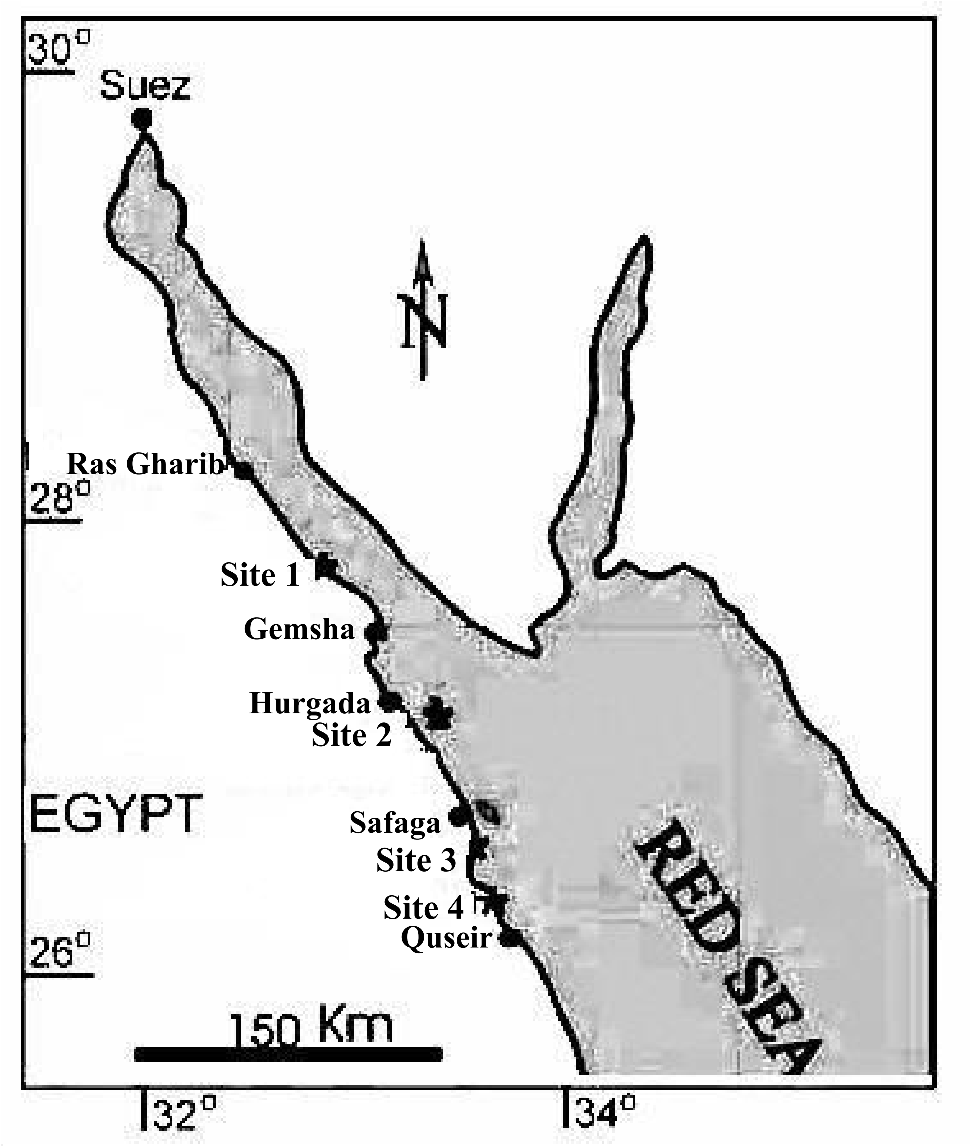

Fig. (1): Location map of the study sites.

*** Study sites**

The relative abundance of different species of corals and other taxa of the studied sites are shown in Tables (1, 2 and 3), and graphically represented in Figs. (2-5).

Site 1 (Ras El-Behar) had 13 recorded stony corals but no recorded soft or hydrocorals. The stony coral *Stylophora pistillata* was the only abundant species, with non expectedly big and thick branches, while most other corals were scarce. Surprisingly, Rinkevich and Loya (1979), in their long term laboratory experiment on *Stylophora pistillata*, found that chronic oil pollution damages the reproduction ability of this coral. Most probably that: although the sexual reproduction, and in turn larval development, of the scleractinian coral *Stylophora pistillata* are damaged by chronic oil pollution, the growth of adult polyp and in turn skeletal growth, i.e asexual reproduction may increase greatly at the expense of other corals. The sea urchin *Diadema setosum* was common in Ras El-Behar and frequent in the other sites, this was associated with the higher abundance of macrolgae and algal turf (the food of sea urchins) in this site. This is in agreement with Falkowski *et al.* (1998) who reported that the competitive balance between corals and macroalgae is shaped primarily by the magnitude of herbivory by sea urchins and nutrient availability. Herbivory is often the important regulator of competition between algae and corals (Hughes *et al*., 1999).

For site 2 (Shabrour Umm Gam'ar), 19 stony corals, 6 soft corals, 2 hydrocorals, 1 black coral (*Cerrhipathes spiralis*) and 1 stoloniferian coral (*Clavularia* sp)were recorded. Among the recorded stony corals, only one species (*Acropora hyacinthus*) was common, 3 species (*Pocillopora damicornis, Tubastraea* sp., and *Favia speciosa*) were frequent and the rest of species were scarce. Among the recorded soft corals, *Sarcophyton* sp. was abundant, 2 species (*Sinularia* sp. and *Xenia* sp.) were common and 3 species (*Lemnalia* sp., *Lobophytum* sp. and *Scleronephthya* sp.) were frequent. Also, the *Clavularia* sp. was frequent. The recorded black and hydrocorals were all scarce. Shabrour Umm Gam'ar, the site suffering from *Acanthaster planci* outbreak during 1998, is characterized by soft corals which are mostly abundant, common or frequent in contrast to stony corals which are mostly scarce. This seems that, soft corals have higher rate of growth, competition for space and recovery than stony corals after *Acanthaster planci* attacks. Benayahu and Loya (1981) found that soft corals are the major competitors overgrowing hard corals. Benayahu (1985) stated that, soft corals compete for space with true stony corals and cause their death. The tabular stony coral *Acropora hyacinthus* is an exception as it is recorded as abundant species. This can be explained by the interpretation of Ammar (2003) that the resistance of the touched species of stony corals could be species specific for a certain species of soft corals. The scarcity of the black coral *Cerrhipathes spiralis* in Shabrour Umm Gam'ar and its absence in the other sites support the claim of Warwick and Clarke (1993) who found an increased variability as a symptom of stress in different marine environments. Porter *et al*. (1999) also mentioned that the impacts of disturbances on coral distribution depend on the type, scale and frequency of disturbance. The increased coralline algae at Shabrour Umm Gam'ar was among the possible reasons that have led initially to *Acanthaster planci* infestation in that site (Ammar, 1998). The highest amount of rocks in Shabrour Umm Gam'ar is associated with the predation of corals, by *Acanthaster planci*, which leave them just bare rocks.

In site 3 (Kalawy), 24 stony corals, 3 hydrocorals, 2 stoloniferian corals, 1 soft coral and 1 blue coral (*Heliopora coerolea*) were recorded. Among the recorded stony corals, 2 species (*Acropora hemperichi* and *Goniopora columna*) were abundant, 5 species were common, 11 were frequent and the rest were scarce. The three recorded hydrocorals (*Millepora platyphylla*, *M. dichotoma* and *Distichopora* sp.) were abundant, common and frequent, respectively. The abundance of hydrocorals in the control site (Kalawy), especially on the reef flat and reef crest agrees with the result of Ammar and Emara (2004) who reported that, *Millepora dichotoma* prefers clear water and cannot tolerate excessive sediments. Ammar (2004) also reported that, *Millepora* sp. prefers high illumination and has a strong skeletal density to tolerate strong waves.

Table (1): Abundance of different species of corals in the studied sites ++++= abundant, +++=common, ++=frequent, +=scarce and – = absent.

	Site 1 (Ras El Behar)	**Site 2 (Shabrour Umm Gam'ar)**	**Site 3 (Kalawy)**	**Site 4 (Hamrween)**
Hydrocorals				
Millepora dichotoma Linnaeus, 1758	-	+	+++	+
Millepora platyphylla Linnaeus, 1758	-	-	++++	+
Distichopora sp. Lamarck, 1816	-	+	++	-
Octacorallia				
Clavularia sp. De Blainville, 1830	-	++	++	-
Tubipora musica (organ-pipe coral) Linnaeus, 1758	-	-	+	-
Sinularia sp. May, 1898	-	+++	-	+
Xenia sp.	-	+++	+	+
Lemnalia sp.	-	++	-	-
Lobophytum sp. Marenzeller, 1886	-	++	-	-
Sarcophyton sp. Lesson, 1834	-	++++	-	-
Scleronephthya sp.	-	++	-	-
Heliopora coerolea (Blue Coral) De Blainville, 1830	-	-	+	-
Hexacorallia				
Stylophora pistillata Esper, 1797	++++	+	++	-
Seriatopora hystrix Dana, 1846	-	+	++	-
Acropora hyacinthus Dana, 1846	++	+++	-	-
Acropora millepora Ehrenberg, 1834	++	-	-	-
Acropora squarrosa Ehrenberg, 1834	++	-	-	++
Acropora cytheraea Dana, 1846	-	-	+	+++
Acropora hemperichi Ehrenberg, 1834	-	-	++++	++
Acropora digitifera Dana, 1846	-	-	-	++
Acropora eurystoma Klunzinger, 1879	-	+	+	++
Acropora humilis Dana, 1846	-	+	+++	++++
Acropora nasuta Dana, 1846	-	-	-	++

Table (1). Continued

Acropora cerealis Dana, 1846	-	-	-	+
Acropora chesterfieldensis Veron & Wallace, 1984	-	-	+	-
Acropora pharaonis Edwards & Haime, 1860	-	-	+++	-
Acropora verweyi Veron & Wallace, 1984	-	-	++	-
Pocillopora verrucosa Ellis & Solander,1786	-	+	++	-
Pocillopora damicornis Linnaeus,1758	-	++	++	++++
Tubastrea sp. Lesson , *1829*	-	++	-	-
Pavona maldivensis Gardinar,1905	+	-	-	-
Pavona varians Verrill,1864	-	-	+++	-
Coscinaraea monile Forskal,1775	+	-	-	-
Favia speciosa Dana,1846	+	++	-	-
Favia pallida Dana,1846	-	-	-	+
Favia laxa Klunzinger, 1879	-	+	-	-
Favia amicorum Edwards & Haime, 1850	-	-	-	+
Favites flexusa Dana,1846	-	+	++	-
Favites persi Faure & Pichon,1978	-	+	-	-
Favites acutocollis Ortmann, 1889	-	-	+	-
Hydnophora micronos Lamark,1816	-	+	-	-
Siderastraea savignyana Edwards & Haime, 1850	-	-	-	+
Goniopora klunzingeri Marenzeller, 1906	+	-	-	-
Goniopora somaliensis Vaughan,1907	-	-	-	++
Goniopora columna Dana,1846	-	-	++++	+
Goniastraea palauensis Yabe, Sugiyama and Eguchi, 1936	-	+	-	+
Goniastraea retiformis Lamark,1816	-	+	-	-
Porites (Synaraea) undulate Klunzinger, 1879	-	-	++	++++
Porites (S.) iwayamaensis Eguchi, 1938	-	-	++	-
Porites (Synaraea) rus Forskal,1775	-	-	-	+++
Porites solida Forskal,1775	-	-	+	++++
Porites lutea Edwards & Haime,1851	-	-	-	++++
Porites compressa Dana,1846	-	-	-	+++
Porites columnaris Klunzinger, 1879	-	+	-	-
Porites echinulata Dana,1846	-	+	-	-
Alveopora sp. Dana,1846	-	-	++	++
Fungia repanda Dana,1846	+	-	+	-
Gardineroseris planulata Dana,1846	++	+	-	-
Platygyra lamellina Ehrenberg,1834	+	-	-	-
Echinophyllia aspera Ellis & Solander,1786	-	-	++	-
Leptoseris mycetoseroides Vells,1954	-	-	+++	-
Psammocora haimaena Edwards & Haime,1851	-	-	+++	-
Montastraea curta Dana,1846	+	-	-	-
Montastraea annuligera Edwards & Haime,1849	-	-	-	+
Montipora circumvallata Ehrenberg,1834	+	-	-	-
Montipora ehrenbergi Verrill, 1872	-	+	-	-
Montipora stilosa Ehrenberg,1834	-	-	++	-
Cerrhipathes spiralis (Black coral)	-	+	-	-

Table (2): Abundance of sea anemones, ascidians, sponges, sea urchins, algae, molluscs, rocks and dead corals in the studies sites

Sea anemones				
Entacmaea quadricolour	+	-	-	-
Palythoa sp.	-	-	++	-
Parazoanthus sp.	-	-	++	-
Ascidians				
Polycitorella sp.	-	++	-	-
Sponges				
Haliclona sp.	+	-	-	-
Gelliodes sp.	-	+	-	-
Phyllospongia lamellosa	-	+	-	-
Aaptos suberitoides	-	-	++	-
Sea urchins				
Diadema setosum	+++	++	-	++
Algae				
Ulva sp.	++	-	-	-
Algal turf	++	-	-	+
Coralline algae	+++	+++	+	+
Molluscs				
Tridacna sp.	+	-	++	+++
Rocks	+	++++	+	++
Dead corals	++	+	+	+

Table (3): Measurements of phosphate, hydrocarbons in water, sedimentation rate and diver carrying capacity in the studied sites.

	Phosphate (µg/L)	**Hydrocarbons in Water (µg/L)**	**Sedimentation Rate (mg/cm^2/day)**	**Number of divers/year (diver carrying capacity=10000diver/year)**
Site 1 (Ras El Behar)	24.96	31.3	1.76	0
Site 2 (Shabrour Umm Gam'ar)	9.92	8.9	0.41	20000
Site 3 (Kalawy)	7.36	5.8	19.60	500
Site 4 (Hamraween)	501.76	6.8	158.20	1000

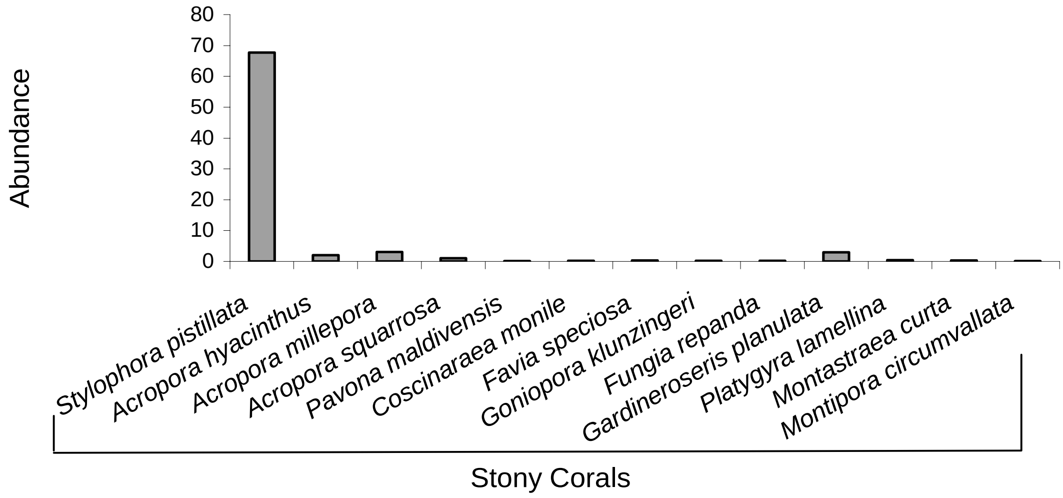

Fig. (2): Graphic representation of the relative abundance of different coral species of site 1 (Ras El Behar).

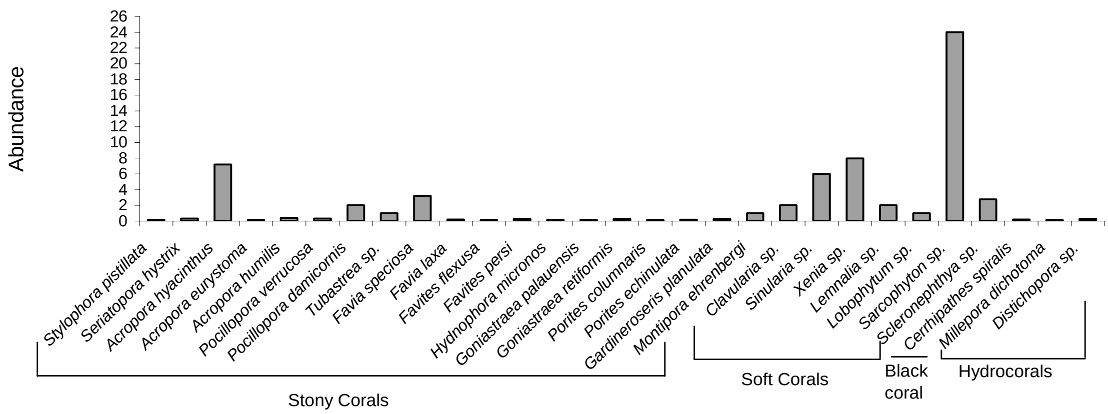

Fig. (3): Graphic representation of the relative abundance of different coral species of site 2 (Shabrour Umm Gam'ar).

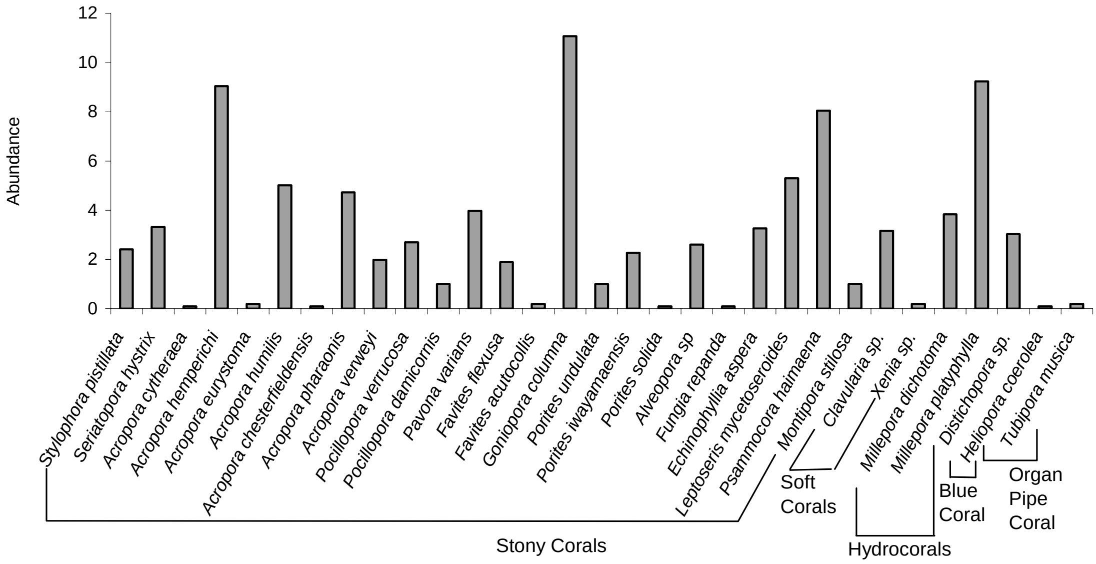

Fig. (4): Graphic representation of the relative abundance of different coral species of site 3 (Kalawy).

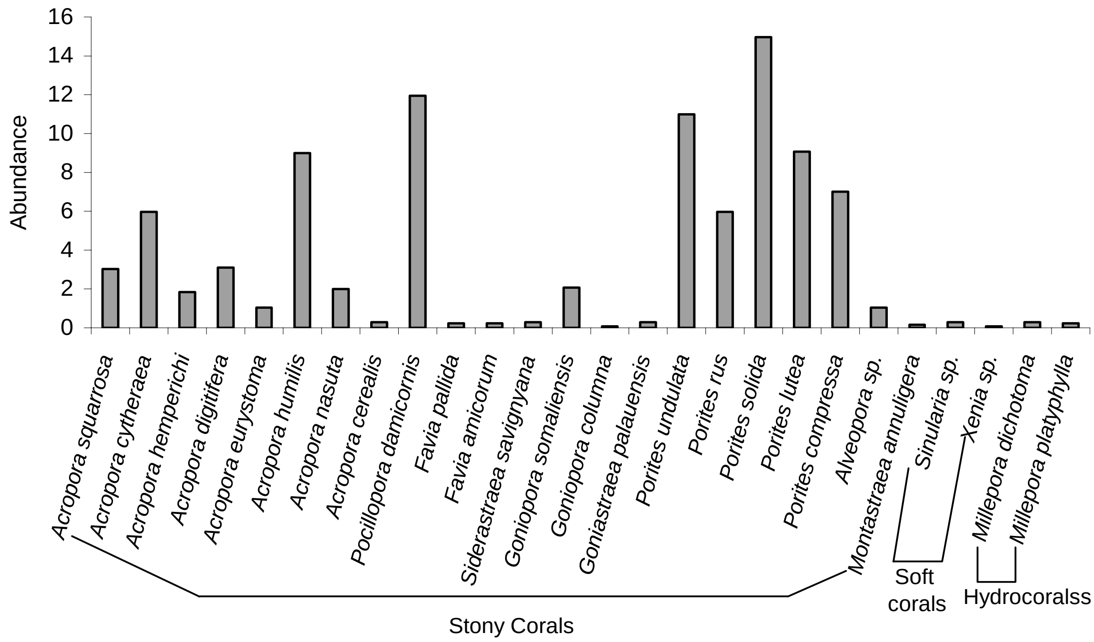

Fig. (5): Graphic representation of the relative abundance of different coral species of site 4 (El Hamraween).

The higher depths (18-22m) of the same control site were characterized by the abundance of the massive stony coral *Goniopora columna*, the encrusting and flattened corals *Pavona varians*, *Leptoseris mycetoseroides* and *Psammocora haimaena*. These depths are mostly overshadowed by the areas upper to the slope because of its sharp steepness. This result agrees with the conclusion of Frick and Schuhmacher (1982) that, branched colonies usually decrease with depth and are replaced by encrusting and flattened colonies, which have a great ability to entrap light. Todd *et al*. (2004) suggested that corallites expand, extend and deepen in high light condition. However the light is the primary controlling factor inducing small-scale morphological change in coral reefs. The highest number and abundance of the species of genus *Acropora* (branching corals) especially in the shallow area (4-8m depth) of the control site confirms the finding of Porter (1976) that light capturing abilities in shallow water is favoured by branching corals which have more photosynthetically-active and hence organically-productive tissue per unit volume of water than a hemispherical head of the same volume. The paucity of those species of *Acropora* (except *Acropora humilis* and *A. hemperichi*), on the reef flat and the reef crest is perhaps due to their lower skeletal strength which cannot tolerate the strong wave breakings in those zones. Brown *et al*. (1985) reported that the corals in exposed areas can have denser skeletons and hence may be more resistant to destruction than those in more sheltered areas. Rodgers *et al*. (2003) mentioned that the skeletal strength obtained from the experiments correlate with the wave energy present in the environment in the region they inhabit, suggesting that structural strength of corals is an adaptive response to hydraulic stress. The ability of *Millepora* sp. and *Acropora humilis*, in contrast to other recorded species, to increase their skeletal densities as an adaptation to exposed conditions can be explained by the statement of Wellington and Glynn (1983) and Scoffin *et al*. (1992) that, the skeletal density react differently with the surrounding conditions. Among the recorded stoloniferian corals, one species (*Clavularia* sp.) was frequent while the other(*Tubipora musica*) was scarce. The only soft coral (*Xenia* sp.) was scarce. The two anemones *Palythoa* sp. and *Parazoanthus* sp. were frequent and recorded only in Kalawy area. Four species of sponges were recorded, the most frequent one (*Aaptos suberitoides*) was found in Kalawy. The zonation of the octocoral *Clavularia* sp. and sea anemone *Palythoa* sp. at 11-15m depth of the control site is probably due to their flexible tissues that can adapt with the current found in that zone.

In site 4 (El-Hamraween), 22 stony corals, 2 soft corals and 2 hydrocorals were recorded. Among the recorded stony corals, 5 species belonging to the genera *Acropora*, *Pocillopora* and *Porites* were abundant, other 3 species of the same genera were common, 7 species were frequent and 7 were scarce. *Pocillopora* was characterized by bright violet colour while *Porites* was characterized by pink patches on their surfaces. The stony coral *Stylophora pistillata* was completely absent in El-Hamraween. The two recorded soft corals (*Sinularia* sp. and *Xenia* sp.) were scarce. The two recorded hydrocorals (*Millepora dichotoma* and *M. platyphylla*) were both scarce. Hamraween, the site having phosphate and sulphur enrichment, is the only site procured as higher number and abundance of *Acropora* as the control site, having even higher abundance of *Porites* and *Pocillopora* than the control site. This indicates that the three mentioned genera Acropora, *Pocillopora* and *Porites* have been positively affected by phosphates and sulphur by increasing in the growth rate. The sharp bright violet colour of *Pocillopora* and bright pink patches of *Porites* sp., beside the well flourishing coral reefs in the phosphate and sulphur enriched site apparently contradict with the result of Hawkins *et al*. (1991) who claimed that coral recovery is likely to be inhibited by the large amount of phosphate.

The presence of sulphur beside phosphorus in the present study may have beneficial synergetic effect that may lead to flourishing corals but this needs further laboratory experiments to confirm. In contrast, Stambler *et al*. (1991) found that phosphorus enrichment alone had no effect while addition of nitrogen to phosphorus slowed the skeletal growth rate of corals. Ward and Harrison (2000) found that elevated phosphorus alone resulted in corals producing more but smaller eggs and more sperms materials while elevation of phosphorus and nitrogen together can have severe effects on the reproductive ability of corals. The stony coral *Stylophora pistillata* is an exception in the present study where it was completely absent in El-Hamraween, the site having phosphate and sulphur enrichment as well as rain flood run-off. Walker and Ormond (1982) found that the rate of death of colonies of the coral *Stylophora pistillata* was 4–5 times as great in the areas harmed by the spillage of phosphate as in a control area in Aqaba, Red Sea. Another reported case for the complete absence of *Stylophora pistillata* is found in the actively rain flooding site Wadi El-Gemal, Red Sea, Egypt (Ammar, 2005). It is to be noticed that the bivalve *Tridacna* sp. was common in El-Hamraween, the site having phosphate and sulphur enrichment, suggesting phosphate and sulphur are useful nutrients to that bivalve.

4. CONCLUSIONS

1. Coral reefs enriched with phosphate in the field, in contrast to most experimental literature, have extraordinary well flourishing corals, beside the bivalve *Tridacna* sp. Therefore, review of various techniques, dealing with the effect of phosphate on corals, and taking care of their precision is necessary.
2. Ras El-Behar, the site impacted by petroleum oil, has 13 reported stony corals but no soft or hydrocorals, while El-Hamraween, the site impacted by phosphate and sulphur enrichments, has 22 stony corals, 2 soft and 2 hydrocorals.
3. The skeletal growth (asexual reproduction) of the scleractinian coral *Stylophora pistillata* enlarges greatly at the expense of other corals, in presence of chronic oil pollution. In contrast, that species is completely suppressed in presence of phosphate and sulphur enrichment.
4. Petroleum oil leads to coral scarcity, space monopolization by one coral, increased sea urchins and algae.

RECOMMENDATIONS

1. 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 literatures.
2. Phosphate and sulphur can be used as feeding nutrients on culturing the corals *Acropora*, *Pocillopora* and *Porites* as well as the bivalve *Tridacna* sp. provided that precise laboratory experiments should be done to determine the critical beneficial concentration of these nutrients.
3. Branches of *Stylophora pistillata* monopolizing space in areas of petroleum oil impact should not be used as asexual recruits for reef rehabilitation since they are non fertile and would not help in improving the diversity through sexual reproduction

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