International Journal of Environmental Monitoring and Analysis
2015; 3(5-1): 1-9
Published online August 31, 2015 (http://www.sciencepublishinggroup.com/j/ijema)
doi: 10.11648/j.ijema.s.2015030501.11
ISSN: 2328-7659 (Print); ISSN: 2328-7667 (Online)

Effect of Anthropogenic Activities on Coral Distribution at Onshore and Offshore Reefs Along the Egyptian Coast, Red Sea

Montaser A. M. Al-Hammady[1], Fattma M. A. Fouda[2], Hussein N. M. Hussein[1], Awad A. M. Elsyed[3]

[1]National Institute of Oceanography and Fisheries, Hurghada, Red Sea, Egypt
[2]Department of Zoology, Faculty of Girls, Ain- Shams University, Cairo, Egypt
[3]Department of Zoology, Faculty of Science, Al-Azhar University, Cairo, Egypt

Email address:
coralreef_niof1@yahoo.com (M. A. M. Al-Hammady)

To cite this article:
Montaser A. M. Al-Hammady, Fattma M. A. Fouda, Hussein N. M. Hussein, Awad A. M. Elsyed. Effect of Anthropogenic Activities on Coral Distribution at Onshore and Offshore Reefs Along the Egyptian Coast, Red Sea. *International Journal of Environmental Monitoring and Analysis*. Special Issue: New Horizons in Environmental Science. Vol. 3, No. 5-1, 2015, pp. 1-9. doi: 10.11648/j.ijema.s.2015030501.11

Abstract: Using SCUBA diving, Line Intercept Transect (LIT) and under water digital camera coral distribution at onshore and offshore reefs was surveyed in respect to the effect of anthropogenic activities. Four sites were selected during this study. The onshore sites comprised Ras Gharib Petroleum Company (site 1), impacted by oil pollution, and Old Al-Qusyer Harbour (site 2) impacted by phosphate shipping. While, the offshore sites were chosen at Small Gifton Island (site 3), and Abu Ramad Island (site 4); each was impacted by diving activities. The present results showed that, 70 species belonging to 23 genera, distributed within 18 families were recorded at the studied sites, of which, 26 species have massive lifeform, 23 branching, 5 encrusting, 6 solitary and only 2 species belong hydrocorals. In addition, 7 species of a hermatypic corals were also recorded. The present study indicated that, either onshore or offshore reefs showed coral decline, but onshore reefs have more degradations. The highest percent cover of dead corals was 29.1% and 34.4 %, recorded at onshore reefs, sites 1and 2, respectively. On contrast, the lowest percent cover was 28.1% and 4.4%, detected at offshore reefs of sites 3 and 4, respectively. On the other hand, site 1 (onshore reef) recorded the highest percent cover of soft corals (40.5%) from 36% the percent of live soft and hard corals, compared with 2.7% at site 4 (offshore reef) from the percent 61.2% of live soft and hard corals. Branching corals have remarkably higher percent (47%) at offshore (site 4) than that recorded (26.5%) at onshore (site 1). However, massive corals recorded relatively higher percent (52.2%) at offshore (site 3) than (50.4%) onshore (site 2). The offshore site 3 recorded the highest diversity (2.6) and highest richness (1.7), compared with the lowest diversity (2.29) and lowest richness (1.35) recoded at onshore site 1. The equability of distributions among species at the studied reefs were 0.83, 0.78, 0.73 and 0.75 at sites 1, 2, 3 & 4, respectively. At site 1, the stony coral Stylophora pistillata was the only abundant species, with non- expected big and thick branches, while most other corals were scarce. On contrast, Porites sp. was the most dominant at sites 2 &3; while the massive coral, Goniastrea retiformis was the most dominant species at site 4.

Keywords: Coral Distributions, Onshore Reefs, Offshore Reefs, Anthropogenic Activities, Red Sea

1. Introduction

Red Sea coral reefs are cited as the most diverse in the world [1]. Despite their obvious value, either onshore or offshore Red Sea reefs are subject to extensive anthropogenic damage [2-3 & 4]. The factors responsible for the observed declines in Red Sea offshore reefs are diving [5-8], fishing activities [9-13] and ship groundings [14]. However, onshore reefs are impacted by a wide range of threats such as landfilling [15], sedimentation [16-17], coastal development [4], swimming & snorkeling [18], coral collection [19], oil pollution [20 & 2] and eutrophication [21]. Coral bleaching as a result of global changes is another important factor that impacts both onshore and offshore reefs [2&4]. In addition, biotic factor may destroying onshore and offshore reefs such as sea urchins, Diadema sp. [22], the crown of thorn sea stars, Acanthaster planci [23], macroalgal competition [24-25]and diseases [26-27&4].

On a global scale, the value of the total economic goods and services provided by coral reefs have been estimated to be US$ 375 billion per year with most of this coming from recreation, sea defense services and food production, this equates to an average value of around US$ 6,075 per hectare of coral reef per year [28]. Degradation of reefs means the loss of these economic goods and services, and the loss of food security and employment for coastal peoples, many of them in developing countries and many of them living in poverty. Unfortunately, the Status of Coral Reefs of the World [29]estimated and report that 20% of the world's coral reefs have been effectively destroyed and show no immediate prospects of recovery, that 24% of the world's reefs are under imminent risk of collapse through human pressures, and that a further 26% are under a longer term threat of collapse.

The Egyptian coast of the Red Sea combines this complex of issues. Tourism, along with destructive fishing methods, diving activities and coastal development, pose the greatest threat [30-31]. According to a Report on Biodiversity Conservation Capacity Building in Egypt (Egyptian Biodiversity CHM, 2006) more than 8 million tourists visit Egypt annually, whereby coastal tourism is the largest subsector within the market. Moreover, several authors have studied the Red Sea reefs and their communities e.g. [32 --37], and [2]. Information about the susceptibility of decline between onshore and offshore reefs, and the degree of impacts on the Red Sea corals is still few.

The present work aims to evaluate the influence of the effect of anthropogenic activities on both onshore and offshore reefs with comparing the corals distribution, diversity and abundance.

2. Materials and Methods

During the present investigation four sites were selected at four widely geographically separated areas along the western coast of the Red Sea (Fig. 1 & Tab. 1). The two onshore reefs were chosen at General Petroleum Company at Ras –Gharib City - Gulf of Suez (polluted by oil pollution) and Old Al-Quseir Harbor at Al-Quseir City (impacted by eutrophication as a result of phosphate shipment). While the two offshore reefs were selected at Small Gifton Island and Abo- Ramad Island; each located off Hurghada and impacted by diving activities.

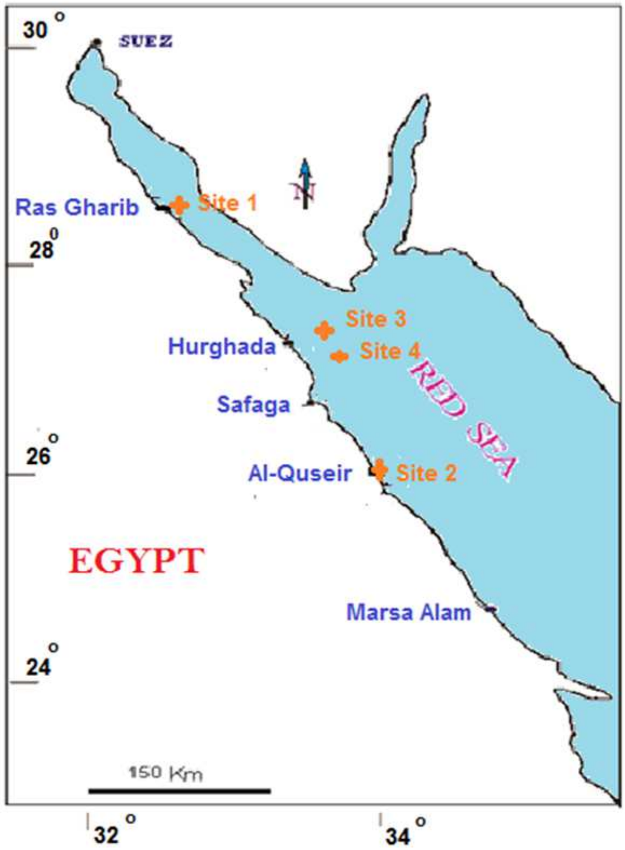


Fig. (1). *Location map of the study sites.*

Table (1). *Location, coordinated position and level of impacts at the studied sites.*

Location	Sites	Coordinated Position		Human activities	Impact level
		Longitude	Latitudes		
Onshore	Site (1)	28° 22′ 1.69″ N	33° 5′ 0.08″ E	Oil pollutions	High
	Site (2)	26° 6′ 12.31″ N	34° 17′ 17.80″ E	Fishing Phosphate pollutions	Moderate Heavy
Offshore	Site (3)	27° 12′ 20.42″ N	33° 58′ 2.73″ E	Fishing Diving	Low High
	Site (4)	27° 9′ 47.48″ N	33° 58′ 47.81″ E	Diving Fishing	Moderate Moderate

To compare the degree of destruction between onshore and offshore reefs, coral community, diversity, and abundance were evaluated and calculated with referring to the most important factors affecting coral diversity and distribution.

All the fieldwork well performed using SCUBA equipment. A 20 m long marked at regular intervals tape was used as a Line Intercept Transect (LIT) according to [38] to estimate the percent cover of corals in the proposed sites. This method depends on calculating the fraction of the length of the line that is intercepted by the object. The LIT was laid down along the depth contour, parallel to the shore. Percentages of living corals (hard and soft), dead corals and other taxa (algae, sponge, sand and rock) were calculated. Coral diversity was calculated by [39]. The evenness index as adapted by [40] was used to calculate the equitability of individual distribution among species. The statistical cluster analysis for the percent cover of different coral species was performed by the computer program STATISTICA, to show the degree of similarity between different coral species.

The percentage cover of a given species or taxa underlying the transect was calculated according to the following formula:

Percent cover = Intercepted length of category / Transect length x 100

Coral diversity was calculated by Shannon-Wiener formula (Shannon and Wiener, 1948) as following:

$$H s = - \sum_{i=1}^{S} p_i \ \ln \ p_i$$

Where, S= total species , i = each species, Pi = Ni /N ,Pi = Number of colonies species/Number of total colonies, Ni is the number of individuals of a given species, and N = the total number of individuals. The evenness index was used as adapted by Pielou (1966) and to show the equitability of distribution of individuals among species. Evenness was use as following: Evenness index (J') = H' (observed)/ H'(Maximum)

Where, H' (observed) = H'N (calculated), and H' (maximum) = log (S), S = number of species. Margalef's species richness index was calculated according the formula cited by English et al., (1997) as following:

$$D = S\text{-}1/ \log eN$$

Where: d= diversity; S= total number of species, and N= total number of individuals.

3. Results

In the present study, 70 species belonging to 23 genera within 18 families, of them 26 species were massive corals, 23 branching corals, 5 encrusting, 6 solitary corals and two species belong to hydrocorals. In addition, stony coral species, other 7 species of a hermatypic corals were also recorded. In general, *Acropora, Favites, Favia, Millipora, Porites, Pocillopora, montipora* and *Stylophora* are the most frequent and common hard coral genera at the studied reefs. In contrast, *Galaxea fascicularis* recorded the lowest percent cover at the studied sites; while, *Nephthea, Sarcophyton, Sinularia* and *Xenia* are the most common soft coral species in the study areas, as shown in Fig.(4).

The highest percent cover of dead corals was 29.1% and 34.4, recorded at onshore reefs, sites 1& 2, respectively. In contrast, the lowest percent cover was 28.1% & 4.4%, detected at offshore reefs, at sites 3 &4, respectively. Site 1(onshore reef), the site impacted by oil pollution, recorded the highest percent covers of soft corals (40.5%) from 36% the percent of live corals, compared with 2.7% at site 4 (offshore reef) from the percent 61.2% of live soft & hard corals. However, the lowest percent live corals was recorded at site 3 (32.2%), of which 90.6% was hard corals and 9.4% was soft corals.

Massive corals were also higher at offshore site 3(52.2%) than in onshore site 2(50.4%). Site 3, the offshore reef, recorded the highest diversity (2.6) and the highest richness (1.7), which declined to the lowest values being 2.29 and 1.35 at the onshore site 1, respectively. The equability of distributions among species at the studied reefs were 0.83, 0.78, 0.73 & 0.75 at sites 1, 2, 3 & 4, respectively. However, among 36 species recorded at site 1, the stony coral, *Stylophora pistillata* and soft coral *Sarcophyton sp.* were the dominant species. On the other hand, *Porites spp.* were the most dominant at sites 2 &3; while the massive coral, *Goniastrea retiformis,* was the most dominant species among 35 recorded species at site 4. Other categories at the study reefs were represented by 34.9 %, 4.4%, 39.7% and 11% at sites 1,2,3 & 4, respectively. As shown in (Tab. 2 & Figs. 2& 3).

Cluster analysis for the percent cover of different coral species at site 1 separated *Stylophora pistillata* and *Sarcophyton sp.* in on group. That clearly, having the highest cover and space monopoly among all corals, as shown in Fig. (5). *Stylophora pistillata* was the only abundant species, with non-expected big and thick branches, while most other corals were scarce. However, at site 2, *Acropora formosa*, *A. humilis*, *Pocillopora damicornis*, and *Porites lutea* were separated in one cluster and having the highest percent cover as shown in Fig. (6). At site 3, *Porites undulata, Millepora dichotoma, Favia pallida, Millepora platyphylla,* and *Pocillopora damicornis* were separated in one cluster, having the highest percent cover of coral species, as shown in Fig. (7). Cluster analysis for the percent cover coral species in site 4 is shown in Fig (8). It is clear that cluster contains of two major groups, *Acropora formosa*, *A. humilis*, *Pocillopora damicornis*, and *Porites lutea* which were separated in one cluster and having the highest percent cover; while, *Acropora hemperchi* and *Montipora meandrina* were separated in one group and having the minimum percent cover.

Table (2). *Percent cover (%), Diversity (H'_N) Evenness index (J') and Richness (D) at studied reefs.*

Categories	Sites			
	Onshore reefs		**Offshore reefs**	
	Site 1:	**Site 2**	**Site 3:**	**Site 4**
No.sp.(intercepted)	36	29	35	35
% Live hard corals	59.5	95.9	90.6	97.3
% Live soft corals	40.5	4.1	9.4	2.7
% Dead corals	29.1	34.4	28.1	4.4
% Other categories	34.9	4.4	39.7	39.7
H'N (diversity)	2.29	2.58	2.6	2.45
D (Richness)	1.35	1.42	1.7	0.98
J' (Evenness index)	0.83	0.78	0.73	0.75

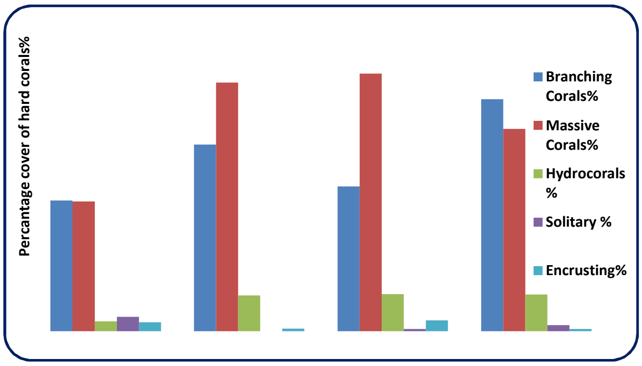


Fig. (2). *Percent cover of corals and other categories at onshore and offshore studied reefs.*

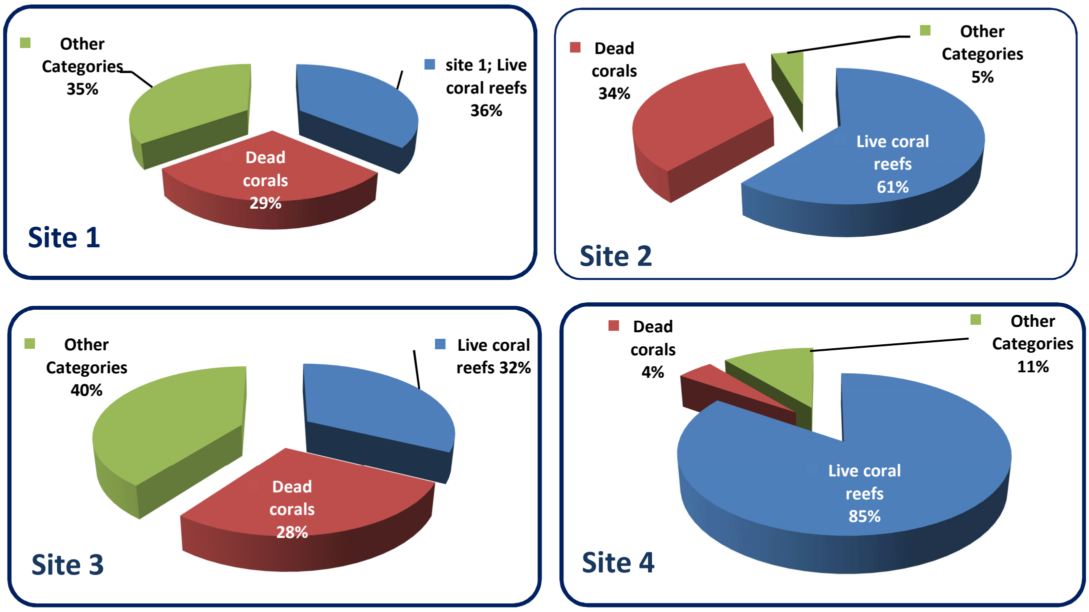


Fig. (3). *Percent cover of live corals, dead corals and other categories study sites.*

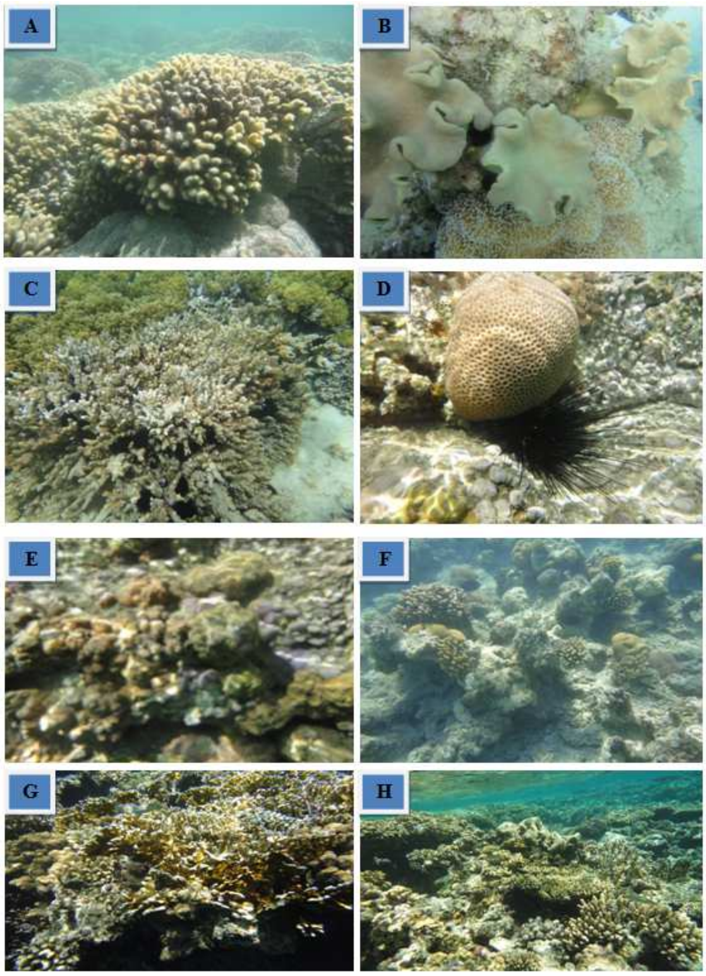


Fig. (4). *A): Stylophora pistillata the most dominant hard coral species at site 1, B): Sarcophyton sp. the most dominant species of soft coral at site 1, C): Dead corals and over growth of algae's at site 1,D): Massive corals the most dominant species at site 2, E): Dead corals at site 2, F): Porites Sp. & Favia Sp. are the most dominant species at site 3, G): Fire coral Millepora Sp. at site 4, H): Branching hard coral at reef flat at site 4.*

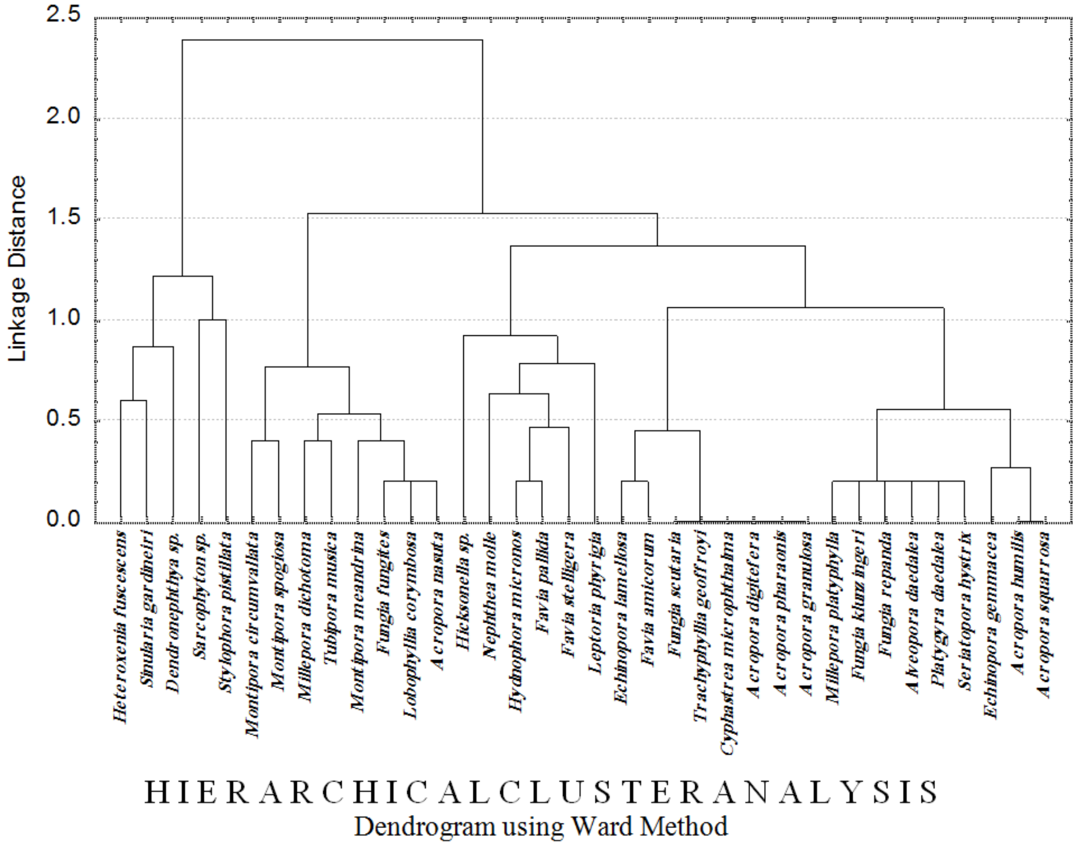


Fig. (5). *Cluster analysis for the percent cover of different species of corals in the studied site 1.*

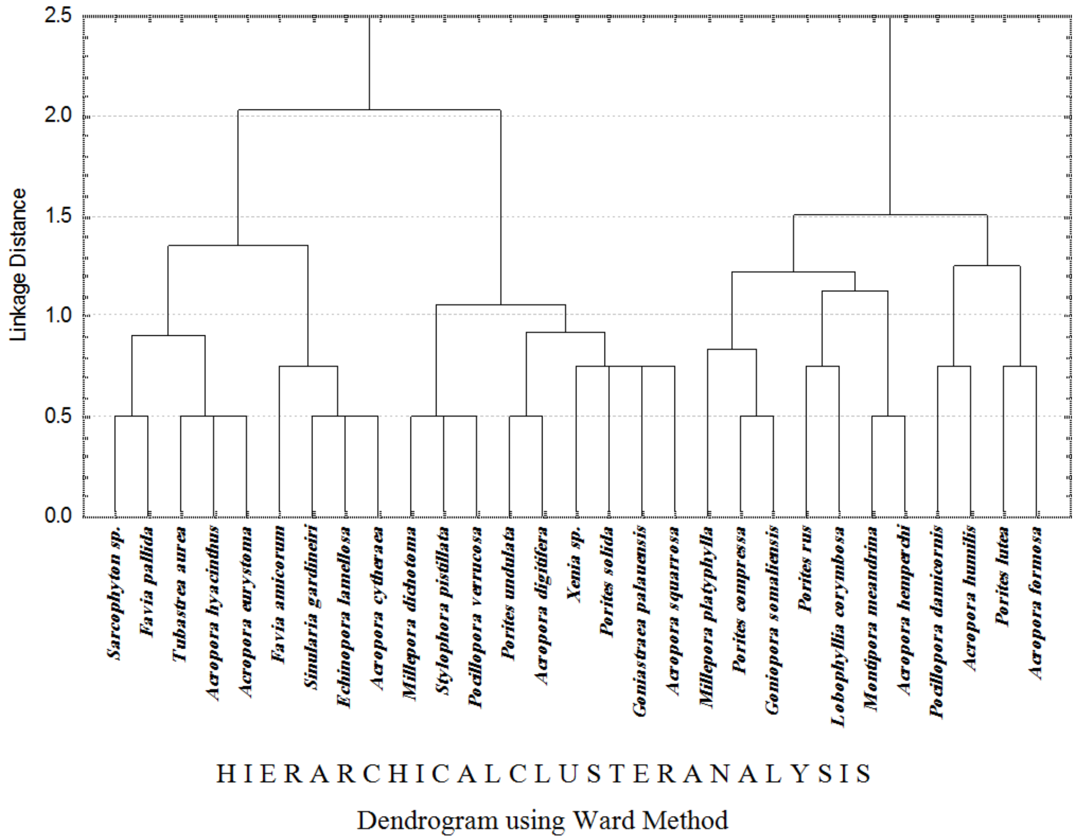
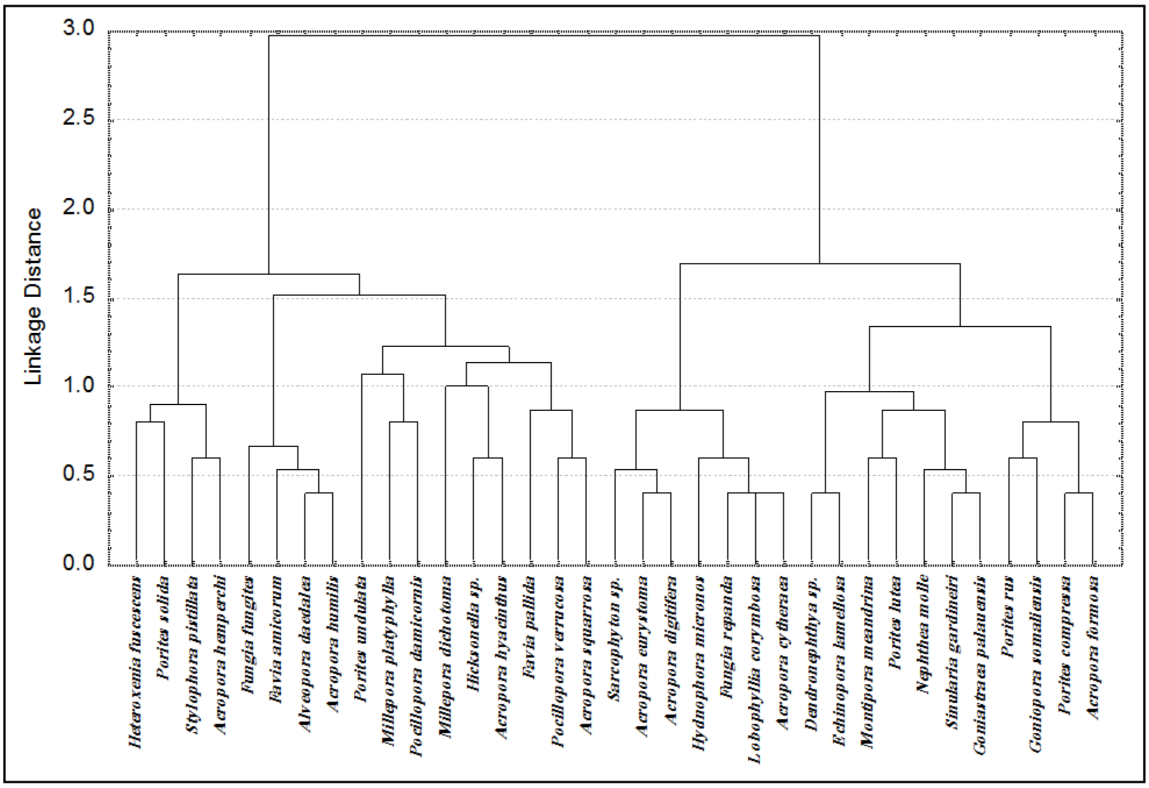


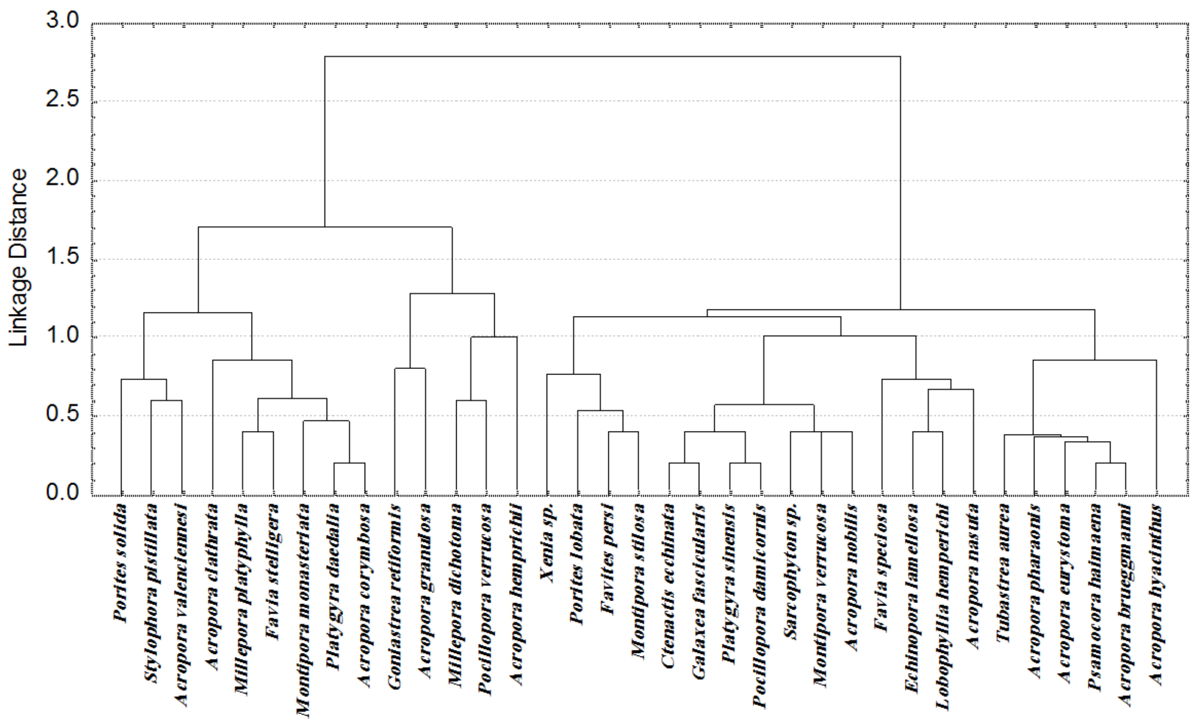
Fig. (6). *Cluster analysis for the percent cover of different species of corals in the studied site 2.*



HIERARCHICAL CLUSTER ANALYSIS

Dendrogram using Ward Method

Fig. (7). *Cluster analysis for the percent cover of different species of corals in the studied site 3.*



HIERARCHICAL CLUSTER ANALYSIS
Dendrogram using Ward Method

Fig. (8). *Cluster analysis for the percent cover of different species of corals in the studied site 4.*

4. Discussions

At the present work, corals of the Red Sea, either onshore or offshore reefs showed remarkable degradations associated with increasing human activities, being more prominent at onshore reefs. Al-Hammady & Mahmoud [4] reported similar results. They found that the Egyptian Red Sea coast has so far appeared to suffer mainly from localized impacts, due to expanding coastal urban and industrial centers, ports and touristic activities. Palmer *et al.,* [41] reported also that, near shore environments directly influenced by different anthropogenic activities have generally low diversity and more destruction.

Despite the high probability of physical contact in very onshore reefs, there are no or few regulations or educational programs for snorkelers and swimmers. In contrast, divers learn or face regulations through their certification, their abilities are commonly tested in so-called check dives prior to first reef dives, and national diving rules often apply (e.g. guided diving in small groups). Among recreationally used reefs, Red Sea onshore reef flats are the most severely impacted zones [42-43]. The present investigation reported similar results that the onshore reef (site 1), the site impacted by oil pollution, swimming and trampling had the highest percent cover of dead corals. However, the same site recorded highest percent cover of soft corals. This could be explained by the conclusion of [44-45] that soft corals have a higher recovery rate and a faster recovery time than stony corals, because soft corals could adapt and compete for space more faster after being subject to impacts especially physical impacts. [46] showed that soft corals replace stony corals and cause their death; this is an important factor affecting coral re-colonization [47]. At the same manner, the stony coral *Stylophora pistillata* was the only abundant species, with non-expected big and thick branches, while most other corals were scarce at site 1. In agreement with the finding of Ammar, [44] and Al-Hammady [2] that, 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. Kotb, [48] in their study at Ras Mohamed indicated that oil pollution leads to the absence of most corals except for a few small colonies of *Stylophora pistillata.*

The higher percent cover of massive corals at offshore reef than at onshore reef is another biological indicator that onshore reefs are exposed for more destructions than offshore reefs. While as, branching coral has higher susceptibility for destruction than massive corals. [49] and [50] reported differences in bleaching susceptibility between corals of different growth forms, that branching coral (e. g. *Acroporids* and *Pocilloporids*) being more severely affected by bleaching than massive species (e.g. *Poritids* and *Faviids*).

Although, diversity and the richness at offshore reefs were higher than those at onshore reefs, offshore reefs are still endangered due to diving activities in comparison to the previous references. Both of [51] and [43] found more significantly damaged colonies, loose coral fragments, and partially dead corals in areas used by divers. The level of physical damage corresponds with visitor numbers [34], [52-53]. Snorkeler's damage is mostly limited to shallow areas where visitors can stand on or kick coral surface [17&.54] studies have been conducted on snorkelers versus SCUBA-divers, though the former are known to deteriorate shallow-water reefs [55-57]. Depending on growth form [17], [58] and species composition, coral communities differ in their susceptibility to recreational activities. Those dominated by branched forms (e.g. members of genus Acropora) are the most fragile [59]. Several previously described studies quantified the level of coral physical damage by either breakage or abrasion in the Egyptian reefs of the Red Sea due to reef walking [60-61, 52], snorkeling and diving activities [51, 63, 62 & 64.

However, Old El-Quseir harbor considers as onshore reef and impacted by phosphates produced from transport of phosphates shipments. This site registered a higher percent cover of live coral in comparison to site 1. Phosphorus in the present study may have beneficial synergetic effect that may lead to flourishing corals but this needs further laboratory experiments to confirm. [65] found that phosphorus enrichment alone had no effect while addition of nitrogen to phosphorus slowed the skeletal growth rate of corals. Al-Hammady (2011) found that elevated phosphorus resulted in corals producing more but smaller eggs.

Acknowledgements

This work is a part of the PhD of the student Hussein Nasr Mohammed.

References

[1] Loya, Y. (1972). Community structure and species diversity of hermatypic corals at Eilat, Red Sea. Marine Biology 13: 100–123.

[2] Al-Hammady, M. A. M. (2011). Patterns of bleaching and fertility in the two Red Sea corals *Stylophora pistillata* and *Acropora humilis* as biomonitors of environmental impacts. Ph.D. Thesis, Zoology Department, Assiut University, Assiut, Egypt. Vol. 4, No. 2, Pp. 62-75.

[3] Ammar, M. S. A. (2011). Coral diversity indices along the Gulf of Aqaba and Ras Mohammed, Red Sea, Egypt. Biodiversitas, 12 (2): 92-98.pp.

[4] Al-Hammady, M. A. M. and Mahmoud, M. A (2013). The Effect of Expanding Coastal Urban, Industrial Centers, Ports and Tourism on the Red Sea Coral Reefs – Egypt. Proc. The International Conference of Environmental Sciences (ICES), 21- 22.

[5] Chadwick-Furman, N. E. (1997). Effects of SCUBA diving on coral reef invertebrates in the US Virgin Islands: implications for the management of diving tourism. In: Proceedings of the 6th International Conference on Coelenterate Biology, pp. 91–100.

[6] Hawkins, J.P and Roberts, C.M. (1997). Estimating the carrying capacity of coral reefs for SCUBA diving. In: Proceedings of the 8th International Coral Reef Symposium, 2:1923–1926.

[7] Schleyer, M.H. and Tomalin, B.J.(2000). Damage on South African coral reefs and an assessment of their sustainable diving capacity using a fisheries approach. Bulletin of Marine Science, 67 (3):10251042.

[8] Zakai, D and Chadwick-Furman, N.E.(2002). Impacts of intensive recreational diving on reef corals at Eilat, northern Red Sea. Biological Conservation, 105:179–18.

[9] Ault, J.S; J.A. Bohnsack, and G. Meester. (1998). A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fishery Bulletin, US, 96:395-414.

[10] Ault, J.S; J.A. Bohnsack, S.G. Smith, and J. Luo. (2005a). Towards sustainable multispecies fisheries in the Florida USA coral reef ecosystem. Bulletin of Marine Science, 76(2):595–622.

[11] Ault, J.S., S.G. Smith, and J.A. Bohnsack. 2005b. Evaluation of average length as an indicator of exploitation status for the Florida coral reef fish community. ICES Journal of Marine Science, 62:417-423.

[12] Ault, J.S; S.G. Smith, J. Luo, M.E. Monaco, and R.S. Appeldoorn. (2008). Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico. Environmental Conservation, 35(3):221-231.

[13] Ault, J.S; S.G. Smith, and J.T. Tilmant. 2009. Are the coral reef finfish fisheries of south Florida sustainable? Proceedings, International Coral Reef Symposium, 11:989-993.

[14] Lirman, D.; Gracias, N.; Gintert, B.; Gleason, A. C. R. 1; Deangelo, G.; Dick, M.; Martinez, E. and Reid, R. P.(2010). Damage and recovery assessment of vessel grounding injuries on coral reef habitats by use of georeferenced landscape video mosaics, Limnol. Oceanogr. Methods, 8: 88–97.

[15] Erftemeijer, L. A; Riegl, B; Hoeksema, W. D. and Peter, A. (2012). Environmental impacts of dredging and other sediment disturbances on corals: A review, Marine Pollution Bulletin 64: 1737–1765.

[16] Loya, Y. (1976). Effects of water turbidity and sedimentation on the community structure of Puerto Rican corals. Bulletin of Marine Science, 26(4):450–466.

[17] Rogers, C. (1990). Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series, 62:185–202.

[18] Hannak, J. S; Kompatscher, S. M and Herler. J. (2011). Snorkeling and trampling in shallow-water fringing reefs: Risk assessment and proposed management strategy. Journal of Environmental Management, 92: 2723-2733.

[19] Ginsburg, R.N; Gischler E. and Kiene, W.E. (2001). Partial mortality of massive reef-building corals: an index of patch reef condition, Florida Reef Tract. Bulletin of Marine Science 69(3):1149– 1173.

[20] Sebens, K. P. (1994). Biodiversity of coral reefs: what are we losing and why? American Zoologist, 34: 115–133.

[21] Koop K; Booth, D.; Broadbent, A; Brodie, J.; Bucher, D.; Capone, D.; Coll, J.; Dennison, W.; Erdmann, M.; Harrison, P.; Hoegh- Guldberg, O.; Hutchings, P.; Jones, G.B.; Larkum, A.W.D.; O'Neil, J.; Steven, A.; Tentori, E.; Ward, S.; Williamson, J. and Yellowlees, D. (2001). ENCORE: the effect of nutrient enrichment on coral reefs: synthesis of results and conclusions. Marine Pollution Bulletin, 42:91–120.

[22] Forcucci, D. (1994). Population density, recruitment and 1991 mortality event of *Diadema antillarum* in the Florida Keys. Bull. Mar. Sci., 54: 917–928.

[23] Ammar, M. S. A; Ghobachi, A. A; Omran, M. A; and Shabban, A. M (2007). Status of coral reef affected by different impacts in some sites of the Red Sea. Egyp. J. Aqua. Res., 33: 224-237.

[24] Dustan, P. (1999). Coral reefs under stress: sources of mortality in the Florida Keys. Nat. Resource, Forum 23: 147–155.

[25] 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.

[26] Porter, J. W. and Tougas, J. I. (2001). Reef ecosystems: threats to their biodiversity. In: *Encyclopedia of Biodiversity*, Levin, S.A. (ed.), Vol. 5, San Diego: Academic Press, pp. 73-95.

[27] Richardson, L.L. and J..D. Voss. (2005). Changes in a coral population on reefs of the northern Florida Keys following a coral disease epizootic. Marine Ecology Progress Series 297:147-156.

[28] Edwards, A.J., Gomez, E.D. (2007). Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme: St Lucia, Australia. iv + 38 pp.

[29] Status of Coral Reefs of the World Report, Available from: Wilkinson, C.; E.D. (2004). http://www.aims.gov.au.

[30] Cesar, H. J. S; Burke, L and Pet-Soede, L. (2003). The Economics of Worldwide Coral Reef Degradation. Cesar Environmental Economics Consulting, Arnhem, and WWF-Netherlands, Zeist, The Netherlands, Zeist, The Netherlands. 23pp.

[31] Saila, S.B.; Kocic, V.L.; McManus, J.W. (1993). Modeling the effects of destructing fishing practices on tropical coral reefs. Marine Ecology Progress Series, 94:51-60.

[32] Crossland, (1938). The coral reef at Ghardaqa, Red Sea. Proc. Zool. Soc. London Ser. A, vol. 108, pp. 513-523.

[33] Sheppard, C.R.C. and Sheppard, A.L.S. (1991). Corals and coral communities of Arabia. Fauna of Saudi Arabia, 12: 3–173.

[34] Riegl, B. and Velimirov, B.(1991). How many damaged corals in Red Sea reef systems? A quantitative survey. Hydrobiologia., 216/217:249–256.

[35] Ammar, M. S. A. (1993). Population studies among shallow reef corals of El-Sukhna, Gulf of Suez (Northern Red Sea). M. Sc. Thesis, Fac. Sci. Zool. Dept. Cairo Univ. 112 pp.

[36] Ammar, M. S. A. (1996). Ecology and distribution of reef-building corals at some locations of the Red Sea. Ph. D. Thesis, Fac. of Sci. Zool. Dept. Cairo Univ., 221 Pp.

[37] Ammar, M. S. A. (2004). Zonation of coral communities and environmental sensitivity offshore a resort site at Marsa Alam, Red Sea, Egypt. Egypt. J. Zool., 42: 67-81.

[38] English, S.; Wilkinson, C. and Baker, V; (1997). Survey manual for tropical marine resources. 2nd Edition. 385 pp.

[39] Shannon, C.E. and Wiener, W.: 1948, The mathematical theory of communication, University of Illinois, Urbana: 177 pp.

[40] Pielou, E.C.: 1966, The measurement of diversity in different types of biological collections, *Journal of TheoreticalBiology*, 13: 131-144.

[41] Palmer, S.E; Perry, C.T; Smithers, S.G. and Gulliver, P. (2010) Internal structure and accretionary history of a nearshore, turbid-zone coral reef: Paluma Shoals, central Great Barrier Reef, Australia. Marine Geology, 276 (1-4). pp. 14-29. ISSN 0025-3227.

[42] Riegl, B. and Piller, W. E. (2000). Mapping of benthic habitats in northern Safaga Bay (Red Sea, Egypt): a tool for proactive management. Vol. 10, 2, Aquatic Conservation: Marine and Freshwater Ecosystems, pp. 127–140.

[43] Hannak J.S ; Kompatscher, S. M and Herler. J. (2011). Snorkeling and trampling in shallow - water fringing reefs: Risk assessment and proposed management strategy. Journal of Environmental Management, 92 : 2723 – 2733.

[44] Ammar, M. S. A. (2007). Recovery patterns of corals at Shabrour Umm Gam'ar, Hurghada, Red Sea, Egypt, after the 1998 outbreak of *Acanthaster planci*. Zool Middle East; 40: 97-104.

[45] Ammar, M. S. A. (2009). Assessment of Present Status and Future Needs of Four Coral Reef Sites along the Gulf of Aqaba, Egypt. The Open Environmental Pollution & Toxicology Journal, 1: 34- 42.

[46] Benayahu, Y. (1985). Faunistic composition and patterns in the distribution of soft corals (Octocorallia Alcyonacea) along the coral reefs of Sinai Peninsula. *Proceeding of the Fifth International Coral Reef Congress*, Tahiti, Vol. 6: 255-260.

[47] Pearson, R.G. (1981). Recovery and colonization of coral reefs. Mar. Ecol. Progress Ser. 4:105-22.

[48] Kotb, M. M. A; Hartnoll, R. G. and Ghobashy, A. F. A.; (1991). Coral reef community structure at Ras Mohamed in the northern Red Sea. Tropical Zoology, 4: 269-285.

[49] Brown, B. E. and Suharson, O;(1990). Damage and recovery of coral reefs affected by El Nino related sea water warming in Thousand Islands, Indonesia. Coral Reefs, 8:163-170.

[50] Gleason, M. G. (1993). Effect of disturbance on coral communities: bleaching in Moorea, French Polynesia. Coral Reefs, 12: 193-201.

[51] Hawkins, J. P and Roberts, C.M. (1992). Effect of recreational SCUBA diving on fore-reef slope communities of coral reef, *Biological Conservation*. 92: 171-178.

[52] Hawkins J. P and Roberts C.M. (1993). Effects of recreational SCUBA diving on coral reefs: trampling on reef flat communities. Journal of Applied Ecology.30:25–30.

[53] Rodgers, K.U.S. and Cox, E.F.(2003). The effects of trampling on Hawaiian corals along a gradient of human use. Biological Conservation, 112:383–389.

[54] Plathong SInglis G.J. and Huber, M.E.(2000). Effects of self-guided snorkeling trails in a tropical marine park. Conservation Biology,Vol.14, (6) :(1821–1830).pp. Great Barrier Reef, Australia Marine Geology (276)- 14–29.

[55] Allison W.R. (1996). Snorkeler damage to reef corals in the Maldives islands. Coral Reefs. 15:215–218.

[56] Riegl, B. and Velimirov, B. (1994). The structure of coral communities at Hurgada in the Northern Red Sea. Marine Ecology, 15: 213-231.

[57] Harriott V.J. (2002). CRC Reef Research Centre & James Cook University; Townsville, Australia. Marine Tourism Impacts and Their Management on the Great Barrier Reef.

[58] Riegl, B.; Heine, C. and Branch G.M.(1996). Function of funnel-shaped coral growth in a high-sedimentation environment. Marine Ecology Progress Series, 145:87–93.

[59] Riegl, B.; Cook, P.A.; (1995). Is damage susceptibility linked to coral community structure? A case study from South Africa. Beitraege zur Palaeontologie 20, 65- 73.

[60] Woodland, D and Hooper, N; (1977). The effect of human trampling on coral reefs. Biological Conservation, 11:1-4.

[61] Liddle, M.J. and Kay, A.M.(1987). Resistance survival and recovery of trampled corals on the Great Barrier Reef. Biological Conservation, 42:1 –18.

[62] Attalla, T. M. (2011). Assessment Study on Natural and Human Impacts on the Coral Reefs of the Red Sea, Egypt. Ms. Sc. Thesis, Suez Canal University, Egypt, 254 Pp. [61] Liddle, M.J. and Kay, A.M.(1987). Resistance survival and recovery of trampled corals on the Great Barrier Reef. Biological Conservation, 42:1–18.

[63] Serour, R. K.(2004) An Environmental Economic Assessment of the Impacts of Recreational SCUBA Diving on Coral Reef Systems in Hurghada, the Red Sea, Egypt. Ms. Sc. Thesis, Faculty of the Graduate School of the University of Maryland,75pp.

[64] Hanafy, M. H.(2012). Effects of recreational scuba diving and snorkeling on coral reefs of the sheltered bays of the Red Sea, Egypt. Egypt. J. Aquat. Biol. & Fish., Vol. 16, (4): 43-56.

[65] Stambler, N.; Popper, N.; Dubinsky, Z. and Stimson, J. (1991). Effects of nutrient enrichment and water motion on the coral *Pocillopora damicornis*. Pacific Science, 45(3): 299-307.