Rapid Assessment of Coral Reefs along the Egyptian Red Sea Coast

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***Abstract*-Coral assessment and distribution have been studied at some sites representing the Egyptian Red Sea coast from north Hurghada with 5km to Shalateen illustrating the most important factors that affect the coral distribution and abundance at the selected sites. The percentage cover of the coral reef community was estimated at each locality by using the standard method (the line intercept transect). During the present investigation, 68 coral species were recorded at seven coastal sites along the Egyptian Red Sea; forty-nine species of them were hard corals and the other 19 species were soft corals. North Hurghada site (NIOF) recorded the least cover of the living coral (66.23%) while Abu-Dabab area recorded the maximum coverage percent (91.50%). In spite of the fact that NIOF site recorded the least cover, it measured the maximum species diversity (3.54) and the maximum recorded number of species (48 species), Shalateen recorded the least diversity (1.97) and the least number of species (24 species). *Pocillopora damicornis* recorded the highest coverage percent of the hard corals (15.6%) at El Sharm El-Bahari, and *Sarcophyton glaucum* recorded the highest soft corals (10.18%) at North Qula'an. Some environmental, biological interaction and anthropogenic activities were the main controlling factors of coral distribution at the studied areas such as overfishing, tourism developments, as well as petroleum and phosphate production, Sedimentation processes, bottom topography and geomorphology.**

Keywords-Coral Assessment; Diversity; Community Distribution; Evenness Index; Red Sea; Egypt

I INTRODUCTION

The Red Sea is still one of the most important areas that contain beautiful coral communities and are widespread throughout the tropical Indo-Pacific area. The abundance and the ecology of the hard and soft corals have been studied by many authors in the Red Sea and the Indo-Pacific regions [1, 2] and in the central Great Barrier Reef (e.g. [3-5]). Moreover, the coral distributions in some localities of the Red Sea have been studied generally referring to the community structure of coral reefs (e.g. [6 - 8]), ecology and biology (e.g. [9 - 13]), the interaction of many factors that affects the distribution and the coral bleaching [14], the affecting factors as sedimentation, overfishing, tourist activities, as well as petroleum and phosphate production [15], geographical relationship and geomorphologic observations of coral reefs at the northern Red Sea [16] and the basis of topographical characteristics of the reef [9]. However, all of these factors had significant influence on the distribution of corals among coral reefs at the studied areas. On the other hand, the biology and ecology of soft corals have been shown by [17 - 21].

Mohammed [13] and Mohammed *et al.* [15] concluded that, many factors could affect the distribution of coral reefs and their structure and abundance such as the biological interaction between the benthos fauna, the bottom topography and geomorphology (e.g. [11], [22 - 24]) as well as the physical factors and anthropogenic activities [8], [12]. These activities include phosphate shipping smoothers and navigation activities, landfill and dredging, mining operations and overfishing [25]. These areas are controlled by water depth, temperature variation [26], tidal range and the degree of exposing, salinity and water mixing [27], light penetration, geographic occurrence, the geomorphologic nature [28], [29] and bottom sediment nature, turbidity and terrestrial inputs.

The present work aims to evaluate, assess quantitatively, and compare the corals distribution, diversity and abundance along the Egyptian Red Sea Coast during January 2009 to February 2010. However the study will illustrate the different ecological factors that affect the coral diversity and richness as well as to explore the human threats on coral communities at each site.

II MATERIALS AND METHODS

A. The Study Area

During the present investigation seven sites were selected in northern Red Sea along the Egyptian coast to evaluate and calculate the coral community, diversity, and abundance referring to the most important factors affecting the coral diversity and distribution as shown in Fig. 1. These sites are highly influenced by different factors and activities such as phosphate shipment at El-El-Hmrawin; overfishing at Shalateen; touristic activities (diving and snorkeling) at NIOF, Sharm El-Naqa, El-Sharm El-Bahari and Abu-Dabab; coastal leveling and landfilling at NIOF; the effect of an active valley at Qula'an. The features and characteristics of the selected stations, as well as the oceanographic parameters were listed in Table 1. The program of samples collection is based on the NIOF field trips, starting in the June 2009 and ended in March 2010, covering seven different distributed areas located at the Egyptian coast of the Red Sea.

B. Methods

Studied sites were surveyed using the line intercept transect (LIT) methods [30] to evaluate the percentage cover of corals in the area relative to other benthos using SCUBA diving equipments. Each transect has 20m length and 2m gap between the neighbor transects. Three replicate transects were counted and averages were calculated at sub-equal depths from 3 to 7meters for all the selected sites. A total of 24 transects were surveyed from all of the studied sites, where the percentage cover and the number of soft and hard corals were estimated. Also, the living corals (soft, hard) and dead corals were calculated. The percentage covers of other taxa including algae, sponges, gorgonians, sea anemones, and sand with rocks were also estimated. The coral samples were brought to the laboratory for identification .They were preserved in 4% formalin in seawater, rinsed in fresh water after 24h, and then transferred to 70% ethyl alcohol. Sclerites or spicules (endoskeleton) were obtained by dissolving soft

coral tissues in 10% sodium hypochlorite. The soft corals (Alcyonacea) were identified according to [31 - 34]. Moreover, the hard corals were identified according to [35], [36].

The percentage cover was calculated from the following formula:

Percentage cover = Intercept length / Transect length × 100

Diversity (H`) and evenness index (J) was calculated in each lagoon according to [37], [38]:

i) Shannon-Wiener species diversity (Hs). HS = - Σ si=1 Pi ln Pi

s = Total species, (i) = Each species

Pi = Number of colonies species/Number of total colonies

ii) Pielou`s evenness index (J). J = H/ln S, where, s = Number of species

Some physical factors (temperature, salinity, and dissolved oxygen) were measured at each site directly by hydrolab instrument (model Surveyor 4, 1997).

III RESULTS

A. Coral Distribution Along the Coastal Area

During the present study a total of 68 coral species belonging to 35 genera were surveyed during the present investigation where, 49 species of them were hard corals (belonging to 23 hard coral genera) and 19 species (belonging to 12 genera) were soft corals, and they were listed in Table 2, in addition to the other species that observed and not intercepted in the line transects. Hurghada site recorded the highest number of Species (48 species), while the lowest number (24 species) was recorded at Shlateen in Fig. 2. So, Hurghada illustrated the highest diversity than any other studied sites. The highest percentage cover of the hard corals has been recorded at El Sharm El-Bahari and reached about 80.25%, whereas the lowest percentage cover has been recorded at Hurghada in front of the NIOF Red Sea Branch (Marine Biological Station, MBS) with 45.87 %. On the other hand, El Sharm El-Bahari recorded the least cover of the soft corals (0.27%) and the highest value was recorded at North Qula'an (24.84%). The dead corals ranged between 2.59% at El Sharm El-Bahari and 13.09% at NIOF as shown in Fig. 3.

Pocillopora demicornis and Stylophora pistillata recorded the highest percentage cover of the hard coral species (15.60 at El Sharm El-Bahari and 13.28 at Shlateen respectively); moreover, Sarcophyton glaucum and Sinularia leptoclados recorded the highest soft coral species (10.18 and 6.67%) at North Qula'an and Sharm El-Naqa respectively, as shown in Table 2. Moreover, Acropora, Favites, Favia, Millipora, Porites, Pocillopora, and Stylophora are the most frequent and common hard coral genera; while, Nephthea, Sarcophyton, Sinularia, and Xenia are common and abundant in soft coral genera.

B. Community Structure and Biodiversity of Corals

During the present investigation, the coral community recorded its highest cover of living corals (91.5%) at Abu-Dabab locality followed by North Qula'an, Sharm El-Naqa and El Sharm El-Bahari (85.06%, 83.20% and 80.52% respectively). While the lowest cover was demonstrated at NIOF (66.23%), which recorded the highest percent of dead corals (13.09%), while El Sharm El-Bahari has the lowest percent of dead corals and reached about 2.59% as in Table 3 and Fig. 3. On the other hand, El Sharm El-Bahari recorded the highest value of hard coral cover (80.25%) and the least soft corals (0.27%). But NIOF recorded the least hard corals (45.87%), while North Qula'an had the maximum soft coral cover that reached 24.84% as in Table 3 and Fig. 4. NIOF and Shlateen sites recorded a high diversity of living organisms (11% and 22.48%) that associated with coral communities.

NIOF area recorded the highest species number and diversity (48 species and 3.54) followed by Abu-Dabab which recorded 35 coral species and its diversity reached 2.84, and followed by North Qula'an (34 species and the diversity was 2.54. while Shlateen demonstrated the least diversity (1.97) and the recorded number of species was decreased to 24 as shown in Table 4 and Fig. 5. On the other hand, the evenness index is the maximum vale at NIOF (0.9) and is related to coral diversity while the minimum value was detected at Shlateen and reached about 0.62. Acropora humilis, Favites sp., Favia favus, Porites solida, Pocillopora sp. and Stylophora pistillata are the most frequent and repetitive hard species along the studied sites; while, Sarcophyton sp. and Sinularia sp. are the most common soft corals.

C. Data Analysis

ANOVA illustrated that, there are no significant differences between the different sites and their diversity and evenness index as shown in Table 5. Whenever, the cluster analysis illustrated that, there are two clusters, the first concerned with the number of species at the studied sites. Where the similarity among El-Hmrawin, El Sharm El-Bahari, Sharm El-Naqa and Shlateen in having equal or sub-equal numbers as in Fig. 6. Another similarity between Abu-Dabab and North Qula'an; while NIOF has a significant difference due to higher recorded number of diverse species. The second cluster is representing the species diversity and evenness index at the surveyed sites which haven't significant differences.

IV DISCUSSION

The Red Sea is biogeographically divisible into Northern, Central, and Southern regions, where the central has the greatest concentration of coral reefs and the highest diversity of hard corals [39], [40]. Shlateen area is affected by a high density of over-fishing processes and the reject water of the desalination plant that present in the area. These factors are leading to increase the turbidity and settlement of sediment on the coral communities which cause the overgrowth of macroalgae on corals and overgrowth of many sponge species in the area. So, the species diversity decreased (1.97) in the area and percentage cover decreased to 70.99%. On the other hand, the NIOF site is affected by sedimentation processes resulted from the previous land filling processes north Hurghada and the interaction between many factors as temperature and direct exposure to sun light [14]. These reasons are the main factors affect the coral cover causing their decrease to about 66.23%, while the species diversity was the maximum values and recorded 3.54 as compared to Shlateen which recorded 1.97. This may be attributed to many factors affecting these areas, such as land filling and sedimentation processes (at NIOF) and overfishing processes and sedimentation due to turbidity resulting by the reject water of the desalination plant (at Shlateen). This is in

agreement with the findings of many authors (e.g. [8], [9], [26], [41], [12]). Mohammed and Mohamed [14] illustrated that the high sedimentation and turbidity rates in the sheltered areas of the northern Red Sea increases the particulate sediment over and around the coral communities, subsequently the coral distribution and biodiversity are degraded.

On the other hand, Abu Dabab area recorded the maximum coral cover (91.50%) as it is managed by environmental protectorate affaires agency which mainly act to protect the marine environment and coral communities, where its diversity reached to 2.84. Sharm El-Naqa and Sharm El-Bahri recorded a sub-equal values of coral cover (83.20% and 80.52% respectively), where they are relatively affected by tourist activities that may slightly affect the species diversity and reached to 2.92 (at Sharm El-Naqa) and 3.03 (at Sharm El-Bahri), where Mohammed et al [15] illustrated that, the tourist activities and anthropogenic impacts affect the coral distribution, diversity and coverage percent.

El-Hamrawin area is affected by phosphate harbor, mining processes and overfishing processes that may affect the coral cover and species diversity where the living corals covered about 75.54% of the area and their diversity reached 2.68. This is in agreement with [7], [12], [13], [15]; where, they illustrated that these activities are completely destroyed the benthic communities in the shallower areas. North Qula'an area is away from the coastal human affects but lies under the effect of the direct floods from the active valleys. In spit of this factor, but the coral cover reached to 85.06% and its diversity is 2.54. This site is protected by a dense area of mangrove plant which protects the coral communities from the flood water of the valley.

The difference among the studied sites may be affected by many other natural factors as the difference in the geographic distribution as well as bottom topography [11], [23] and geomorphology of the sites [22], [24], [43] and the interaction between physical and biological factor [13] that influenced the distribution, zonation, and diversity of corals, as well as the interaction between physical and biological factors influences the identity, distribution and abundance of coral species and macro-benthic organisms in the area; moreover, longitudes and latitudes may be another factor affecting the coral distribution and diversity. Finally, the differences in coral diversity and evenness index between the different localities can be attributed to the interactions between the environmental conditions in the different sites such as surface temperature, salinity, dissolved oxygen and turbidity [39], where the temperature is ranging between 27°C -29°C at different sites and lies in the range of 26°C -32°C pointed out by [44]. There are no significant differences between the diversity in the different sites using ANOVA test.

V CONCLUSION

5.1. Anthropogenic activities (land filling and over-fishing) are responsible for decreasing the coral community's distribution, diversity, and number of species at most localities as NIOF and Slateen.

5.2. The bottom topography, geomorphology, geographic distribution, longitudes, and latitudes are major factors controlling the coral distribution and differences in diversity of species and their numbers.

5.3. Competition as well as complex interaction between biotic and abiotic factors is another factor influencing the corals distribution and diversity.

5.4. Acropora humilis, Favites sp., Favia favus, Porites solida, Pocillopora sp., Stylophora pistillata, Sarcophyton sp. and Sinularia sp. are the most common and frequent coral species along the Red Sea Coast.

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TABLE I

THE LATITUDE, LONGITUDE AND THE SOME OCEANOGRAPHIC PARAMETERS AT THE STUDIED SITES

Site	Position		Depth	Temperature	Salinity	pH
	Latitudes	Longitudes				
NIOF	27˚ 17' 13" N	33˚ 46' 43" E	3	29.32	41.7	7.89
Sharm El-Naqa	26˚ 53' 39" N	33˚ 58' 22" E	8	27.34	40.54	8.14
El-Hmrawin	26˚ 15' 15" N	34˚ 12' 10" E	4.5	27.11	40.24	8.09
El Sharm El-Bahari	25˚ 52' 04" N	34˚ 24' 57" E	6	31.54	40.74	8.3
Abu-Dabab	25˚ 20' 19" N	34˚ 44' 26" E	8	26.57	40.53	8.14
North Qula'an	24˚ 21' 35" N	35˚ 17' 47" E	5	32.84	41.23	8.3
Shlateen	23˚ 09' 10" N	35˚ 36' 58" E	4	30.26	41.12	8.2

TABLE II

THE PERCENTAGE COVER OF CORAL SPECIES AT THE STUDIED SITES

	Specis	NIOF	Sharm El-Naqa	El-Hmrawin	El Sharm El-Bahari	Abu-Dabab	North Qula'an	Shlateen
Hard Corals	*Acropora humilis*	2.35	3.5	6.85	7.78	8.65	0.00	3.65
	A. squarrosa	0.33	0	2.5	1.80	3.15	3.57	0
	A. hemiprichi	0.65	2.2	2.25	1.35	0.00	2.66	3.61
	A. pharaonis	0.55	2.5	6.4	1.43	0.00	0.00	0
	A. cytherea	1.32	3.5	2.85	2.58	0.00	0.00	0
	A. digitifera	0.00	1.2	3.65	1.83	2.75	0.00	1.71
	A. clathrata	1.22	0	3.25	4.88	0.00	0.00	0
	A. valida	0.00	0	0	3.05	1.55	0.00	0
	A. venosa	0.00	0	0	1.13	0.00	0.00	0
	A. granulosa	0.12	0	0.76	0.00	0.00	0.00	0
	Acropora sp.	0.68	0	0	1.33	2.10	0.00	0
	Echinopora fruticolosa	2.50	4.2	0	0.00	0.00	3.36	3.21
	Echinopora lamellosa	0.00	2	0	0.00	0.00	1.88	0
	Favites sp	0.98	0	0	0.00	1.75	1.32	0
	Favites peresi	0.42	0.5	1.55	3.85	2.15	4.11	2.56
	Favites flexuosa	0.35	0	0	0.00	0.00	1.22	1.02
	Favia laxa	0.00	1.2	0.9	1.13	1.20	3.45	2.84
	Favia speciosa	1.65	0	1.3	0.00	0.00	0.33	0
	Favia favus	2.35	2.3	1.15	2.58	1.45	0.00	5.45
	Galaxea fascicularis	3.99	0	0	0.00	0.25	0.66	0
	Goniastrea pectinata	0.39	0	0	0.00	1.68	1.75	0
	Hydnophora exesa	0.00	0	0	0.00	0.33	0.00	0
	Lobophyllia corymbosa	2.35	0	0	0.00	0.00	2.42	2.48
	Millipora sp	0.00	0	0	0.00	0.00	0.12	0.22
	Millipora dichotoma	1.38	5.8	1.1	3.30	9.15	0.00	1.02
	Millipora platyphylla	0.00	5.7	0	0.73	1.02	0.00	3.11
	Montipora sp	1.65	0	0	0.78	0.32	0.22	1.39
	M. venosa	1.03	0	0	0.00	0.00	0.00	5.45
	M. spongeosa	0.66	0	0	0.00	0.00	0.00	3.87
	Porites solida	2.58	5.8	12.5	5.38	9.75	6.28	3.2
	Porites lutea	0	7.8	3.65	0.00	7.35	2.45	0
	Porites columna	0	0	0	0.00	7.55	0.00	0
	Pocillopora demicornis	0	3.2	3.58	15.60	2.55	0.00	0
	Pocillopora verricusa	0.92	3.3	11.3	13.28	3.56	0.00	0
	Pavona explanulata	0	0.7	0	1.28	0.00	2.36	0
	Pavona decussate	0	0	0	0.00	0.00	1.21	0
	Platygyra deadelia	4.11	0	0	2.55	3.15	5.15	4.64
	Platygyra lamellina	0	0	0	0.00	0.00	1.75	0
	Plesiastrea versipora	0	0	0	0.00	0.51	0.00	0

CONTINUE OF TABLE II

	Specis	NIOF	Sharm El-Naqa	El-Hmrawin	El Sharm El-Bahari	Abu-Dabab	North Qula'an	Shlateen
Hard Corals	*Stylophora pistillata*	8.18	4.2	1.35	1.18	3.35	4.98	13.28
	Styllophora wellsi	0.62	0.00	0	0.00	1.35	1.21	3.21
	Seriatopora histrix	1.21	0.00	0	0.00	0.22	2.05	0
	Siderastrea savignyana	0	0.00	0	0.14	0.13	1.88	0
	Turbinaria mesenterina	0.17	2.1	0	0.00	0.00	2.94	0
	Cosenaria	0.00	0	0	1.22	2.25	0.00	0
	Cycloseries sp	0.00	2.2	0	0.00	0.00	0.00	0
	Cycloseries marginata	0.23	0	0	0.00	0.00	0.89	1.44
	Ctenactis echinata	0.38	2.83	0.25	0.00	0.33	0.00	0
	Fungia fungites	0.55	0.12	0.00	0.09	0.00	0.00	1.85
Soft Corals	*Alcyonium sp*	1.50	0.08	0	0.00	0.00	0.00	0
	Heteroxenia fuscescens	1.32	0	2.75	0.00	0.00	2.14	0
	Lobophytum pauciflorum	1.17	4.8	0.65	0.00	3.79	0.00	0
	Nephthea gracilima minor	0.17	0	1.15	0.11	1.65	0.00	0
	Nephthea molli	0.00	3.5	0	0	0.90	0	0
	Nephthea sp	0.67	0	0.9	0	0.24	1.5	0.11
	Sarcophyton glaucum	2.32	0	0.75	0.16	0.00	10.18	0.65
	Sarcophyton spongiosum	0.17	0	0	0.00	0.00	2.88	0
	Sarcophyton sp.	3.12	0	0	0.00	0.00	0.00	0
	Sinularia polydactyla	3.34	0	0.95	0.00	3.49	2.13	1.02
	Sinularia leptoclados	1.54	6.67	0	0.00	0.00	1.02	0
	Sinularia gardineiri	1.18	0	0	0.00	0.00	2.44	0
	Tubipora musica	0.00	1.3	0.5	0.00	1.23	0.00	0
	Xenia macrspiculata	1.31	0	0.75	0.00	0.65	2.55	0
	Anthella simplex	0.43	0	0	0	0	0	0
	Paralemnalia thyroides	0.32	0	0	0	0	0	0
	Capenella fungiformis	0.39	0	0	0	0	0	0
	Cladiella sp.	0.51	0	0	0	0	0	0
	Nephthea chabrolli	0.90	0	0	0	0	0	0
	Dead corals	13.09	8.35	6.75	2.59	6.10	7.08	5.13
	Rocky bottom	0.33	2.11	11.69	4.38	0.87	1.25	0.18
	Sandy bottom	9.35	2.55	0.94	6.88	0.18	0.88	1.22
	Echinodermis	2.31	0.12	1.6	1.12	0.00	0.00	0.19
	Algae	7.54	0.74	1.23	1.25	0.00	0.00	7.49
	Tridacna	0.11	2.35	2.25	3.26	1.35	2.75	0.22
	Sponge	0.00	0	0	0.00	0.00	0.00	14.58
	Black Sponge	1.04	0.58	0	0.00	0.00	2.98	0

TABLE III

THE PERCENTAGE COVER OF DIFFERENT TAXA AT THE STUDIED SITES

Taxa	**NIOF**	**Sharm El-Naqa**	**El-Hmrawin**	**El-Sharm El-Bahari.**	**North Qula'an**	**Abu-Dabab**	**Shlateen**
Hard corals	45.87	66.85	67.14	80.25	60.22	79.55	69.21
Soft corals	20.36	16.35	8.40	0.27	24.84	11.95	1.78
Dead corals	13.09	8.35	6.75	2.59	7.08	6.10	5.13
Sand and rocky bottom	9.68	4.66	12.63	11.26	2.13	1.05	1.40
Other living things	11.00	3.79	5.08	5.63	5.73	1.35	22.48

TABLE IV

SUMMERY OF THE STATISTICAL ANALYSIS OF THE SURVEYED COMMUNITIES AT THE DIFFERENT STATIONS.

Station	**NIOF**	**Sharm El-Naqa**	**El-Hmrawin**	**El-Sharm El-Bahari.**	**North Qula'an**	**Abu-Dabab**	**Shlateen**
Diversity	3.54	2.92	2.68	3.03	2.54	2.84	1.97
Evenness	0.9	0.89	0.81	0.92	0.72	0.68	0.62
colony no.	124	105	97	119	96	86	53
sp. No.	48	27	27	27	34	35	24
Hard coral species	31	22	19	25	26	28	21
Soft coral species	17	5.00	8.00	2.00	8.00	7.00	3.00

TABLE V

ONE WAY ANOVA OF THE CORAL DIVERSITY OF THE STUDIED SITES

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	148.691	6	24.782	0.078	0.998
Within Groups	4452.996	14	318.071		
Total	4601.687	20			

Figure 1 The selected studied sites along the Red Sea coast

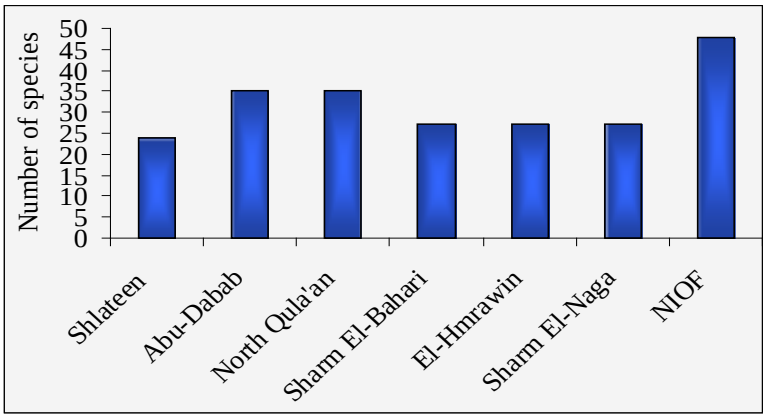

Figure 2. The species number of corals at the investigated sites.

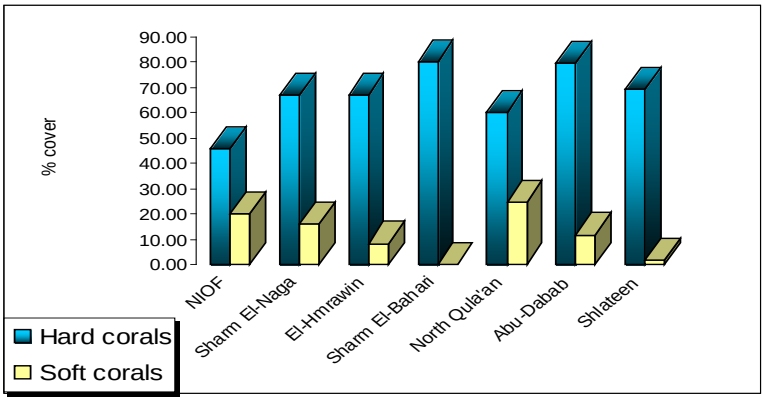

Figure 3 The percentage covers of the hard and soft corals at the investigated sites

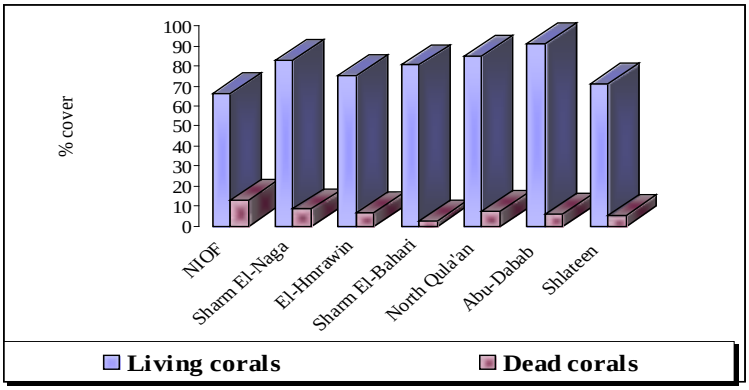

Figure 4 The percentage cover of living (hard & soft) and dead corals

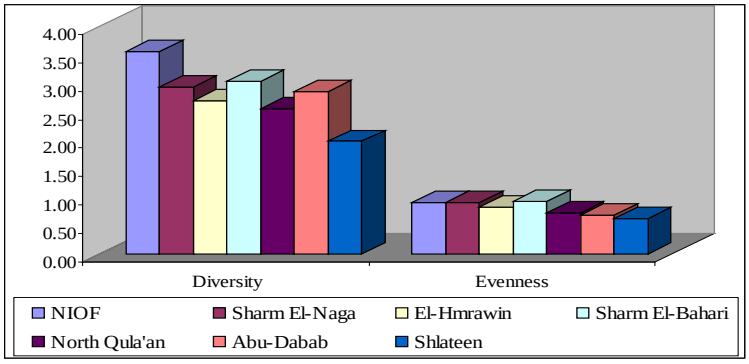

Figure 5 The species diversity and evenness index at different sites

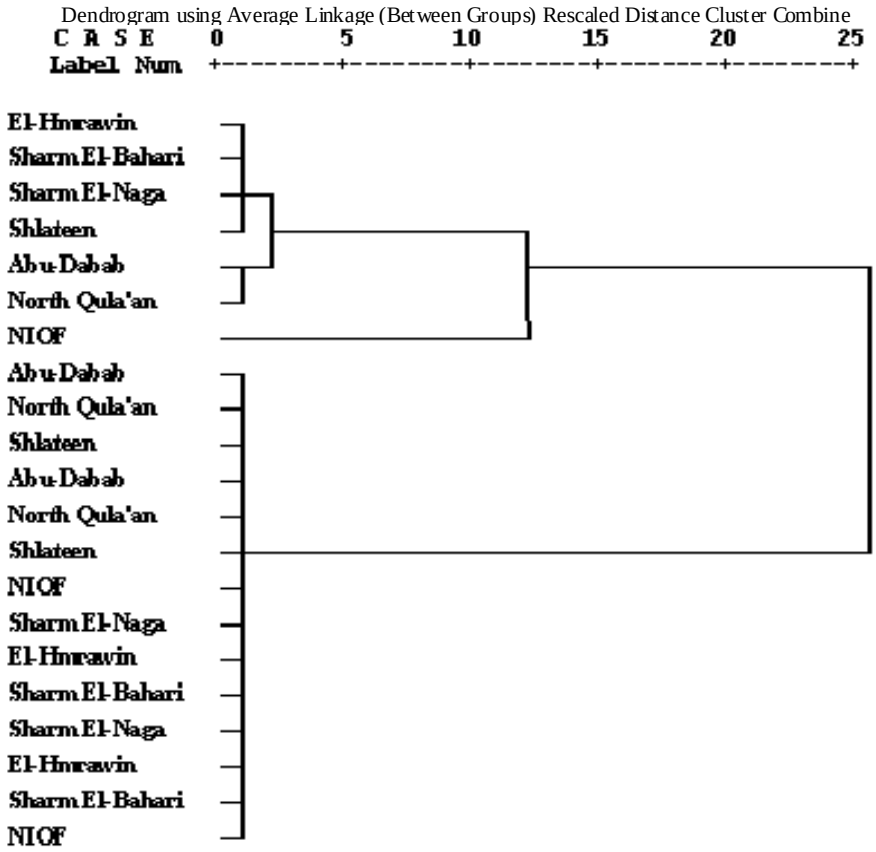

Figure 6 Cluster analysis of number of species, diversity and evenness index of corals at the studied sites