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Distribution and Diversity of Living Natural Resources from the Most Northern Red Sea Islands, Egypt: I- Hard and Soft Corals

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ABSTRACT

The present study is a part of a monitoring program of the most important living natural resources, investigating the substrate cover distribution in the most northern islands of the Egyptian Red Sea. These resources include both hard and soft corals. This study was made during winter 2017 using Line Intercept Transact (LIT) to monitor the diversity and distribution of those resources. Eight islands located at the entrance of the Suez Gulf were surveyed using standard methods. Monitoring work for the hard and soft corals using transect was done by diving and snorkeling in the study areas. In the current study, the highest percentage cover of hard corals was 84 % recorded at Ghanim Island compared with the lowest cover of 41.3 %, estimated at Ashrafi Island, with mean percentage cover for all Islands averaged 60.1%. *Acropora* and *Stylophora* were the most abundant hard coral genera with a percentage cover of 35.8% and 17.6 %, respectively. Soft corals were the highest at Tawila Island with a percentage cover of 6% and the *Nephthea* was the highest soft coral genera with a percentage cove of 1.0 %. The monitoring work showed the diversity and distribution of these natural resources, especially coral reefs, and the extent to which these resources are affected by human activities, especially tourism activities, and also extraction and drilling for oil near the study areas. Observations on hard and soft corals in the study areas may be useful and important in the development of those areas in the future.

1. INTRODUCTION

The Red Sea has unique marine habitats as coral reefs, mangroves and seagrass beds. They provide key resources for coastal populations: food, shoreline protection and stabilization, and economic benefits from tourism (Barrania, 2010). The earliest studies on the coral reefs of the Red Sea are undertaken by Peter Forsskål as part of the Danish Arabia Felix‟ expedition in 1761-67 (Head, 1987). Coral reefs extend throughout the latitudes of the Red Sea to the tip of Gulf of Aqaba. The basic form of coral reefs in the Red Sea is that of fringing reefs laying close to shore of widths varying from a few meters to over 1 km. The reefs are not continuous throughout the Sea and are separated by narrow channels known as Marsas or Sharms, originated from drowned river valleys that connect to Wadis (Mergner, 1971; Head, 1987).

Coral reefs worldwide are subjecting to extensive anthropogenic damage (Sebens, 1994; Al-Hammady and Mahmoud, 2013; Al-Hammady, *et al*., 2015) and their existence threatened by the economic activities they support (White *et al.,* 2000). Two anthropogenic factors contributing the coral reef decline are eutrophication (Koop *et al.,* 2001) and damage from snorkelers & SCUBA divers (Zakai and Chadwick-Furman, 2002). Sedimentation, which may be enhanced by anthropogenic activities (Loya, 1976; Rogers, 1990) is also known to affect coral community structure and can damage coral colonies (Rogers, 1990). Coral colonies affected by natural or anthropogenic stressors may suffer partial mortality, which has been shown to be a good indicator of reef condition (Ginsburg *et al.,* 2001). Generally, eutrophication, increased sedimentation flowing from disturbed terrestrial environment, diving, fishing activities, mining and oil pollution are the main causes of reef destruction and decline (Sebens, 1994).

The coastal and marine resources of the Red Sea have been contributed to the food, energy, industrial and recreational needs of Egypt (Hilmi, *et al.*, 2012). But on other hand some environmental problems are found along the Red Sea coast and Islands, like recreation, tourism activities, landfilling, dredging, water pollution, solid waste disposal, phosphate pollution and fishing practices, increased marine activities, increasing the number of marine boats and fishing boats, many petroleum pollution incidents. By the law 102 /1983 Ministry of Environment in Egypt (nature conservation sector) declare 22 Islands in the Red Sea as protected area since 1995 from Gifton Island in front of Hurghada (north) to Halayeb Island at 22^0 and Egyptian border with Sudan. In 2006 the northern Islands (Tawila Island, Ashrafi Island (Mokwarate), Ghanim Island, Small Gubal, North Um Elhimat, South Um Elhimat, North Geisum and South Geisum were added to the Red Sea Protected Islands (Figs. 1 & 2). Most of these north islands are remote area and they locate near the entrance of Gulf of Sueze, that is have strategic important for maritime transportation. In addition, these Island are surrounded by some petroleum and fishing activities (Figs. 1&2).

Egyptian reefs are fringing reefs alongside the coastline extend from the north at the Gulfs of Suez and Aqaba to Ras Hedarba in the South at the border of Sudan. The northern part of the Red Sea has the highest coral diversity and number of islands, while the south has the highest terrestrial biodiversity for the whole country (Hassan *et al.,* 2002; Shaalan, 2005). Eight common genera of soft coral were have been recorded in the Egyptian Red Sea.; *Xenia*, *Heteroxenia*, *Sarcophyton*, *Lobophytum*, *Litophyton*, *Sinularia*, *Nephthea*, and *Dendronephthea* (Roushdy, 1954, Vine, 1986). But recently, Ismail *et al*. (2017) recorded eleven soft coral genera in the Red Sea. Geographically, coral diversity varies quite considerably in the Egyptian Red Sea due to changes in water temperatures, salinity, sediment load and light and anthropogenic impacts (Abou Zaid, 2002). The average percentage of live coral cover for the Egyptian Red Sea is 45% at 5m and 33% at 10m (Hassan *et al.,* 2002). The percentage of live cover varies depending on the geo-morphological types of reef in the Red Sea. Reef flat areas typically range from 11-35%, while the highest live coral cover is found along reef walls, ranging from 12-85% and reef slopes 2-62% (Abou Zaid 2000). On average, the percentage of hard coral cover remains stable from north to south, but soft coral cover slightly increases towards the south. The mean size of hard and soft corals increases towards the southern part of the Egyptian Red Sea (Kotb *et al.,* 2001; Ismail *et al*., 2017).

The abundance, distribution and percentage cover of the hard and soft corals have been studied by many authors in the Red Sea and the Indo-Pacific regions. They investigated the distribution patterns of hard and soft corals along the Egyptian Red Sea Coast (Mohammed *et al*., 2010; Ismail *et al*., 2017) and in the central Great Barrier Reef (Dai, 1990 and Fabricius, 1997). Moreover, the coral distribution in some localities of the Red Sea have been studied generally referring to the community structure of coral reefs (Ammar & Nawar, 1998; Ammar, 2004, Al-Hammady and Mahmoud, 2013, Al-Hammady, *et al*., 2015; Ismail *et al*., 2017), ecology and biology (Loya, 1976; Kotb, 1996; Kotb *et al.,* 2001; Mohammed, 2003 and 2006). The interaction of many factors that affecting the distribution and coral bleaching (Mohammed and Mohammed, 2005) have been studies including, the sedimentation, overfishing, tourist activities, petroleum and phosphate production and discharge of desalination Plants on the marine environment (Mohammed *et al.,* 2009; Madkour 2013; Nasr *et al.,* 2019).

In the Red Sea coast of Egypt, most of the previous studies about substrate cover focused on the north (Gulf and Aqaba and Ras Mohamed) and south (Hurghada to Marsa Alam) parts of the Red Sea and neglected the Red Sea islands especially those located at the north. To fulfill such gap, the present study was designed to investigate the distribution and diversity of living natural resource in the northern protected Islands especially hard and soft corals after long time they declare as protected areas. The result could be helping the decision maker as it was noticed during collecting the current data some of ecotourism development starting in Tawila Island.

2. MATERIALS AND METHODS

2.1. Geomorphology of the study Islands:

Eight northern Red Sea Islands lie at the entrance of Suez Gulf comprised: Tawila Island, Ashrafi Island (Mokwarate), Ghanim Island, Small Gubal Island, North Um Elhimat Island, South UmElhimat Island, North Geisum Island and South Geisum Island were surveyed during this study (Figs. 1 & 2). The data were collected during the winter 2017 involved marine key habitat biota (fauna and flora) including substrate cover of hard corals, soft corals, dead corals, rubles, sand, algae and sponges. These islands are treated in details as following:

2.1.1. Tawila Island lies at 27°:35':15.24" N and 33°:45':52" E, with a total area of 21.5km^2. It has about 22 km a distance from the beach. Tawila Island has sandy beach and surrounded by many shallow lagoons. It is used in sporting tourism activity and snorkeling. During the current study the construction of hotels was starting on the Island (Figs. 1 & 2).

2.1.2. Ashrafi Island lies at 27°:45':57" N and 33°:42':4.49" E, with a total area of 1.4 km^2 and is about 12 km far from the beach. Ashrafi Island consists of three longitudinal small islands located at the entrance of Gubal Straits. This island is of coral origin and is characterized by submerged coral reefs separated by narrow channel (Figs. 1 & 2).

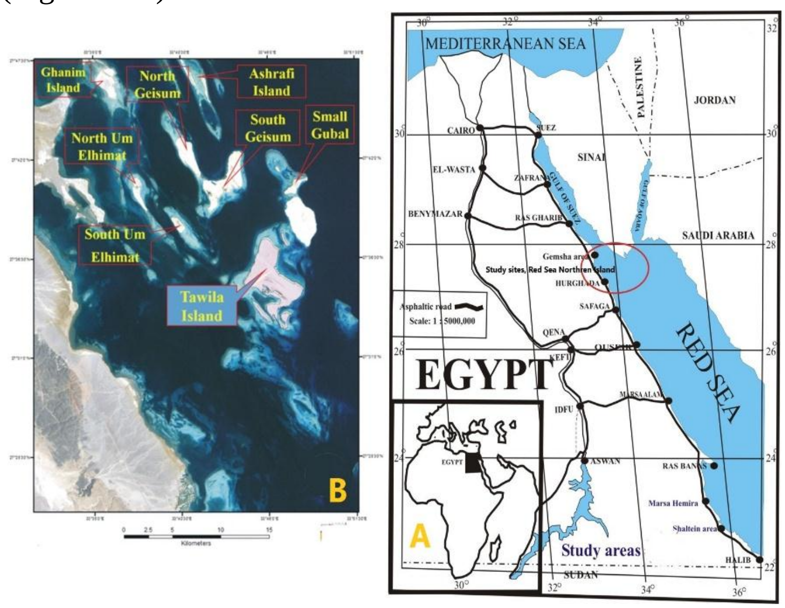

Figure.1: Maps show general locations of the study sites along the most northern Egyptian Red Sea (A) Modern picture by Google earth 2019, (B) The northern Islands of the Red Sea.

2.1.3. Ghanim Island: It is located at 27°:46':23" N and 33°:35':51.7" E near the coast of Gabal El Zeit (group of Petroleum Company), with a total area of 4.6km^2 and is about 3 km far from the beach. Ghanim Island is a small Island and is located near popular Marsa Ras El Bahar (grounding small fishing boat). The Island is surrounded by the barrier submerged reefs that extend to the Ashrafi Island (Figs. 1 & 2).

2.1.4. Small Gubal Island: It is located at 27°:41':23" N and 33°:46':34.6"E. It has a total area of 1.5km^2 and is far about 30 km from the beach. This island is located at the south entrance of Sueze Gulf and characterizes with sandy beach used by safari boat tourism. This island is characterized with nesting activity for hawksbill turtles (Figs. 1 & 2).

2.1.5. Northern Um Elhimat Island**:** This island locates at 27°:39':9.1" N and 33°:38':19.45"E, and is about 4.5 km from the beach (Ras Gemsa). It is surrounded by barrier submerged reef. There is a petroleum platform is located about 3km east of the Island (Figs. 1 & 2).

2.1.6. South Um Elhimat Island: This island is located at 27°:37':56.91" N and E33°:40':29.91"E. It lies at the south of North UmElhimat Island and the two islands are surrounded by barrier submerged reef (Figs. 1 & 2).

2.1.7. North Geisum Island locates at 27°:41':5.63" N and 33°:41':26.78"E and is about 0.5 km from the beach. It lies at the north of south Geisum Island, but the two are separated by submerged back reef (Figs. 1 & 2).

2.1.8. South Geisum: It locates at 27°:39':4.29" N and 33°:42':33.25"E, and is about 5 km west of Gubal Island, with a total area of about 9.7km^2. This island is characterized by a monospecific mangrove stand (*Avicenna marina*), surrounded by submerged back reefs and few lagoons. This island has an old harbor at the southern part, extends for 200 m long (Figs. 1 & 2).

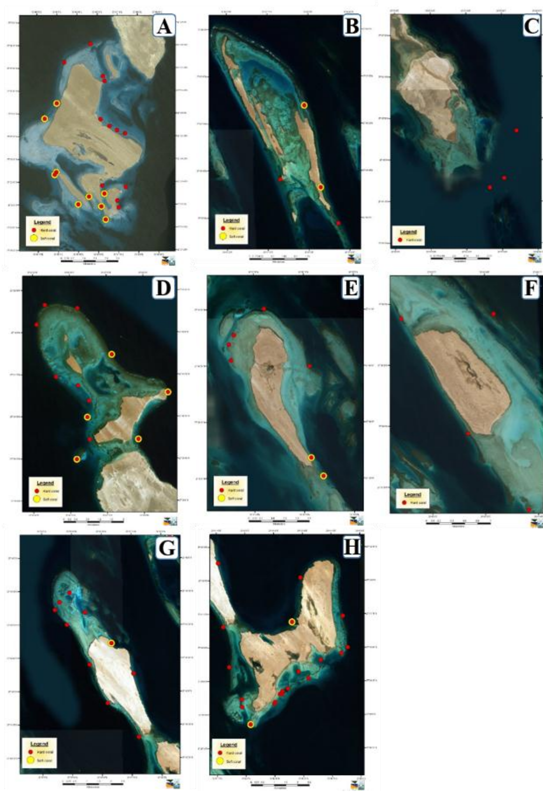

Fig. 2: GIS map representing hard and soft corals in Red Sea northern Islands, A) Tawila Island, B)Ashrafi Island, C) Ghanim Island, D) Small Gubal, E) North UmElhimat, F) South UmElhimat, G) North Geisum and H) South Geisum.

2.2. Field work:

In this study, Safari boat was using for transportations to and between selected islands. The data of coral reef assemblages were collected using SCUBA diving and snorkeling (free diving). The data were recorded using waterproof sheet at depth contour of 2-6m. The surveyed benthic substrate cover data was performed using the Line Intercept

Transect (LIT) methods according to English *et al.* (1997). A 25 m long tape transect was used to record the coral genera of the substrate cover (hard corals and soft corals). At the same time, data of dead corals, algae, sand, rubbles, rocks and sponges were recorded to evaluate the percentage cover of substrate every one-meter length of the LIT at each site. All colonies within each line transect were recorded, identified at generic level, counted, photographed by Gopro underwater Camera. The different coral genera of the study areas were identified according to Sheppard and Sheppard (1991); Wallace (1999); Veron (2000) and Richards (2018).

2.3 Statistical Analysis:

The collected data was statistically analyzed using SPSS programme (V. 20) and Excel Office. The number of replicates of LIT was different according to the island size; therefor, 3 replicates were taken at Ashrafi and Ghanim Island, 4 at North Um Elhimat Island, 5 at South Um Elhimat Island, 7 at North Geisum Island, 8 at Small Gubal and South Geisum Island and 12 at Tawila Island. By using the statistical program the following quotation and relations were concluded: percentage substrate cover means ± SD, analysis of variance (ANOVA&MANOVA) and the Multiple Range Comparisons (Least Significant Difference; LSD) was selected from Post Hoc window, Pearson correlation coefficients were applied in the present data. Probability values of <0.05 and <0.01 were defined as significant throughout the current work where NS denotes to non-significant. By using GIS program, the results were shown on maps to explain the distribution of coral reefs and substrate covers at the studied sites. The percentage cover of a given species or taxa underlying LIT was calculated according to English *et al*. (1997) formula as following: Percent cover = (Intercepted lengths of category / Transect length) x 100.

Index of general diversity (Shannon -Wiener index)

This index (Shannon and Wiener, 1948) is perhaps the most widely used index of heterogeneity. It is calculated by the following formula: $H = 3.3219 \log N - \frac{1}{N} \sum n_i \log n_i$, Where: N= total number of individuals of all species, n_i= number of individuals of "**a**" species). The Shannon index varies from a value of 0 for communities containing only a single species to high values for communities containing many species, each with a small number of individuals.

Evenness index: According to Pielou (1966) the evenness index was calculated from the following equation: $E = \frac{H}{S}$, Where: H= Shannon index, S= Number of species.

Species richness: Species richness index was calculated according the formula cited by English *et al*. (1997) as following:D = S-1/Ln N, Where: S= total number of species, N= total number of individuals in the sample.

3. RESULTS AND DISCUSSION

3.1. Biotic and abiotic components:

During the current study biotic (living) and abiotic (nonliving) components were recorded (Table 1). The abiotic components comprised sand, rubles, rock and dead corals; while the biotic components were represented by hard corals, soft corals, algae and sponges. Sixteen living substrate taxa were recorded. Hydrocorals were the first of that taxa and are belonging to genus *Millepora*, family Milleporidae, Class Hydrozoa, Phylum Cnidaria. Ahermatypic corals (soft corals) were represented by four genera compressed *Sarcophyton*, *Sinularia*, *Xenia* and *Nephthea* which belong to, Subclass Alcyonaria (Octocorallia). In contrast, the hermatypic corals (hard corals) were represented by the highest number of genera (9 genera) compressed *Acropora*, *Montipora*, *Stylophora*, *Pocillopora*, *Seriatopora*, *Fungia*, *Porites*, *Favia* and *Platygyra*) belong to Subclass Zoantharia (Hexacorallia). On the other hand, both of sponges and algae were low abundant but play a significant role in marine environment (Table 1). The hard coral genera in the present study are classified according to life form into: branching corals, comprising 5 genera of *Acropora*, *Montipora*, *Stylophora*, *Pocillopora* and *Seriatopora*), massive corals comprise two genera of *Porites* and *Platygyra* and solitary corals including two genera of *Fungia* and *Favia* (Table 1).

3.2. Distribution of living and nonliving components:

The results of percentage cover of both living and nonliving components are given in Table (2). Eight substrates cover categories (hard corals, soft coral, dead coral, rubbles, algae, sand, rock and sponges) in the eight northern studied islands were recorded. The hard coral percentage cover in northern islands ranged from the lowest percentage (41.3%) at Ashrafi Island to the heights percentage cover (84%) at Ghanim Island with mean percentage cover of 60.1% (Table 2 & Fig.2). On the other hand, soft coral percentage cover ranged from the lowest (0.6 %) at North Geisum to the heights cover (6.0 %) at Tawila Island with mean percentage of 2.5% (Table 2 & Fig.2). No soft corals were recorded at Ghanim Island and South Um Elhimat.The values of nonliving components were variable during this study. Dead coral cover ranged from 10.7% at Ghanim Island to 39% at South Geisum with an average of 30.3% (Table 2). The mean percentage cover of rubbles recorded the lowest value of 0.5% at Small Gubal Island with highest percentage cover of 4.0% at Ashrafi Island and completely disappeared at Ghanim and South Um Elhimat Islands (Table 2). Sand percentage cover was ranged from the lowest value of 1 % at North Um Elhimat Island to the heights cover 5.3 % at Ghanim Islands with mean percentage of 1.9% (Table 2). Rocks were recorded only at Ashrafi Island with mean percentage cover of 5.3% and disappeared at other sites (Table 2).

Table 1. Classification of coral reef genera (hard and soft corals) collected from the most northern islands along the Egyptian Red Sea.

Phylum:					Porifera	(Sponges)
Phylum:					Cnidaria	
Class					Hydrozoa	
			Family		Milleporidae	
				Genus	***Millepora***	(Fire corals)
Class					Anthozoa	
	Subclass				Alcyonaria or Octocorallia	(Soft corals)
		Order			Alcyonacea	
			Family		Alcyoniidae	
				Genus	***Sarcophyton***	
					Sinularia	
			Family		Xeniidae	
				Genus	***Xenia***	
		Suborder			Alcyoniina	
			Family		Nephtheidae	
				Genus	***Nephthea***	
Subclass					Zoantharia or Hexacorallia	(Hard corals)
		Order			Scleractinia	
			Family		Acroporiidae	
				Genus	***Acropora***	
					Montipora	
			Family		Pocilloporidae	
				Genus	***Stylophora***	
					Pocillopora	
					Seriatopora	
			Family		Fungiidae	
				Genus	***Fungia***	
			Family		Poritidae	
				Genus	***Porites***	
			Family		Faviidae	
				Genus	***Favia***	
			Family		Merulinidae	
				Genus	***Platygyra***	

The percentage cover and occurrence of other living components, algae and sponges were variable. No algae were recorded at 4 Islands (Ghanim Island, Small Gubal, South Um Elhimat and North Geisum) while the highest algal percentage cover was 9.3 % recorded at Ashrafi Island with mean percentage of 2.5 % (Table 2). Sponges were recorded only at two islands with percentage cover of 0.3 % and 4.5% in Tawila and South Geisum Islands, respectively.

Table 2: Percentages substrate cover (%) at the Red Sea northern Islands.

Type	Substrate Category	Tawila Island	Ashrafi Island	Ghanim Island	Small Gubal	North Um Elhimat	South Um Elhimat	North Geisum	South Geisum	Mean ± SD	Total ± SD
Living cover	Hard corals	52.0	41.3	84.0	64.5	65.0	64.0	61.1	48.5	60.1± 12.6	65.6 ± 27.0
	Soft corals	6.0	4.0	0.0	3.5	3.0	0.0	0.6	2.5	2.5± 2.1	
	Algae	5.0	9.3	0.0	0.0	4.0	0.0	0.0	1.5	2.5± 3.4	
	Sponges	0.3	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.6± 1.5	
Non-Living cover	Dead corals	30.7	36.0	10.7	31.5	26.0	34.4	34.3	39.0	30.3± 8.5	34.4 ± 13.4
	Rubbles	3.3	4.0	0.0	0.5	1.0	0.0	1.1	2.0	1.5± 1.4	
	Sand	2.7	0.0	5.3	0.0	1.0	1.6	2.9	2.0	1.9± 1.7	
	Rocks	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7± 1.8	

During the current study, the hard coral cover was negatively correlated with dead coral (r=-.82, *p*=0.01), rubbles (r=-.53, *p*=0.01), algae (r=-.30, *p*=0.05) and positively correlated with total number of individual (r=.92, *p*=0.01) (Table 3). The soft coral cover was positively correlated with Shannon richness (r=.65, *p*=0.01) and Shannon diversity (r=.62, *p*=0.01) (Table 3).

The hard coral covers recorded here in the northern islands are close to the previously published works (Riegl and Velimirov, 1994, and Hussein, 2016). The highest percentage of hard coral cover at Ghanim Island (84%) compared to Ashrafi Island (41%) most likely related to the negative correlation between the hard coral and algae (-.30), dead coral (-.82), rock (-.53) and positive correlation with total number of individual (0.92) (Table 3).

The percentage cover of algae was 9% at Ashrafi Island and was zero at Ghanim Island as the algae compete with the coral in light and nutrient. In the same time, the high percentage cover of hard corals at Ghanim Island higher than that at Ashrafi Island may be attributed to the positive correlation between hard coral cover and total number of Individual, as the total number of individual was 3 times higher in Ghanim Island than that at Ashrafi Island (Fig. 3). The most important factors for resilience are the recovery which includes, the replenishment of coral recruitments in denuded locations (Hughes *et al.*, 2010), the presence of suitable substrates for coral settlement and survival (Victor, 2008), and low cover of algae, where their high abundance can directly kill corals, trap sediment, prevent coral settlement (Mumby *et al.*, 2007).

Table 3: The values of correlation coefficients (r) for association between densities of substrate cover and other biotic and abiotic factors. SR mean Shannon richness, TI mean Total number of individual, SE mean Shannon Equitability and SD mean Shannon diversity.

Substrate categories	Hard corals	Soft corals	Dead corals	Rubble	Algae	Sand	SR	TI	SE	SD
	r^{sig}	r^{sig}	r^{sig}	r^{sig}	r^{sig}	r^{sig}	r^{sig}	r^{sig}	r^{sig}	r^{sig}
Hard coral	-	NS	-.82**	-.53**	-.30*	NS	NS	0.92**	NS	NS
Soft coral	NS	-	NS	NS	NS	NS	65**	NS	NS	.62**
Dead coral	-.82**	NS	-	-.53**	NS	NS	NS	-.88**	NS	NS
Rubbles	-.53**	NS	.30*	-	.38**	.34*	NS	-.59**	NS	NS
Algae	-.30*	NS	NS	.38**	-	NS	NS	-.34*	NS	NS
Sand	NS	NS	NS	.34*	NS	-	NS	NS	NS	NS
SR	NS	.65**	NS	NS	NS	NS	-	NS	.30*	.90**
TI	.92**	NS	-.88**	-.59**	-.34*	NS	NS	-	NS	NS
SE	NS	NS	NS	NS	NS	NS	.30*	NS	-	NS
SD	NS	62**	NS	NS	NS	NS	.90**	NS	NS	-

Dead corals were also very high at Ashrafi Island (36%) according to the fishing activity compared to 11% at Ghanim Island. The high percentage cover of dead corals recorded at Ashrafi Island is related may be due to the illegal overfishing activity, petroleum, and tourism because it located near the Gabal El Zait; in contrast, Ghanim Island is a sheltered island and is subjected to low fishing activity (Mohammed, 2003; Ammar, 2004; Mohammed, 2006 and Mohammed *et al.*, 2009).

3.3. Percentage covers of hard coral genera:

Nine genera of hard corals in addition to only one genus of Hydrocorals were represented in Red Sea northern Island. These genera comprised stony coral genera of *Acropora*, *Pocillopora*, *Stylophora*, *Porites*, *Favia*, *Montipora*, *Seriatopora*, *Platygera* and *Fungia*, in addition to Hydrocorals of genus *Millepora* (Table 4).

Acropora was the highest hard coral genus in the present study. It has the highest percentage cover average 45.0% at Small Gubal Island, but declined to the lowest value of 20 % at Ashrafi Island, with a mean percentage cover of 35.8 % (Table 4). Genus *Stylophora* came in the second order with the highest value of 38.7% at Ghanim Island, and the lowest (5.0%) at small Gubal Island with a percentage mean of 17.6 % (Table 4). *Pocillopora* came in the third order and was represented by the highest ratio of 6.7% at Ashrafi Island, and the lowest ratio of 1.1% at North Geisum with mean percentage was 1.9 % and was disappeared at four islands. The ratios of percentage covers of the remaining genera were declined sharply and recorded general averages of 1.5, 0.9, 0.2, 0.7, 1.3, 0.2 and 0.1 for *Porites, Favia, Millepora, Montipora, Seriatopora, Platygera* and *Fungia*, respectively (Table 4). The hard coral percentage cover in the eight northern islands differs from one island to another. The highest hard coral percentage cover was 84% at Ghanim Island and the lowest was 41.3% at Ashrafi Island with mean percentage cover of 60.1 % (Tables 2 & 4).

Table 4: Percentage cover (%) of hard coral genera at the Red Sea Northern Islands.

Hard coral genera	Tawila Island	Ashrafi Island	Ghani m Island	Small Gubal	North um Elhimat	South um Elhimat	North Geisum	South Geisum	Mean ± SD
Acropora	30.3	20.0	41.3	45.0	39.0	44.0	37.1	29.5	35.8±8.3
Pocillopora	4.3	6.7	0.0	3.0	0.0	0.0	1.1	0.0	1.9±2.5
Stylophora	10.7	12.0	38.7	5.0	23.0	17.6	19.4	14.5	17.6±9.8
Porites	0.3	0.0	1.3	8.0	1.0	0.0	0.0	1.5	1.5±2.6
Favia	0.7	1.3	0.0	2.5	0.0	0.8	0.0	1.5	0.9±0.9
Millepora	1.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.2±0.4
Montipora	2.0	0.0	0.0	0.0	0.0	1.6	0.6	1.0	0.7±0.8
Seriatopora	1.7	1.3	2.7	0.0	1.0	0.0	2.9	0.5	1.3±1.1
Platygyra	0.3	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.2±0.4
Fungia	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1±0.2
Total	52	41.3	84.0	64.5	65.0	64.0	61.1	48.5	60.1±12.6

The results of multivariate analyses (MANOVA) of the interaction between sites and hard corals as independent factors and *Stylophora*, *Acropora,* Shannon Equitability (J), *Porites* and *Favia* as dependent factors are showed in Table (5). In the case of sites, all factors were significant: *Stylophora* ($p<0.01$), Shannon Equitability (J) ($p<0.05$), *Porites* ($p<0.01$), *Favia* ($p<0.05$) except of *Acropora* ($p<0.09$). In the case of hard corals all factors were highly significant except of Shannon Equitability (J). In the case of Sites versus hard corals *Stylophora*, Shannon Equitability (J), *Porites* and *Favia* were significant.

Further statistical analyses (LSD) (Tables 6) has revealed significant differences of *Stylophora* ($p<0.05$), *Porites* ($p<0.01$), algae ($p<0.05$), and rock ($p<0.05$) at different Northern Islands.

Table 5: Values of MANOVA for the distribution of significant hard substrate cover in the Red Sea Northern Islands.

Source of variations	Dependent variables	Sum of squares	DF	Mean squares	F- values	Sig.
Sites	*Stylophora*	167.0	7	23.9	11.0	.001
	Acropora	94.3	7	13.5	2.4	.097
	Shan. Equitability (J)	0.4	7	0.1	3.1	.049
	Porites	24.2	7	3.5	23.1	.000
	Favia	3.3	7	0.5	3.1	.051
Hard corals	*Stylophora*	326.8	17	19.2	8.9	.001
	Porites	39.1	17	2.3	46.0	.000
	Favia	844.8	17	49.7	8.4	.001
	Acropora	25.2	17	1.5	9.9	.000
	Shan. Equitability (J)	5.2	17	0.3	2.0	.129
Sites* Hard corals	*Stylophora*	195.9	15	13.1	6.0	.003
	Acropora	177.3	15	11.8	2.1	.113
	Shan. Equitability (J)	0.9	15	0.1	3.0	.044
	Porites	24.0	15	1.6	10.7	.000
	Favia	8.1	15	0.5	3.6	.023
Error	*Stylophora*	21.7	10	2.2		
	Acropora	55.2	10	5.5		
	Shan. Equitability (J)	0.2	10	0.02		
	Porites	1.5	10	0.15		
	Favia	1.5	10	0.15		

Table 6: Values of ANOVA for the distribution of significant substrate cover in the Red Sea northern Island

Substrate category		Sum of Squares	DF	Mean Square	F	**Sig.**
Stylophora	Between Groups	195.481	7	27.926	2.160	**0.05**
	Within Groups	543.099	42	12.931		
	Total	738.580	49			
Porites	Between Groups	24.347	7	3.478	2.931	**0.01**
	Within Groups	49.833	42	1.187		
	Total	74.180	49			
Algae	Between Groups	23.388	7	3.341	2.166	**0.05**
	Within Groups	64.792	42	1.543		
	Total	88.180	49			
Rock	Between Groups	4.840	7	0.691	2.334	**0.04**
	Within Groups	12.440	42	0.296		
	Total	17.280	49			

3.4. Percentage covers of soft coral genera:

Four genera of soft corals were recorded at the northern Red Sea Islands, comprised: *Sarcophyton, Sinularia, Nephythea* and *Xenia* (Table 7). *Nephythea* had the highest values of percentage covers during this study. It has the highest percentage cover of 3.0

% at North Um Elhimat Island and the lowest value of 0.5 % at South Geisum with mean percentage cover of 1.0 %. Genus *Xenia* was recorded only at Tawila Island with percentage cover of 3.7% (Table 7). *Sinularia* recorded the highest percentage cover of 1.5% at Small Gubal Island and the lower value of 1.0% at South Geisum Island with mean percentage cover of 0.6 %. The highest percentage cover of *Sarcophyton* was 1.0 % at Tawila and South Geisum Islands and the lowest value of 0.5% at Small Gubal Island, with a mean percentage cover of 0.4 % (Table 7). The soft coral percentage covers at the eight northern islands were fluctuated between islands. The highest soft coral percentage cover was 1.5% at Tawila Island, declined to the lowest value of 0.6% at South Geisum Island with mean percentage of 0.6% (Table 7). In the present study, there are three islands without soft coral covers comprised Ghanim Island and North and South Um Elhimat Islands.

Table 7: Percentage cover (%) of soft corals at Red Sea Northern Island.

Soft coral Genera	Tawila Island	Ashrafi Island	Ghanim Island	Small Gubal	North Um Elhimat	South Um Elhimat	North Geisum	South Geisum	Mean ±SD
Sarcophyton	1.0	0.0	0.0	0.5	0.0	0.0	0.6	1.0	0.4±0.4
Sinularia	1.3	1.3	0.0	1.5	0.0	0.0	0.0	1.0	0.6±0.7
Nephythea	0.0	2.7	0.0	1.5	3.0	0.0	0.0	0.5	1.0±1.3
Xenia	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5±1.3
Total	6.0	4.0	0.0	3.5	3.0	0.0	0.6	2.5	2.5±2.1

The result of multivariate analysis (MANOVA) of the interaction between sites and soft corals as independent factors and *Nephthea, Sinularia, Sarcophyton* and sponges as dependent factors are shown in (Table 8). In the case of sites, soft corals and sites versus soft corals, all factors were highly significant, *Nephthea* ($p<0.01$), *Sinularia* ($p<0.01$), *Sarcophyton* ($p<0.01$) and sponges ($p<0.01$). Limited knowledge of the distribution and abundance of soft corals in northern Red Sea Islands (Ismail, *et al*., 2017), and most works were done in the Gulf of Aqaba and central Red Sea (Riegl and Velimirov, 1994).

The previous studies showed that, eight genera of soft corals were recorded in the Egyptian Red Sea. These genera comprised: *Xenia*, *Heteroxenia*, *Sarcophyton*, *Lobophytum*, *Litophyton*, *Sinularia*, *Nephthea*, and *Dendronephthea* (Gohar, 1940; Roushdy, 1954; Vine, 1986). Recently, Ismail *et al*. (2017) recorded elven genera of soft corals in eight sites along the Red Sea and the Gulf of Aqaba namely; *Alcyonium*, *Capanella*, *Lobophytum*, *Litophyton*, *Heteroxenia*, *Xenia*, *Cladiella*, *Sarcophyton*, *Sinularia*, *Dendronephthea* and *Nephthea*. Most recent, marine soft corals have evolved unique characteristic in metabolic capability to produce natural product that may be useful, especially for the treatment of cancer (Abdelkarem, *et al*., 2019 & 2020 and Tammam, *et al*., 2020).

In the present study soft coral ratios were high at Tawila Island with cover of 6% and lowest in North Geisum (0.6%) with mean percentage of 2.5%, but disappeared at Ganim and South Um Elhimat Islands. The current results of soft coral in the Red Sea are in the range given by other authors (Riegl and Velimirov, 1994; Hassan *et al.*, 2002; Hussein 2016; Ismail *et al.*, 2017). Riegl and Velimirov (1994) recorded the soft corals at nine sites in the Red Sea and gave range of soft coral cover in the north Red Sea concerning Small Gubal Island (1-9%). Hassan *et al.* (2002) recorded the average of percentage cover of soft corals in the Red Sea, Egypt, to be 10%. Hussein (2016) recorded percentage cover of soft corals, at Small Gifton to be 8% and 3% in Abu Ramada Island. Finally, Ismail *et al*. (2017) studied the distribution of soft corals in the Egyptian Coasts of the Red Sea and they postulated that the mean percentage cover of soft coral of 5 main genera (*Sinularia*, *Sarcophyton*, *Lobophytum*, *Xenia* and *Nephthea*) was about 7%.

3.5. Diversity of coral reefs:

In the current study the highest number of both hard and soft coral genera was 14, recorded at Tawila Island, compared with the lowest number (4 genera) recorded at each of Ghanim and South Um Elhimat Islands (Fig. 3). On the other hand, the highest number of individuals was 21 individual/site, recorded at Ghanim Island, while the lowest number was 11.3 individual/site at Ashrafi Island (Fig. 3). In contrast, the highest value of species richness was 3.9 at Small Gubal and the lowest was 2.4 individual/ site at South Um Elhimat (Fig. 3). The highest value of Shannon Equitability (J) was with 0.9 recorded at North Geisum and the lowest was 0.6 at Ghanim Island, Small Gubal and South Geisum (Fig. 4). Shannon diversity (H) was also the highest (1.0) in Tawila Island with and lowest in South Um Elhimat with 0.6 (Fig. 4).

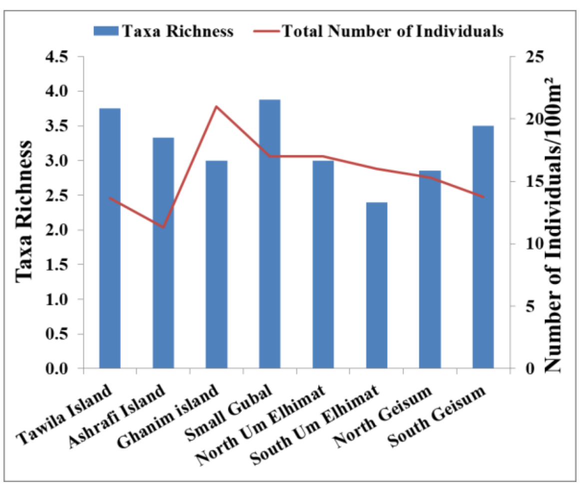

Fig.3. Species richness and total number of individuals, of biotic substrate cover in different Red Sea Northern Islands

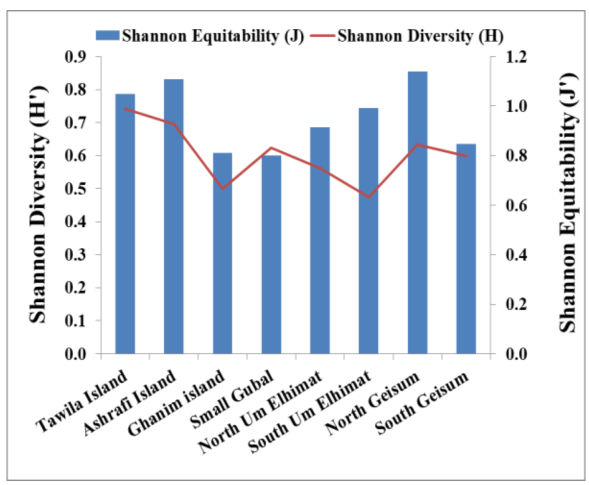

Fig. 4. Shannon equitability and shannon diversity of biotic substrate cover in different Red Sea Northern Islands.

Table (9) shows the Shannon-Wiener diversity (HN) and Evenness index (J) from the present work and the other studies on the Red Sea. It is obvious that, the lower species diversity was recorded during the present study at Ghanim Island compared to the other sites of northern Islands. The low value of Evenness (J) at Ras Gharib compared with other Red Sea sites may be attributed to oil pollution and fishing activities as discussed by Al-Hammady and Mahmoud (2013) and Al-Hammady, *et al*. (2015). The invertebrate communities recorded in the Suez Gulf were fewer than that in south Red Sea. This may be due to that the Gulf of Suez suffers from some threats such as oil pollution and overfishing in some areas (Khalaf, *et al*., 2002; Mahdy, *et al*., 2018; Nasser, *et al*., 2019). This agrees with the findings of Ammar *et al.* (2011); Al-Hammady and Mahmoud (2013) and Al-Hammady, *et al.* (2015) who postulated that, the oil pollution and fishing activities causing coral scarcity susceptibilities. Epstein *et al*. (2000) concluded that, soluble oil fractions resulted in reductions in planula larva settlement only, while, dispersants and soluble fractions caused larval morphology deformations, loss of normal swimming behavior and rapid tissue degeneration.

Table 9. The Diversity and Evenness of coral reefs in different Red Sea regions.

Site	Diversity H	Evenness index J	References
Tawila Island	1.0	0.8	Present Study, 2020
Ashrafi Island	0.9	0.8	
Ghanim Island	0.7	0.6	
Small Gubal	0.8	0.6	
North Um Elhimat	0.7	0.7	
South Um Elhimat	0.6	0.7	
North Geisum	0.8	0.9	
South Geisum	0.8	0.6	
Ras Gharib	1.4	0.8	Al-Hammady, *et al*., 2015
Ras Gharib	1.0	0.3	Al-Hammady and Mahmoud, 2013
Hurghada	1.3	0.4	
North Red Sea	3.0	0.9	Mohammed, 2006
Hurghada	3.0	0.9	Mohammed, 2003
Abu-Galawa	1.8-2.4	0.9-1.0	Ammar and Nawar, 1998
Sharm El-Shiekh	2.8	0.8	Kotb, 1996
Hurghada	2.5	0.9	Ali, 1994

4. CONCLUSION AND RECOMENDATION

The distribution and varieties of hard and soft corals in the northern Red Sea Islands were varied among sites. These data gave available information on the natural resources of the northern Islands. These islands are threatened by all human activities which can cause damage of the natural resources at those islands. Integration of planning, management and research in the Islands of the Red Sea is necessary to prevent insidious degradation of the terrestrial and marine environments and to achieve ecologically sustainable use of coastal resources and conservation of these environments. This study provided baseline information on the living natural resources especially hard and soft corals in the northern Island along the Egyptian Red Sea. Hence, it could be useful for the management and sustainable development of the Red Sea environments.

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ARABIC SUMMARY

توزيع وتنوع المصادر الطبيعية الحية بالجزر الشمالية للبحر الأحمر، مصر: ١- المراجين الصلبة و اللينة

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٣-المعهد القومي لعلوم البحار والمصايد فرع البحر الأحمر، ٨٤٥١١ الغردقـــة، البحر الأحمر، مصر.

تعتبر الدراسة الحالية هى الأولى من نوعها والتى تتعلق برصد أهم الموارد الطبيعية الحية وخاصة المراجين الصلبـــة و اللينة بمناطق الجزر الشمالية على الساحل المصري للبحر الأحمر. تمت عمليات المسح وتجميع العينات من ثماني جزر تقع عند المدخل الجنوبي لخليج السويس عند التقائه بشمال البحر الأحمر والمتاخمة للمجرى الملاحى الدولى والكثير من منصات إستخراج زيت النفط (البترول). وتعتبر الشعاب المرجانية أهم هذه الموارد الطبيعية الحية، سواء الصلبة منها أو اللينة. ولقد تمت هذه الدراسة من خلال إستخدام المعاملات المختلفـة لعمليات الرصد البيئى و المسح لمناطق الجزر الشمالية خاصة الشعاب المرجانية الصلبة واللينة والتعرف على تنوعها وتوزيعها بمناطق الدراسة. كما تم تجميع المعلومات و عمل الرصد و المسح البيئى لمناطق الشعاب المرجانية باستخدام الطرق القياسية (المقطع العرضي) من خلال الغوص أوالسباحة باستخدام نظارات الرؤية تحت الماء خلال فصل الشتاء لعام ٢٠١٧.

أوضحت النتائج الحالية أن النسبة المئوية للغطاء المرجاني الصلب سجلت أعلى قيمة في جزيرة غانم حيث وصلت إلى ٨٤% وانخفضت إلى أدنى قيمها في جزيرة الأشرفي لتسجل ٤١.٣ ٪ ، بمتوسط عام 60.1 ٪ للمرجان الصلب في جميع الجزر. ولقد أظهرت الدراسة أن جزيرة طوال كانت الأعلى قيمة فى نسبة الغطاء للمرجان اللين وصل إلى ٦٪. كما ساد كل من جنسي ***Acropora*** و ***Stylophora*** من المراجين الصلبة جميع مواقع الدراسة بنسب عالية وصلت إلى ٣٥.٨ ٪و ١٧.٦ ٪ على التوالى، بخلاف جنس ***Nepthea*** الذي ساد غيره من المراجين اللينة حيث وصلت نسبته ١٪. كما أظهرت أعمال رصد تلك الموارد الطبيعية الحية تنوع وتوزيع هذه الموارد، وخاصة الشعاب المرجانية، ومدى تأثرها بالأنشطة البشرية، خاصة الأنشطة السياحية، وكذلك استخراج النفط بالقرب من مناطق الدراسة. وتعتبر هذه البيانات عن الموارد الطبيعية الحية خاصة المراجين الصلبة واللينة في مناطق الدراسة مفيدة ومهمة في أعمال تطوير تلك الجزر في المستقبل. ونظرا لأن بعض تلك الجزر يتم حاليا تنيميتها سياحيا فقد يكون هذا العمل مفيدا لصناع القرار للمواكبة بين التنمية وحماية الموائل البحرية.