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Coral diversity indices along the Gulf of Aqaba and Ras Mohammed, Red Sea, Egypt

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ABSTRACT

Ammar MSA (2011) Coral diversity indices along the Gulf of Aqaba and Ras Mohammed, Red Sea, Egypt. Biodiversitas 12: 92-98. Eight sites extending from Ras Mohammed to the northern tip of the Gulf of Aqaba were surveyed for seven different indices of diversity. These sites are: Ras Ghozlani, Marsa Breika, Temple, Katy, Islands, Canyon, South Nuweiba and Marsa Muqabela. The study proved that the healthy condition can be expressed either by a high value of Shannon index or low value of these other indices. Canyon, having effective management, is considered as the healthiest site (based on Shannon species diversity H`) while South Nuweiba is the least healthiest of all sites because of the illegal destructive fishery overexploitation. Sites having old damage with improved values of richness indices and low values of dominance indices (healthy conditions) like Ras Ghozlani and Marsa Breika had enough time and effective management to improve their diversity, while sites with non improved diversity like Temple and Katy are characterized by sponge and ascidian domination representing potent competitors with corals beside the increased nutrients in those sites. Islands and Marsa Muqabela have low values of richness indices because Marsa Muqabela has the highest value of boring worms and considerable sediments.

Key words: Coral reefs, diversity, Gulf of Aqaba, Red Sea, Egypt.

INTRODUCTION

Although many indices estimate diversity, species richness recently has been used as a surrogate for diversity in many studies in ecology, biogeography, and conservation. Underlying assumptions of this approach are that all diversity indices, including those that weight species importance by their relative abundance (e.g., evenness), are correlated positively, and that richness accounts for a large proportion of the variance in diversity (Wilsey et al. 2005; Mellin et al. 2006; Franceska and Perrin 2008).

As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. However, the IUCN Global Marine Programme works on issues such as integrated coastal and marine management, fisheries, marine protected areas, large marine ecosystems, coral reefs, marine invasives and protection of high and deep seas. Ecological and socio-economic monitoring of coral reefs and their associated communities is a crucial management tool. Ecological monitoring focuses on the physical and biological parameters of coral reefs, while socio-economic monitoring aims to understand how people use and interact with coral reefs (Wilkinson et al. 2003; Scopélitis et al. 2010).

Coral reefs occupy only 0.1% of the ocean's surface, yet they are the world's richest repository of marine biodiversity, however coral reefs have survived over the course of more than 400 million years of evolution, and possess richness, diversity of life and structure that are integral foundations for humanity.

Coral reef communities are in a state of change throughout their geographical range, factors contributing to this change include bleaching (the loss of algal symbionts), physical damage, and disease and increasing abundance of macroalgae (Ostrander et al. 2000; Raymundo et al. 2007; Andrew et al. 2008). Overfishing and nutrient loading have altered interactions among macroalgae and their herbivores, leading to significant increases in macroalgal cover (Hatcher 1990; Jackson 1997; Done 1999; Barile and Lapointe 2005; Yñiguez et al. 2008; Bahartan et al. 2010; Lapointe and Bedford 2010). The increased abundance of macroalgae negatively affects coral growth and recruitment, and this has long-term consequences on the physical structure of the reef (Miller 1998; Littler et al. 2006; Costa et al. 2008).

Long-term studies have documented transitions in reef community structure (McClanahan et al. 1999; Lambo and Ormond 2006; Tam and Ang 2009) to a state where macroalgae are dominant, but the data are largely comparative over time scales measured in years and do not indicate the actual time scale of the transition. We have shown that transitions in reef community structure can be rapid and such changes may have long term consequences.

Coral reefs are among the most diverse ecosystems on earth; however, coral reefs in different parts of the world support different levels of biodiversity coral reef ecosystems are the pinnacle of biodiversity in the natural world, approximately 25% of all marine species inhabit coral reefs, where the number of individual species may be as high as one million (Davidson 1998; Meixia et al. 2008). The same author pointed out that although coral reef ecosystems cover only 1% of the total earth surface, the areas of the world in which they are found are also the areas of the world where the greatest growth in human population is occurring. These ecosystem services include biodiversity, maintenance, production of food such as sea food and fish, coastal protection, aesthetic and cultural benefits, recreation and tourism (Daily 1997; Moberg and Folke 1999; Mumby et al. 2008). Shehata (1998) pointed out that although the Gulf of Aqaba is relatively small body of water, it hosts an extraordinary diversity of corals and related marine life, the same author indicated that approximately 210 scleractinian hard coral species and 120 species of soft coral have been recorded in the Gulf.

The purpose of the present study was to quantify the different diversity indices along a broad area extending from Ras Mohammed (Northern Red Sea) to the northern tip of the Gulf of Aqaba, Egypt.

MATERIALS AND METHODS

Eight sites extending from Ras Mohammed to the northern tip of the Gulf of Aqaba were surveyed. These sites are indicated in Table 1 and Figure 1. Figure 2-5 indicate recent site research condition.

Table 1. Latitudes and longitudes of the study sites

Sites	Latitudes	Longitudes
1. Ras Ghozlani	27° 47.527` N	34° 15.752` E
2. Marsa Breika	27° 50.827` N	34° 18.533` E
3. Temple	27° 50.827` N	34° 18.533` E
4. Katy	27° 50.930` N	34° 18.001` E
5. Islands	28° 28.634` N	34° 30.682` E
6. Canyon	28° 33.297` N	34° 31.229` E
7. South Nuweiba	28° 56.481` N	34° 38.395` E
8. Marsa Muqabela	29° 21.995` N	34° 47.071` E

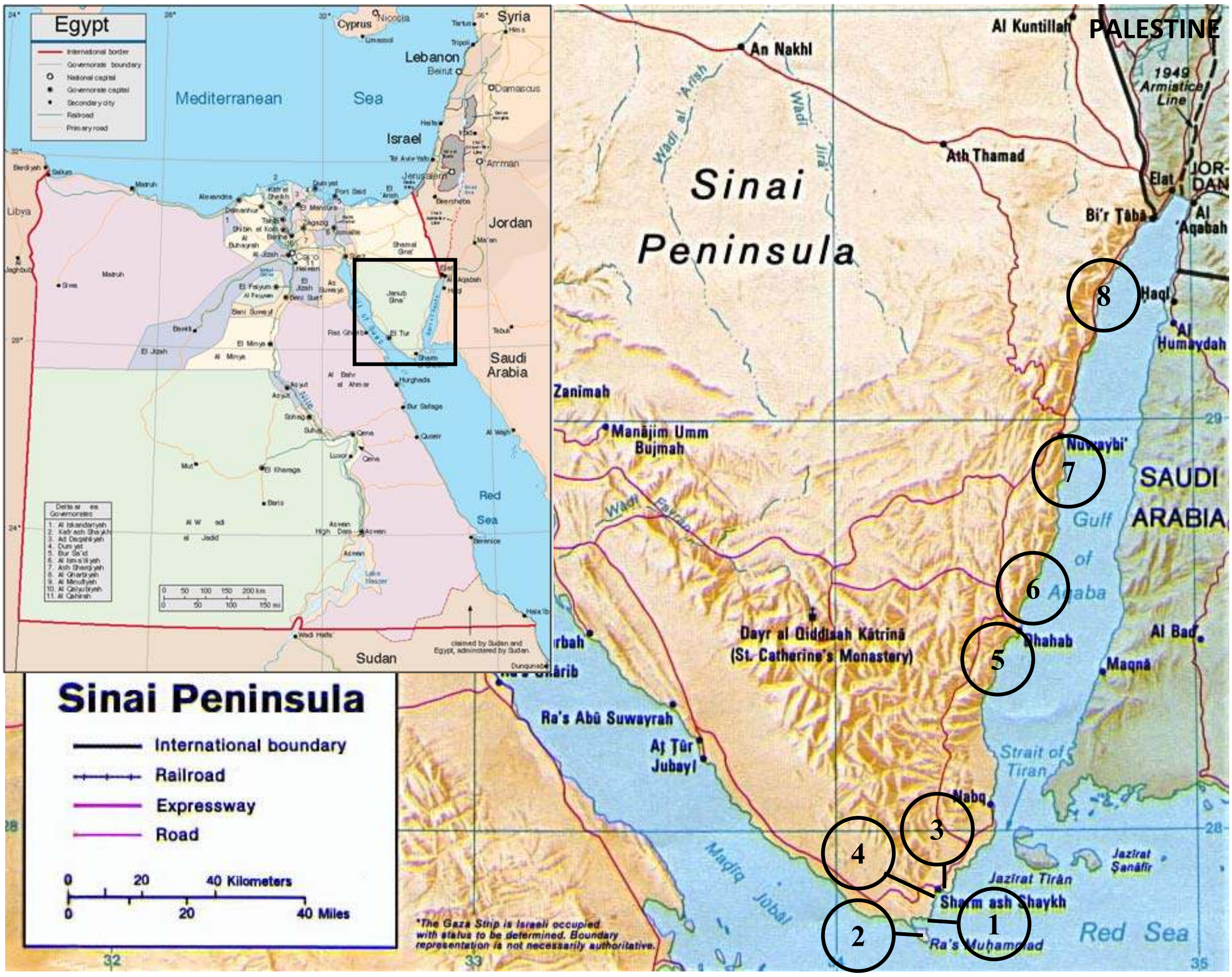

Figure 1. Map of the studied sites. 1. Ras Ghozlani, 2. Marsa Breika, 3. Temple, 4. Katy, 5. Islands, 6. Canyon, 7. South Nuweiba, 8. Marsa Muqabela.

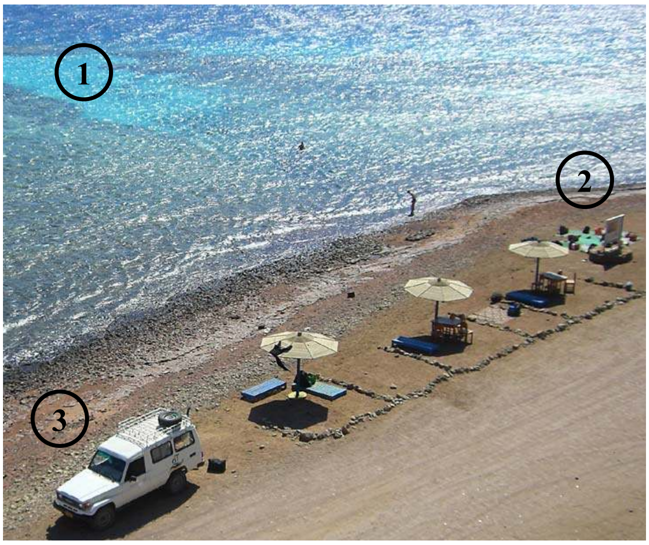

Figure 2. Effective management in Canyon including guidance signs, patrolling, and fixing a pass to deep water to avoid damage of shallow water reefs. Note: 1. A fixed pass for passage to deep water, 2. A guidance sign, 3. Patrolling car of EEAA (Egyptian Environmental Affairs Agency)

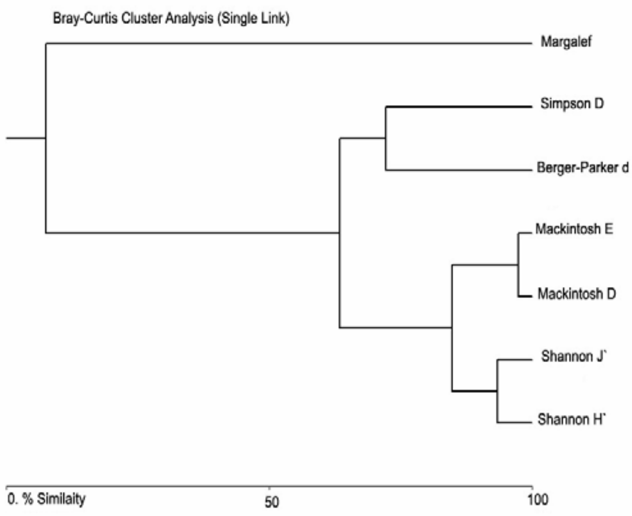

Figure 6. Bray-Curtis cluster analysis (single link) of different diversity indices

Figure 3. Interlacing fishing nets due to illegal fishing activities causing reef damage in South Nuweiba

Figure 4. Improved diversity in Ras Ghoslani

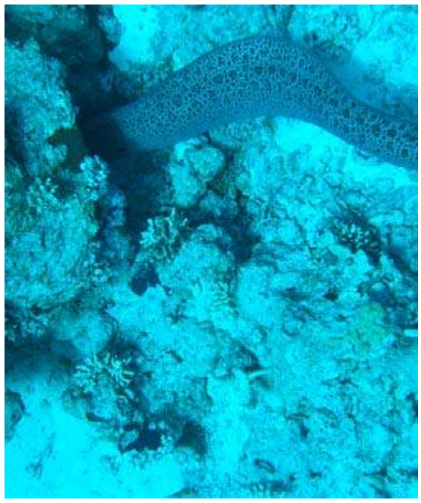

Figure 5. Non improved diversity in Katy. A moray is shown living in caves

The list of study sites are graphically represented in Figure 1. SCUBA diving and the camera frame (as a quadrat) were used for surveying the benthic coral reef communities. Ten frames, one meter intervals and one meter from the object were surveyed along a transect fixed horizontally along the reef contour at the depths 1m, 5m, 10 m, 15 m, 20 m, 30 m, 40 and 50 m (when found) or till the end limit of coral growth at each of the studied sites. A FinePix F50, 12 Mega Pixels Digital Camera, was used for taking a series of underwater photos to help identification of species and other taxa habitats. The computer software Photogrid 1.0 beta Acad was used for ecological analysis of digital photographs of corals and other taxa or habitats

Different indices of coral diversity were calculated using the computer software Biodiversity Professional Version 2 (McAleece et al. 1997). Diversity was measured by seven different indices (Shannon diversity index (H`), Shannon evenness index (J`), Berger-Parker dominance (d), Simpson diversity D, Margalef M Base, Mackintosh diversity (D) and Mackintosh evenness (E).

RESULTS AND DISCUSSION

Results

Averages of different indices of diversity are shown in Table 2. Shannon diversity index H` are all beyond 0.70 ranging from 0.74 at South Nuweiba to 0.95 at Canyon; however, Shannon evenness index J` is in the range between 0.70 at Marsa Muqabela and 0.80 at Canyon. Berger-Parker dominance d represents higher variations between sites ranging from 0.25 at Canyon to 0.42 at South Nuweiba. Simpson diversity D has lower values ranging from 0.13 at Ras Ghozlani and Canyon to 0.25 at Temple and South Nuweiba. Margalef diversity M has higher values of diversity but in contrast to other indices, it is lowest in South Nuweiba and highest in Ras Ghozlani and Marsa Breika respectively. Although Mackintosh diversity D and Mackintosh evenness index E has values lower than those of Margalef, they have a similar variation between sites having lowest values in Marsa Breika and highest value in South Nuweiba.

Similarity matrix of different diversity indices is shown in Table 3 and the Bray-Curtis cluster analysis of different indices of diversity is shown in Figure 6. Mackintosh D and Mackintosh E are grouped together having the highest % similarity (97.33%), followed by Shannon H` and Shannon J` which are grouped together (93.49%). However, Simpson D and Berger-Parker are grouped together having a % similarity of 72.15%, finally Margalef index is separated in one group having the lowest % similarity with other groups.

Values of indices for richness in general are lowest where indices for dominance are highest, however, all indices of richness are lowest in South Nuweiba while indices of dominance are highest in the same site. Richness indices are highest in Canyon for H` and J` and highest in Marsa Breika for Margalef M. Dominance indices are all lowest in Canyon except Mackintosh eveness (E) which which is lowest in Marsa Breika.

Results of the present study indicate that, sites having old damage like Ras Ghozlani and Marsa Breika seem to have improved values of richness indices and low values of dominance indices, contrary the two sites Temple and Katy suffered also old breakage but the richness values of diversity seem to have not been improved. However, Islands and Marsa Muqabela have slightly lower values of richness indices.

Percent cover of live corals and other habitats in the study sites is shown in Table 4 while the coral species list is shown in Table 5. Canyon has the highest percent cover of live corals (42.38%) while South Nuweiba has the lowest one. Katy has the highest values of both sponges and ascidians while South Nuweiba has the highest values of broken corals, dead corals, sediments, echinoderms and anemones. Marsa Ghozlani has the highest value of bare rocks and rubbles while Marsa Breika has the highest value of sands.

Table 2. Average of different indices of diversity in the studied sites

Index	Sites							
	1	2	3	4	5	6	7	8
Shannon H' Log Base 10.	0.94	0.91	0.75	0.75	0.86	0.95	0.74	0.82
Shannon J'	0.78	0.73	0.70	0.79	0.76	0.80	0.77	0.70
Berger-Parker Dominance (d)	0.30	0.35	0.40	0.41	0.35	0.25	0.42	0.32
Simpsons Diversity (D)	0.13	0.19	0.25	0.23	0.21	0.13	0.25	0.19
Margalef M Base 10.	38.45	38.86	30.33	26.30	28.38	33.16	23.75	28.23
Mackintosh Diversity (D)	1.23	1.17	1.21	1.19	1.20	1.17	1.28	1.18
Mackintosh Eveness (E)	1.13	1.12	1.14	1.15	1.14	1.14	1.16	1.15

Note: 1. Ras Ghozlani, 2. Marsa Breika, 3. Temple, 4. Katy, 5. Islands, 6. Canyon, 7. South Nuweiba, 8. Marsa Muqabela

Table 3. Similarity matrix of different indices of diversity

	Shannon H`	Shannon J`	Berger-Parker d	Simpson D	Margalef M	Mackintosh D	Mackintosh E
Shannon H`	-	93.4902	58.8235	38.0723	5.2876	82.2018	84.795
Shannon J`	-	-	63.4202	41.5243	4.7576	77.0115	79.5515
Berg-Parker d	-	-	-	72.1461	2.2377	45.0523	46.9405
Simpson D	-	-	-	-	1.2689	28.1891	29.5051
Margalef	-	-	-	-	-	7.4915	7.1164
Mackintosh D	-	-	-	-	-	-	97.3348
Mackintosh E	-	-	-	-	-	-	-

Table 4. Percentage cover of live corals and other habitats in the studied sites.

Sites	Live corals and their habitats													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	26.97	3.17	58.82	2.28	4.91	0.00	0.52	0.56	0.35	2.42	0.00	0.00	0.00	0.00
2	39.78	9.13	35.75	0.00	14.11	0.00	0.04	0.00	0.29	0.00	0.04	0.39	0.00	0.00
3	36.04	1.35	55.56	0.00	2.85	0.00	0.00	0.00	0.95	1.50	0.00	3.25	0.00	0.00
4	28.29	3.79	44.31	0.00	11.71	0.00	0.00	2.14	3.81	0.00	0.00	5.36	0.00	0.00
5	40.06	0.00	23.42	1.78	8.07	1.51	0.03	0.94	0.16	0.00	0.00	17.11	0.00	0.00
6	42.38	6.00	36.78	0.73	12.73	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.50	0.00
7	18.77	17.29	20.50	0.29	26.29	1.54	0.00	0.00	0.00	0.00	0.00	0.00	1.53	6.71
8	42.06	7.28	23.44	0.09	21.56	0.19	0.00	0.00	0.00	0.00	0.16	3.91	0.13	0.03

Note: 1. Ras Ghozlani, 2. Marsa Breika, 3. Temple, 4. Katy, 5. Islands, 6. Canyon, 7. South Nuweiba, 8. Marsa Muqabela. A. Live Corals, B. Dead Corals, C. Bare Rocks, D. Rubbles, E. Sands, F. Echinoderms, G. Molluscs, H. Ascidians, I. Sponges, J. Crevices, K. Boring Worms, L. Algae, M. Anemones, N. Broken Corals.

Table 5. Species list in the study sites.

Species and habitats	Site 1	2	3	4	5	6	7	8
Hexacorallia								
Stony corals								
Acanthastrea echinata			*					
Acanthastrea faviaformis					*			
Acanthastrea maxima					*			
Acropora aculeus	*							
Acropora digitifera					*	*		
Acropora eurystoma						*		
Acropora formosa								
Acropora formosa		*						
Acropora forskali						*		
Acropora gemmifera					*	*		
Acropora granulosa						*		
Acropora hemperichi	*	*			*	*		
Acropora humilis	*	*			*	*		*
Acropora hyacinthus					*	*		
Acropora maryae		*		*				
Acropora nasuta	*					*	*	*
Acropora pharaonis						*		
Acropora robusta					*	*		
Acropora sp. (new)			*					
Acropora squarrosa			*					
Acropora tenuis					*	*	*	
Acropora valida		*			*			
Acropora valida		*	*			*		
Alveopora daedalea		*						
Alveopora lizardi	*							
Alveopora tizardi			*					
Asteriopora myriophthalma	*		*	*				
Asteriopora myriophthalma		*				*	*	
Coscinaraea monile			*			*		
Ctenactis echinata	*				*			
Cyphastrea microphthalma	*		*				*	
Cyphastrea serailea							*	*
Echinopora forskaliana	*			*				
Echinopora fruticulosus	*		*	*				
Echinopora gemmacea	*		*	*	*	*		*
Echinopora lamellosa	*				*		*	*
Echinopora trianensis	*							*
Favia amicorum		*	*					
Favia favus		*				*		*
Favia lacuna		*					*	*
Favia lacuna	*							
Favia laxa		*	*					
Favia laxa	*			*		*		*
Favia mtthai						*		
Favia pallida		*	*	*		*		*
Favia rotundata						*		
Favia sp. *(new)*					*			
Favia veroni			*					
Favites abdita	*	*			*			*
Favites chinensis	*					*		
Favites complanata	*				*			*
Favites flexusa						*	*	
Favites halicora	*	*	*	*	*	*	*	*
Favites pentagona	*					*		
Favites vasta	*			*			*	*
Galaxea fascicularis			*	*	*		*	
Gardineroseris planulata	*							
Goniastrea cf. aspera	*							
Goniastrea pectinata	*	*	*					
Goniastrea persi	*			*				*
Goniastrea retiformis	*	*	*	*	*	*	*	
Goniopora ciliatus					*			
Goniopora stokesi		*						
Gyrosmilia interrupta	*	*						*
Hydnophora exesa				*	*			
Hydnophora microconus			*		*			
Leptastrea purpurea			*	*		*	*	*
Leptoseris explanata		*						
Leptoseris incrustans					*	*		
Leptoseris mycetoseroides				*		*		
Lobophyllia cf pachysepta								*
Merulina ampliata		*						
Montipora aequituberculata	*							
Montipora cocosensis		*	*	*		*		
Montipora informis		*				*		
Montipora informis				*	*			
Montipora meandrina					*			
Montipora stilosa		*				*		
Montipora tuberculosa		*		*				
Montipora verrucosa	*	*				*		
Mycedium elephantotus		*						
Mycedium umbra		*						
Oxypora lacera						*		
Pachyseris rugosa				*				
Pachyseris speciosa					*			
Pavona cactus		*						
Pavona clavus				*				
Pavona decussata	*	*	*	*			*	
Pavona varians	*			*	*			
Platygyra acuta	*							
Platygyra carnosus						*		*
Platygyra crosslandi					*			*
Platygyra daedalea				*			*	*
Platygyra lamellina	*	*			*	*		*
Plesiastrea versipora							*	*
Pocillopora damicornis	*	*		*		*	*	*
Pocillopora verrucosa	*	*	*		*		*	*
Porites columnaris				*			*	*
Porites lichen			*	*				
Porites lobata					*			*
Porites lutea	*	*			*	*	*	*
Porites mayeri		*						
Porites nodifera		*	*					
Porites rus			*					
Porites solida	*	*	*	*	*	*		
Porites sp.	*							
Psammocora hemispherica	*							
Psammocora profundacella						*		
Psammocora profundacella		*	*					*
Seriatopora caliendrum	*	*	*					
Seriatopora hystrix	*	*		*				
Siderastrea savignyana	*	*					*	*
Stylocoeniella guentheri		*				*		
Stylophora mamillata		*		*	*			
Stylophora pistillata	*	*	*	*	*	*	*	*
Stylophora wellsi					*		*	
Symphillia sp.				*		*		
Trachyphyllia geoffroyi						*		
Tubastrea aurea			*					
Tubastrea coccinea			*					
Tubestrea micranthus		*						
Turbinaria informis							*	*
Turbinaria mesentrina	*		*			*	*	
Black corals								
Antipathes sp. *(black coral)*		*						
Protoptilum sp.								*
Hydrocorals								
Millepora dichotoma		*	*		*		*	*
Millepora platyphylla					*	*	*	*
Millepora alcicorrnis							*	
Octocorallia								
Soft corals								
Anthelia glauca	*	*	*	*	*	*		
Briareum hamra				*				
Cladiella sp.		*	*		*	*		
Heteroxenia fuscescens			*					
Heteroxenia ghardaqensis	*	*	*	*		*		*
Lithophyton arboreum	*	*	*					
Lithophytun sp.	*			*		*	*	*
Lobophytum sp.	*		*					*
Rhytisma sp.	*	*	*	*		*		*
Sarcophyton sp.		*	*		*	*		*
Sinularia sp.		*			*			
Sympodium caeruleum	*	*	*					
Xenia macrospeculata	*	*	*	*				*
Xenia sp.	*							
Xenia umbellata			*	*				*
Gorgonians								
Paraplexaura sp.		*						
Anella sp.			*					

Note: 1. Ras Ghozlani, 2. Marsa Breika, 3. Temple, 4. Katy, 5. Islands, 6. Canyon, 7. South Nuweiba, 8. Marsa Muqabela. * . Rcorded in that site

Discussion

Seven different indices of diversity were used to compare their values with each other and with the healthy status of sites. However, Stirling and Wilsey (2001), Reitalu et al. (2009) and Johnston and Roberts (2009) indicated that Shannon index is better for analysis as it reflects effects of evenness and richness components along with their intercorrelations. In the present study, there are some differences in diversity between sites, these differences can be explained by the different stresses the sites are exposed to (Boumeester 2005). Canyon is considered as the healthiest site (based on Shannon species diversity H`) while South Nuweiba is the least healthiest of all. Surprisingly, sites like Canyon, Ras Ghozlani and Marsa Breika, having considerably high values of Shannon index H`, have also high number of divers (beyond the diver carrying capacity, DCC). A possible explanation of that result is that divers in these sites became more eco-concious and the damage caused in these sites during low protection in the past creates enough substrates (of dead corals and rocks) beside recruiting fragments that initiates the increase in diversity. Fragmentation could be the most important form of regeneration for many major reef-building corals (Highsmith 1982; Garrison and Waed 2008) and may help to mitigate some of the diver damage effects (Hawkins and Roberts 1992; Work et al. 2008). It is not surprising that sites like Canyon, with highest Shannon index H`, has the lowest value of other diversity indices like Berger-Parker dominance d, Simpson diversity D and Mackintosh diversity D because Shannon index depends on the informationa theory (complicated computation) while Simpson, MacIntosh and Berger-Parker depends on the species dominance measures (simple computation).

The lowest values of richness indices and highest values of dominance indices in South Nuweiba is associated with the recent physical damage arising mainly from illegal destructive fishery overexploitation which destroys the reef assemblage in that site. Physical forces and bioerosion degrade the reef's structural framework (Sammarco 1996; Glynn 1997; Ammar and Mahmoud 2006; Ammar et al. 2006; Ammar 2009), leading in turn to a decline in coral diversity. The highest values of richness indices and lowest values of dominance indices (a healthy condition) in Canyon is associated with the low amount of sediments beside the effective management (Acevedo et al. 1989; Ammar and Emara 2004).

The improved values of richness indices and low values of dominance indices (healthy conditions) in the sites having old damage like Ras Ghozlani and Marsa Breika mean that they had enough time and effective management to improve their diversity, also this is associated with low values or absence of sponges, ascidians, anemones, broken corals, echinoderms and algae (De Voogd et al. 2004; Pawlik et al. 2007). Although the two sites Temple and Katy suffered also old breakage, diversity was not improved because of the sponge and ascidian domination that represent potent competitors with corals beside the high amount of nutrients (nitrates) in those sites. Sponges and ascidians dominate in areas of high particulate organic nitrogen (Ribes et al. 2005; Yahel et al. 2005; Ribes et al. 2005; Shenkar et al. 2008) and have negative effects on developing coral embryos and larvae (Sammarco, 1996). Lack of significant predators makes ascidians very successful competitors (Lambert 2002).

Islands and Marsa Muqabela have low values of richness indices because Marsa Muqabela has the highest value of boring worms and considerable sediments while Islands has the highest amount of algae, considerable echinderms (mainly the urchin, *Diadema*) and considerable ascidians. Sedimentation may lead to reef degradation by causing coral mortality through sediment smothering and burial, and then by suppressing the re-growth of surviving adult colonies through increased competition with algae (Nugues and Roberts 2002). Bioerosion can be extensive, being caused by grazing fish, sea urchins, boring bivalves, etc., resulting in a net loss of calcium carbonate from the reef (Sammarco 1996; Baker et al. 2008). Reefs with high inputs of sediments are often dominated by algal turfs which are known to inhibit coral settlement (Aerts and van Soest 1997; Birrell et al. 2005; Ammar 2007).

CONCLUSION

The study proved that; sites like Canyon, with highest Shannon index H`, has the lowest value of other diversity indices because Shannon index depends on the information theory (complicated computation) while Simpson, MacIntosh and Berger-Parker indices depend on the species dominance measures (simple computation). Thus, the healthy condition can be expressed either by a high value of Shannon index or low value of these other indices. Canyon has the highest values of richness indices and lowest values of dominance indices (a healthy condition) due to the low amount of sediments beside the effective management while South Nuweiba has the lowest values of richness indices and highest values of dominance indices because of the illegal destructive fishery overexploitation. Sites having old damage with improved values of richness indices and low values of dominance indices (healthy conditions) like Ras Ghozlani and Marsa Breika had enough time and effective management to improve their diversity, while sites with non improved diversity like Temple and Katy is characterized by sponge and ascidian domination representing potent competitors with corals beside the increased nutrients in those sites. Islands and Marsa Muqabela have low values of richness indices because Marsa Muqabela has the highest value of boring worms and considerable sediments while Islands has the highest amount of algae, considerable echinderms (mainly the urchin *Diadema*) and considerable ascidians.

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