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Distribution patterns and ecological aspects of the sea urchin *Diadema stosum* in the Red Sea, Egypt.

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ABSTRACT

Diadema setosum populations were surveyed at three sites representing different habitats of the Red Sea; El-Giesum at the northern Red Sea, Ras Mamlah at the Gulf of Aqaba and Beer Odeeb at the Gulf of Suez. A comparison among these sites was carried out for distribution patters, habitat preference and the character of habitat, which is preferred by *D. setosum* in addition to its role in the ecosystem at each site.

At Beer Odeeb, the population density from sand recorded 1-2.3 ind./m^2, seagrasses 1.7-3.8 ind./m^2, rocks 2.1-7.9 ind./m^2, while it recorded its maximum densities at dead and live coral habitats. At Ras Mamlah the density recorded its minimum at sandy habitats (0-1.3 ind./m^2) and its maximum at live coral habitats (2.3-28.9 ind./m^2). The same pattern was recorded at El Geisum its minimum was at sandy habitat (0-0.3 ind./m^2) and its maximum was from live coral habitat (1.3-32.4 ind./m^2). Abundance of *D. setosum* was highest at El Giesum (163240 individuals) with 68.2% of the population recorded from the live coral habitat, followed by Ras Mamlah at the Gulf of Aqaba that recorded abundance of 87335 individual; live coral habitat accommodated 69.7% of the population. Finally, Ber Odeeb site at the Gulf of Suez recorded the lowest abundance (28176 individuals), with the highest percentage recorded from dead coral habitat being 34.8%, while live coral habitat at this site accommodated 24.3% of the population. The distribution pattern of *D. setosum* populations was determined using the coefficient of dispersion. The study revealed a difference in dispersion among the different habitats and sites. One way ANOVA revealed that the habitat preferences are varied according to the sites, areas on the reef and habitats. The three sites shared the preferable areas for the urchin, which are the fore reef and 5m depth, while the reef crest was not favorable for urchin existence.

In conclusion, the study revealed that live and dead corals environment were the most preferred habitat for *D. setosum*, in contrast, sand, seagrasses and rocky habitats were unfavorable. The species showed habitat preference according to the physical conditions and different habitats at each site. The presence of the urchin in this habitat is essential for protecting the coral fauna and for the health of the environment.

INTRODUCTION

Coral reef ecosystem is subjected to increasing stresses all over the world. It is predicted that these stresses will become more frequent as a result of ongoing changes, especially climate change and inappropriate land and sea use.

Grazing animals, especially sea urchin are known to play a major role in the ecology of coral reef habitats (Williams and Polunin 2001; Coppard and Campbell 2007) by altering the distribution, relative abundance and species composition of marine algae. Consequently sea urchin grazing is recognized as an important factor in restoring and maintaining recolonization of corals because it can protect corals from competition with other benthic organisms (Glynn *et al*. 1979; Dumas *et al*. 2007).

Echinoids are an abundant group of reef invertebrates. They are prominent part of coral reef cryptofauna (Sammarco, 1982), and are found in many reef habitats including corals (Lessios *et al*., 2001), algae and seagrasses (Sloan and Cambpell, 1982).

Diadema setosum is one of the most important components of the benthic fauna effect and affected by other fauna and by the substrate. On distribution basis, *D. setosum* ranges in distribution from central Japan to southern Australia, and from Clarion Islands off Mexico to the Gulf of Suez. Throughout this distribution range it occupies variety of habitats. Fishelson (1971) described different Red Sea communities existing at different habitats, and divided Red Sea habitat into soft bottoms, rocky shores and corals. He declared both *D. stosum* and *Echinometra mathaei* as from the most dominant species in subtidal live and dead coral habitats for the former and subtidal rocky and dead coral habitats for the later.

Populations of *Diadema* are known to fluctuate within a certain area. This seems to be characteristic of the species. The factor controls this fluctuation is predation (Ogden *et al*., 1973), type of substrate (Aziz, 1995), food and shelter availability (McClanahan and Muthiga, 2001), wave action (Khamala, 1971). The population densities recorded worldwide is differing according to these factors. For instance Bauer (1980) recorded an increase in abundance from 24000 individuals in 1964 to 51400 individuals in 1978 at western north Atlantic due to the diverse of habitats. Ogden *et al*. (1973) recorded density of 8.7 ind./m^2 and he referred this high density to the decreased in the number of predators. Sangmanee *et al*., (2012) recorded density of 16 ind./m2 at Chonburi Province in the inner Gulf of Thailand.

In comparison with fishes, available data on the factors structuring reef invertebrates is scarce. For urchins, species exhibit close linkage with substrata deriving from their life habits (feeding strategies, locomotory behavior, substrate relations etc.) and spatial distributions are generally expected to reflect similar trends (Lawrence, 2001). Yet, a high variability is often observed as the result of complex interactions between habitat variables including depth,wave exposure, water/sediment composition and the presence/absence of reef building or covering species (Laine, 2003)

While results tend to be species-specific and strongly scale-dependent, recent works suggested that spatial distributions of coral-associated organisms are influenced by a rather diverse set of environmental factors relative to both substrate and water column, whose respective contributions may vary (Bozec *et al*., 2005).

Few works have examined the relative contributions of habitat variables to the distribution of coral reef urchins. The current study aims to investigate the spatial distribution of one common urchin species (*Diadema setosum*) in three sites; the first at northern Red Sea (El Giesum), the Second at the Gulf of Aqaba (Ras Mamlah) and the third at the Gulf of Suez (Beer Odeeb). The effects of substrate and the habitat preferences were studied and the effect of each water body on urchin density and distribution were investigated.

MATERIALS AND METHODS

Study sites

Three sites were surveyed during the period from September to November, 2017. The first site is Beer Odeeb at the Gulf of Suez. The site lies at the Gulf of Suez, 35 km south of Suez city, with sandy shoreline. The site is subjected to high human impact due to the oil activities at SUMED oil terminals and Ras Sadat oil terminals, which exist at the south of the site. The reef flat is extended to about 50 meters, with scattered live coral areas. The marine ecosystem at the site is generally poor. Fishes at the site recorded very low diversity (only 6 species) and density. Abodoufduf saxaliatus and Thalassoma flunzingeri were the most abundant species. Benthic invertebrates also recorded low diversity and density. Whereas echinoderms recorded the highest diversity at the site. The Echinoid E. mathaei and D. setosum were the dominant species.

The second site is Ras Mamlah at the Gulf of Aqaba The site lies between Dahab and Nuweiba (about 30 km south of Nuweiba), inside Abou Galum protectorate at the Gulf of Aqaba. It has a sandy shore, with a reef flat extends to about 70 meters. The site subjected to high human impact due to the high tourism activities. The reef flat begins with small rocky area, followed by small patches of sea-grass over rocky bed. Followed by rocks, covered with brown algae, then a dead coral zone to the end of the mid-reef. The fore-reef, reef crest and reef slope are covered with high percentage of live corals, interrupted with small dead corals and rocky patches. Fishes are well established at the site: mainly small fishes as family Chaitodontedea and Pomacentridae. Benthic invertebrates recorded low diversity and density, few gastropods, bivalves, sponges and echinoderms. Both E. mathaei and Diadema setosum were the most abundant invertebrate species.

The third site is El Giesum at Hurghada Red Sea. The site lies at Hurghada city at the Red Sea with sandy shoreline. The reef flat is long extends 170 meters. The site subjected to a moderate tourism impact, and has a good marine ecosystem. The reef flat is about 170 meters in length, the back reef composed of rocky and dead coral patches over an old fossil reef, interrupted with very small sand patches and low cover of soft and hard corals. The mid-reef is composed mainly of live corals with high percentage of branched and soft corals, while the fore-reef, reef crest and reef slope are composed of live corals with a small percentage of dead corals and rocky patches. Fishes are well diverse at the site with high densities, especially Acanthurus shoal. Benthic invertebrates were also flourished at the site and well distributed at the whole reef area. The echinoids E. mathaei, Tripneustus gratilla and D. setosum, the bivalve Tridacna squamosa, the gastropod Dendropoma maxima were the most dominate species (Fig. 1).

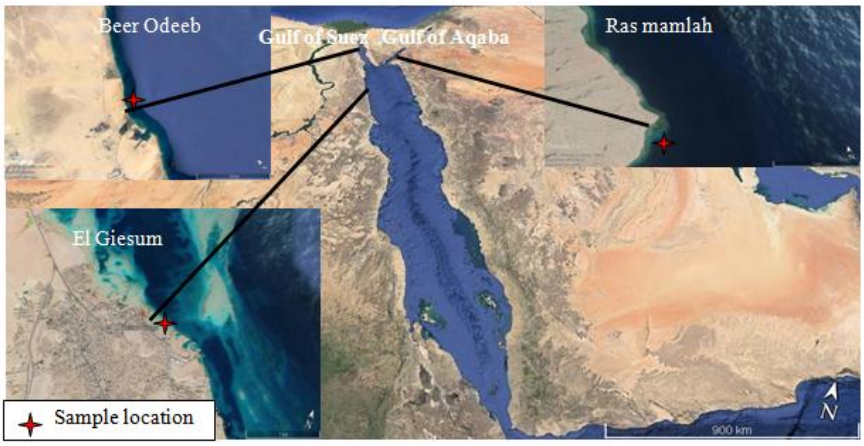

Fig. 1 Location of the study sites at Gulfs of Suez and Aqaba and the Red Sea.

Population density and habitat distribution

Estimation of *D. setosum* populations was carried out using underwater visual transects. Direct visual assessment is the method conventionally used and is effective

for the direct enumeration of population (Lokani *et al*., 1996). At the study site transects were covering the different zones and habitats. The length of each transect was about 100 m. Between 5-9 replicates were done at each zone and/or depth. Along each transect 20 quadrates were made of 1m x 1 m (m^2). The shallow areas were surveyed by snorkelling and the deep areas were surveyed by SCUBA diving.
The population density of different sea urchin species inside each quadrate was counted and expressed as number of individuals/ m^2. At each quadrate the different biotopes of the reef and type of substrate were described (sandy, rocky, corals).

Abundance:

Abundance of *D. setosum* populations were estimated by using the following formulae:

$$T = X * N$$

where:

T= Species abundance

X=mean number per transect

N= number of transects that fit into the total area (N= total area/ transect area).

The total area of each site was calculated during this survey by using a boat with a fixed speed and the area was calculated by:

$$A = S * T$$

where A is the area, S is the boat speed and T is the time.

Coefficient of Dispersion

Coefficient of dispersion (*CD*) is a measure used to quantify whether a group of organisms are clustered or dispersed (Walag, Canencia 2016). It was expressed as:

$$CD = variance / mean;$$

where *CD* lesser than 1 (< 1) is regular/uniform, greater than 1 (> 1) is clumping, equal to 1 (= 1) is random.

Statistical analysis

SPSS statistical program was used to carry out the statistical analysis for the obtained data (Norusis, 1990). Statistical analyses were used to examine relationships between population's densities and as factors as site, area on the reef and habitat. The cross classified test was used to determine the variation in densities of the urchin's populations in respond to the different sites, area of existence and type of substrate. Duncan Test was also used to test the equity of the three changeable (sites, areas and type of substrate) on *D. setosum* population densities, that determined which of these changeable parameters has the greatest effect on the density. One way ANOVA was used to determine the species habitat preference.

RESULTS

Population density and habitat distribution

The population density of *D. stosum* was widely different according to different habitats and species behavior as well as adaptation to certain environmental conditions. Temporal variations in species density and their distribution at different habitats is presented in Figs. (2-4), while live and dead corals were the most suitable habitat for *D. setosum*. In contrast, sand, seagrasses and rocky habitats were unfavorable for populations of *D. setosum*.

At Beer Odeeb there is a progressive increase in density from sand (1-2.3 ind./m^2) seagrasses (1.7-3.8 ind./m^2), rocks (2.1-7.9 ind./m^2), while it recorded its maximum densities at dead and live coral habitats, ranged from 2.1 to 14.1 and 1.1 to 24.5 ind./m^2, respectively. The data revealed that fore reef area recorded the maximum densities at all habitats (Fig. 2).

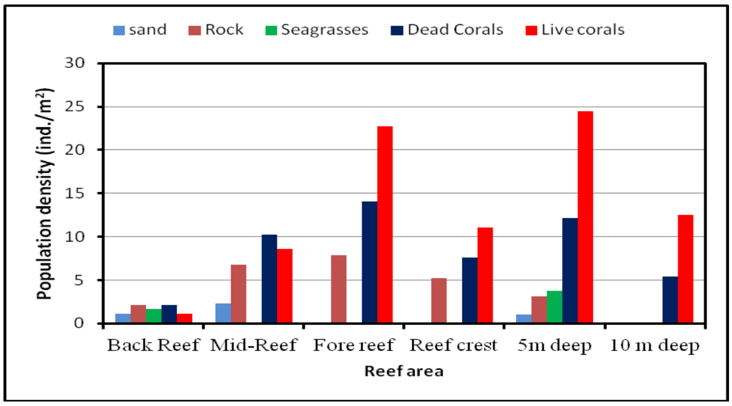

Fig. 2: Population densities of *Diadeima setosum* (ind./m^2) at different reef areas recorded from Beer Odeeb.

The data showed the same conclusion for Ras Mamlah but with greater densities in live coral habitat (2.3-28.9 ind./m^2) and dead coral habitat (3.5 – 18.6 ind./m^2). The fore reef area recorded the maximum density at rocky habitat (7.8 ind./m^2), dead coral habitat (18.6 ind./m^2) and live coral habitat (28.9 ind./m^2). While at sandy habitat the maximum density was recorded from 5 m deep, being 1.3 ind./m^2, while the maximum urchin's densities at seagrass habitat was recorded at mid reef area being1.2 ind./m^2 (Fig. 3).

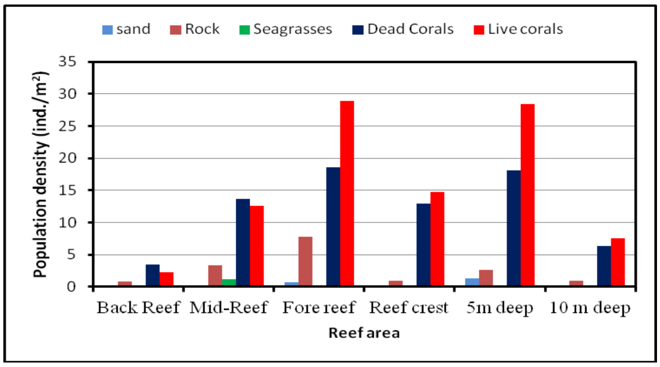

Fig. 3. Population densities of *Diadeima setosum* (ind./m^2) at different reef areas recorded from Ras Mamlah.

At Al-Geisum, the urchin's density in sandy habitat was minimum among all stations studied; it ranged between a minimum of 0.1 ind./m^2 at mid reef and a maximum of 0.3 ind./m^2 at the fore reef, while there was no record of *D. setosum* at back reef, reef crest and 10 m deep. At seagrass habitat, the urchin was only recorded from mid reef area being 1.5 ind./m^2. Also rocky habitat showed lower density than the other two sites; it ranged between a minimum of 0.2 ind./m^2 at reef crest, and a maximum of 1.5 ind./m^2 at 5 m deep. In contrary, the live coral habitat showed the maximum density among all stations; it recorded a minimum of 1.3 ind./m^2 at back reef area and a maximum of 32.4 ind./m^2 at 5 m deep. The dead coral habitat exhibited the same pattern; it recorded a minimum density of 3.4 ind./m^2 at back reef area and a maximum density of 21.2 ind./m^2 at fore reef area (Fig. 4).

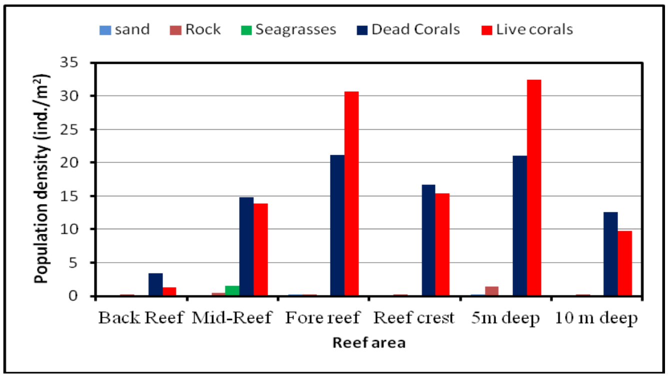

Fig. 4. Population densities of *Diadeima setosum* (ind./m^2) at different reef areas recorded from Al Giesum.

Estimated abundance

The abundance of *D. setosum* (total number of animals counted in the whole survey) showed high variation between the different habitats. The site total area and the area of different habitats inside each site were determined (Table, 1).

Table 1: The total area of the study sites and the area of each habitat (m^2).

Site	Total area (m^2)	Sand (m^2)	Rock (m^2)	Seagrasses (m^2)	Dead Corals (m^2)	Live corals (m^2)
Beer odeeb	5000	3200	800	20	700	280
Ras Mamlah	5000	250	600	50	1200	2900
El-Geisum	9000	900	650	50	290	4500

Live coral habitat recorded the maximum abundance at both Ras Mamlah and Al Geisum being 60900 and 111325, respectively. While Ber odeeb recorded its highest abundance at dead coral habitat being 9800, followed by live coral habitat that recorded 6860 individuals. Among all site, Al Giesum recorded the highest abundance of *D. setosum*, followed by Ras Mamlah, while Ber Odeeb recorded the lowest abundance. The abundance dropped from a maximum of 111325 individuals at live coral habitat at Al Geisum to a minimum of 60 individuals at seagrass habitat at Ras Mamlah (Table 2).

Table 2: Variation in abundance of *D. setosum* at different habitat in the study sites.

Site	Sand	Rock	Seagrasses	Dead Corals	Live corals
Beer odeeb	5120	6320	76	9800	6860
Ras Mamlah	325	4450	60	21600	60900
El-Geisum	180	910	75	50750	111325

Coefficient of Dispersion

The distribution pattern of *D. setosum* populations was determined using the coefficient of dispersion. The study revealed a difference in dispersion among the different habitats and sites. The urchin showed a random distribution pattern in sandy habitat at both Ras Mamlah and El Geisum, while it showed regular pattern at Ber Odeeb. While at the rocky habitat *D. setosum* showed regular pattern at both Beer Odeeb and Ras Mamlah and clumped distribution pattern at El Geisum site. On contrary, seagrass habitat showed random distribution pattern at all sites. At dead coral habitat; *D. setosum* exhibited clumped distribution at both Ber Odeeb and El Geisum, while it showed regular distributions at Ras Mamlah. Live coral habitat showed clumped pattern at both Ber Odeeb and Ras Mamlah, while it showed regular distribution at El Geisum (Table 3).

Table 3: The coefficient of dispersion (CD) of *D. setosum* recorded from different habitats at the study sites.

	Ber odeeb	Ras Mamlah	El-Geisum
sand	0.89	1	1
Rock	0.93	0.87	1.04
Seagrasses	1	1	1
Dead Corals	1.23	0.89	1.58
Live corals	1.76	1.01	0.76

Effect of different factors (site, area, substrate) on the *D. setosum* density

Statistical analyses were used to determine the variation in densities of the urchin's populations in respond to the different sites, area of existence and type of substrate. The cross classified test showed that there were a significant relation between the site, the area of existence and different substrates with the density of *D. setosum* (Table 4).

Table 4. Data obtained from cross classified test between sites, area and type of substrate and the population density of *D. setosum* populations, density is the dependent variable.

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	57711.933[a]	89	648.449	233.348	.000
Intercept	32219.173	1	32219.173	11594.232	.000
Site	95.340	2	47.670	17.154	.000
Area	8734.174	5	1746.835	628.607	.000
Substrate	33955.480	4	8488.870	3054.763	.000
Site * Area	140.871	10	14.087	5.069	.000
Site * Substrate	1856.618	8	232.077	83.514	.000
Area * Substrate	11815.720	20	590.786	212.597	.000
Site * area * Substrate	1113.729	40	27.843	10.020	.000
Error	2250.906	810	2.779		
Total	92182.012	900			
Corrected Total	59962.839	899			
R Squared = .962 (Adjusted R Squared = .958)					

The data showed that there were significant differences in population densities with different sites and area, sites and substrate, area and substrates and sites, areas and substrates. The interaction between the sites and areas, sites and substrates and areas and substrates were significant. Moreover, the interaction between sites, areas and substrates were also significant. The R^2 value obtained from the analysis showed that sites, areas and substrates affected the density of sea urchin population by a percentage of 96%.

To test the equity of the three changeable parameters (sites, areas and type of substrate) on *D. setosum* population densities Duncan Test was used, that determined which of these changeable has the greatest effect on the density. Due to Duncan test, the density of the sea urchin showed significant differences between the three sites (Table 5). The test also showed whether the significant differences recorded between the different areas on the reef have the same effect on *D. setosum* densities. Two areas showed different effect on urchin's density than other areas, back reef area (1.2)[a] and 10 m deep (3.7)[b]. Whereas reef crest area (5.6)[c] and mid reef (5.7)[c] areas showed the same effect on the urchin densities. Moreover, fore reef area (9.84)[d] and depth 5m (9.88)[d] showed the same effect on urchin densities (Table 6). The test also showed that fore reef (9.84) and 5m deep (9.87) has the greatest effect on urchin's densities.

Table 5: Results obtained from Duncan test for the three surveyed sites.

	site	N	Subset		
			1	2	3
Duncan[a,b]	Beer odeeb	300	5.6030		
	Ras Mamlah	300		5.9487	
	El-Geisum	300			6.3980
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 2.779.
a. Uses Harmonic Mean Sample Size = 300
b. Alpha = .05

Table 6. Results obtained from Duncan test for the homogenous effect of areas on the reef on *D. setosum* population densities.

	Region	N	Subset			
			1	2	3	4
Duncan[a,b]	Back Reef	150	1.2193			
	10 m deep	150		3.7001		
	Reef crest	150			5.5547	
	Mid-Reef	150			5.7053	
	Fore reef	150				9.8413
	5m deep	150				9.8787
	Sig.		1.000	1.000	.434	.846

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.779.
a. Alpha = .05.

Duncan test was also carried out for the effect of the significant differences recorded between the different types of habitats on *D. setosum* densities. Only two habitats showed the same effect on the urchin's densities, sandy habitat (0.39)[a] and seagrass habitat (0.42)[a]. While the other types of habitats showed different effect on the urchin's densities as rocky habitat (2.46)[b], dead coral habitats (11.55)[c] and live coral habitats (15.09)[d]. The test also showed that live coral habitats (15.09) has the greatest effect on urchin's densities, followed by dead coral habitat (11.54) (Table 7).

Table 7: Results obtained from Duncan test for the homogenous effect of habitats on *D. setosum* population densities.

	Substrate	N	Subset			
			1	2	3	4
Duncan[a,b]	sand	180	.3900			
	Seagrasses	180	.4228			
	Rock	180		2.4594		
	Dead Corals	180			11.5461	
	Live corals	180				15.0978
	Sig.		.852	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.779.
a. Uses Harmonic Mean Sample Size = 180.000.
b. Alpha = .05.

Habitat preferences

One way ANOVA was used to determine the habitat preference for *D. setosum*, the preferred habitat at each area and at each site. Population densities *D. setosum* showed significant differences between the sites. At Beer Odeeb, both rocks (1.96^c) and dead corals (2.05^c) were the preferred habitat at back reef area, while only dead corals was the preferred habitat at the med reef area, while the other areas showed that the live coral habitat as their preferred habitat. Ras mamlah at the Gulf of Aqaba showed dead coral as a preferred habitat at back reef area (3.4^c) and med reef area (13.29^c), while live corals were the preferred habitat for other areas. El Geisum at the Red Sea showed a different preference for *D. setosum* from the two other sites; they preferred dead coral habitat at back reef area (3.3^c), med reef area (14.7^c), reef crest (15.4^c) and 10 m deep (12.6^c), whereas they prefer live corals habitat in only two areas, fore reef (29^c) and at depth 5 m (30.6^c) (Table 8).

Table 8: Habitat preference of *D. setosum* at the different sites and areas according to population density using one way ANOVA.

Site	Area	S	R	S.G	D.C	L.C
Beer odeeb 5.6^a	B.R 1.5^a	1.09^a	1.96^c	1.47^b	2.05^c	1.03^a
	M.R 5.3^b	2.1^a	6.59^b	0^c	9.8^d	7.85^c
	F.R 9^c	0^a	7.7^b	0^a	13.86^c	23.37^d
	R.C 5.1^b	0^a	5.1^b	0^a	7.76^c	12.56^d
	5M 9.2^c	1.63^a	3.75^b	4.15^b	12.47^c	24^d
	10M 3.6^{ab}	0^a	0^a	0^a	5.2^b	12.6^c
Ras Mamlah 5.9^b	B.R 1.23^a	0^a	0.91^b	0^a	3.4^c	1.88^d
	M.R 6^b	0.2^a	3.47^b	0.78^a	13.29^c	12.36^d
	F.R 10.2^c	0.59^a	7.36^b	0^a	14.5^c	28.8^d
	R.C 5.6^b	0^a	1.01^a	0^a	12.47^b	14.6^c
	5M 9.5^c	$.83^a$	2.9^a	0^a	16.75^b	27.01^c
	10M 3.1^{ab}	0^a	0.51^a	0^a	6.26^b	8.54^c
El-Geisum 6.4^c	B.R 0.9^a	0^a	0.14^a	0^a	3.3^c	1.1^b
	M.R 5.8^b	0.06^a	0.41^{ab}	1.2^b	14.7^d	12.7^c
	F.R 10.3^c	0.32^a	0.27^a	0^a	21.86^b	29^c
	R.C 6^b	0^a	0.15^a	0^a	15.4^c	14.2^b
	5M 10.93^c	0.2^a	1.77^a	0^a	22.1^b	30.6^c
	10M 4.45^b	0^a	0.23^a	0^a	12.6^c	9.6^b

DISCUSSION

Diadema setosum is one of the conspicuous and very important species of echinoids, and is an important constituent of the near shore marine biota. It is adapted to a very wide range of conditions, from intertidal zone to a depth of 50 meters and from subtropical to tropical waters. It ranges from hard substrate to those that live in sandy and seagrass habitats (Hasan, 1995). *D. setosum* is also one of the most important species at the coral ecosystem because it is contributing significantly to the food chain and to modification of the substrate (Lirman 2001). It is one of the most important benthic fauna effect and affected by the other fauna and by the substrate. It is one of the major biological factors that protect corals from competition, as algal grazing by echinoids is recognized as being crucial in restoring and maintaining coral re-colonization (Lirman 2001).

Regarding the different sites surveyed during the current study, El-Geisum at the Red sea showed greater abundance of *D. setosum* population (163240 individuals) than the other two sites. At this site 68.2% of the population were recorded from the live coral habitat, while the other habitats recorded very small percentage ranged from 0.1% at the sandy habitat to 31% at the dead coral habitat, followed by the population at Ras Mamlah at the Gulf of Aqaba that recorded abundance of 87335 individuals, live coral habitat accommodate 69.7% of the population. Finally Ber Odeeb site at the Gulf of Suez recorded the lowest abundance (28176 individuals), with the highest percentage recorded from dead coral habitat being 34.8%, while live coral habitat at this site accommodated 24.3% of the population. *D. setosum* flourished in live corals that explain the highest abundance of the species in ElGeisum site as it have high live coral cover, while the live coral cover is lower at

Ras Mamlah, Gulf of Aqaba due to the high tourism activities their and the sandy substrate. Whereas the temperate characters and the pollution at the Gulf of Suez reduced the live coral areas, and subsequently reduced the abundance of *D. setosum* in the site, which indicated by the highest abundance that recorded from dead coral areas. There are markedly different environmental conditions in the Gulf of Suez than the adjacent waters, Gulf of Aqaba and Northern Red Sea (Pearse, 1983, Lawrence, 1983). The unusual environmental conditions in the Gulf of Suez appear to have affected the abundance of its fauna. While temperature has very limited effect on the difference in abundance of *D. setosum* between the sites surveyed as seasonal sea temperature changes at Northern Red Sea are very similar to those at Gulf of Suez (Pearse, 19^3). It therefore seems unlikely that temperature stress by itself could limit the existence of the urchin.

D. setosum is abundant and conspicuous echinoid at the study areas. It has a worldwide distribution, from central Japan to southern Australia and from Clarion Islands off Mexico to the Red Sea (Mortensen, 1943). Such a wide distribution indicates that this species is capable of exploiting the ecological niches of many coastal waters. This is because of its life history features which make successful colonization at new habitats. It is able to tolerate extreme environmental conditions of temperature and salinity. Although, it is shored lived species it has a long breeding season with continuous spawning activity (Pearse, 1970, Alsaffar and Lone 2000). Distribution and abundance of echinoids depend on many biotic and abiotic factors (Ebert 1982, Dotan 1990). Fluctuation in abundance of the animals may be due to change in their distribution in response to change in substrate type, food availability, change in dispersion from aggregated to random, a restricted to specific locality due to the lack of suitable habitat, and heavy predation (Miller, 1985). Wave activity, water depth, substratum composition, food, predation, and behavior have been reported to contribute to the distribution of echinoid species on coral reefs (Regis & Thomassin 1982, Lawrence 1983, Tegner & Levin, 1983, McClanahan 1998, Dotan 1990). In the present study, it seems that the sharp decline in density from El-Giesum site (Red Sea) to Beer Odeeb site (Gulf of Suez) is the result of the effect of substrate, where live and dead coral substrates are much flourished in El-Giesum site than Beer Odeeb site. This provides diversity in microhabitat and the availability of food that accommodates more individuals. During the current study, *D. setosum* populations showed spatial variation in density between the surveyed sites and different areas in each site. Moreover variations were recorded between different substrate according to habitat preferences. While a certain part of urchin distributions could be linked to environmental variables, most of the spatial variability remained unaccounted for. Similar trends were also highlighted by other authors, with high spatial patchiness reported for sea urchins as the result of diverse factors interacting at multiple scales (e.g. Sanchez-Jerez *et al*., 2001).

It was concluded that there were several factors affect the spatial distribution of *D. setosum*. The first and most important factor is the type of substrate; the species prefers the live and dead coral substrates that rich with microhabitats and food. The microhabitats provide refugee for the urchin from predation, that is explain the high density recorded from coral areas at El-Giesum site in spite of the presence of natural enemies represented by different types of fishes that feed on the urchins as family Lethrinidea, trigger fish ..etc. The urchins are found mainly in burrows, crevices and under corals, which provide high protection against predation. On the other hand, sandy, seagrasses and to lower extent rocky habitats are lacking microhabitats and subsequently no refugee for the urchin make it highly sensitive from predation; here the density is controlled by the number of predators present in the area as there is no escape for the urchins from predation. For instance, densities ranged from 0 to 1.1, 0 to1.3 and 0 to 0.3 ind./m^2 in sandy habitats at Beer Odeeb, Ras Mamlah and El-Giesum, respectively, while the density was much higher at live coral habitats, it ranged from 1.1 to 24.5, 2.7 to 28.9 and 1.3 to 32.4 ind./m^2 at the same sites, respectively. *D. setosum* was recorded in dead coral, live coral and seagrass habitats (Aziz 1995), it preferred some habitat types, which were dead coral and live coral colonies (Puspita *et al.*, 2012). The reason of live coral preference was due to the existence of microhaitats as concluded by Krausman (1999), who reported that genus *Diadema* is spend most of his life hiding in a crevices that is usually found on living coral colonies. The analyzed of microhabitat preference on live coral colonies shows that massive coral was preferred by *D. setosum* because massive coral is hard and solid substratum with simple architecturally structure. This is in accordance with the opinion of Dumas *et al.* (2007). The current study has been reached to the same conclusion of Szabo and Anderson (2012) that *D. setosum* tend to avoid fine sediments, such as fine sand or mud. The second important factor controlled the distribution of the urchin under investigation is the food availability. It feeds mainly on filamentous algae that grow on dead coral and between live coral colonies (Shunula and dibalema, 1986; Lawrence, *et al*, 2013) and on coral fragments. The feeding behavior of the urchin makes it very important member at the reef ecosystem as it is very efficient grazer, which favors the existence of live coral by eliminate the algae from the substrate and give the corals the opportunity to re-colonization and make it higher competitor over the algae. The role of *D. setosum* on the reef ecosystem and the preferable habitat for it makes it occupy the live coral habitats as the most favorable habitat for the urchin.

The results of the present study emphasized the species-specific patterns with a significant part (96%) of the spatial variability that explained by habitat variables, suggesting that the physical nature of substrate exerts a prevailing influence on spatial distributions.

The distribution pattern of *D. setosum* populations was determined using the coefficient of dispersion, the study revealed a difference in dispersion among the different habitats and sites; this may be attributed to the physical factors and the presence of predators. Also due to the type of substrate, the area on the reef as well as the biological interaction between different species at each site, all these factors affected the species behavior inside the ecosystem. The random distribution pattern that has been shown in some habitats and areas was due to the low densities and the unsuitability of these habitats to the urchin. While, most individuals had regular (uniform) distribution due to the availability of food, the high density of the species and the suitable substrate and high variation of microhabitats. The clumped distribution recorded in some habitats was due to the pressure of predators that force individuals to group in protected areas, the individuals have a tendency towards clumping for protection and food. Those clumped behavior is the reason of an organism in order to protect themselves from their predator and to facilitate the fertilization. The clumped distribution may be explained by spatial variation of habitat availability and limited dispersal ability (Medrano 2015).

One way ANOVA revealed that the habitat preferences are varied according to the sites, areas on the reef and habitats. The three sites shared the preferable areas for the urchin, which are the fore reef and 5m depth. This is due to the two regions are subtidal areas and never exposed as back reef and med reef areas, because the urchins can't tolerate the exposure to air. While the reef crest is not favorable for urchin existence due to the vigorous waves, which subject pressure on the urchin's population live there. The 10 m depth was not suitable area for *D. setosum* in the surveyed sites due to the lower percentage of live coral cover and hard bottoms. At both Beer Odeeb and Ras Mamlah, the urchin prefers live coral habitat at fore reef, reef crest, 5 m depth and 10 m depth areas, while it prefers dead coral habitats at both back reef and med reef areas that is explained by the low cover of live corals in these two areas thus the urchin occupied the second category of habitat preference (dead coral areas). On contrary, at El Giesum site, Red Sea, live coral habitat was preferred in both fore reef and 5 m depth, where the live coral cover is flourished and has high microhabitats, while the dead coral habitat was the favorable for the sea urchin at back reef, med reef, reef crest and 10 m depth. This pattern was achieved as a result of territorial fishes that feeds on sea urchin and occupied the live coral areas in reef crest and 10 m deep, thus the urchin didn't prefer the live coral habitats in these areas to avoid predation.

CONCLUSION

As a matter of fact, the spatial patchiness of reef urchins is usually not easy to explain (McClanahan and Muthiga, 2001). It can be concluded from this quantitative study emphasized the importance of substrate characteristics in shaping the density distributions, with respect to species characteristics and environmental gradients.
As an efficient grazer, it controls the algal expanding and reduces its ability for competing against corals. This gives the coral the ability to recolonize and grow. The species showed habitat preference according to the physical conditions and different habitats at each site. The study revealed its preference to live coral habitats. The presence of the urchin in this habitat is essential for protecting the coral fauna and for the health of the environment.

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