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Effect of hard installation on coral community succession and growth rate at Taba Heights international marina at the northern Gulf of Aqaba, Egypt.

Mohamed Hamza Hasan
Aquatic Environment Department, Faculty of Fish Resources, Suez University, Suez, Egypt
Email: marinehamza@yahoo.com

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ABSTRACT

Hard substrate plays an important role in the life of coral species, affecting their existence, percentage cover and growth rates. The purpose of this study was to determine the diversity, percentage cover and the succession of coral species on newly constructed hard substrate. Also to measure the growth rate of nine scleractinian corals. Taba Heights international marina has three quays, along the study period (2007-2017), a record of coral species in each quay were recorded and the successions of coral communities were studied. In total, 12 coral species were recorded from all of the surveyed quays during the 10 years period, nine hard and three soft coral species. All the recorded species were found in the first quay, while the second and third quays recorded 5 and 4 species, respectively. From the species recorded only the soft coral *Xenia macrospiculata* and the hard corals *Stylophora pistillata*, *Acropora pharaonsis* and *Porites solida* were recorded from all the three quays. At the first quay, the soft coral species were succeeded with the hard coral species. Three soft coral species were recorded at the beginning of the study at November, 2007, *Xenia macrospiculata* recorded a percentage cover of 5%, decreased to reach 0.3% at July, 2015, until it is totally disappeared at January, 2016 to the end of the study. The same pattern was recorded by the other two soft coral species *Dindrophyllia robusta* and *Sarcophyton trocheliophorum*. On contrary, the hard coral species began with lower percentage cover increased gradually with successive periods during the study. The total area covered by corals was determined at each quay; at the first quay soft coral represented 5% of the total area at November, 2007 decreased to 0.4% at July, 2015 before it totally disappeared at January, 2016. On contrary, hard coral at the same quay represented 1.4% of the total quay area at November, 2007 increased to 17.5% at July, 2017. The same pattern was obvious for the other two quays but with lower percentage cover. Nine hard coral species were measured for growth rate determination five branched and four massive species during the period of study (2007-2017). *Acropora hemperichi* recorded the highest rate of linear extension over the total period of study was 11.44 cm y^{-1}. Followed by *Stylophora pistillata* which recorded mean growth rate 7.52 cm y^{-1}. On the other hand *Porites solida* showed the lowest growth rate of 0.07 cm y^{-1}.

Over the ten years period of study, the coefficient of regression statistical analysis showed that both linear extension rate per branch for branched corals and radial growth for massive corals showed significant increase with time but with different rates.

INTRODUCTION

Despite that coral reefs are productive and diverse ecosystems characterized by a huge biodiversity and a high level of endemism, it is sensitive ecosystem affected by any minor change which could cause a degradation of the overall ecosystem (Head, 1987). The high productivity of coral ecosystems are well known even they are surrounded by water poor in nutrients necessary for primary production (Hoegh-Guldberg, 2000).

Corals are affected by certain factors that enhance or degrade the coral communities. These factors include substrate (Macintyre, 1988), turbidity and sedimentation rate (Rogers, 1990), salinity (Guest et al. 2012), illumination (Harriott and Banks, 1995), tourism activities (Bryant et al. 1998) and boat anchoring and grounding (Jameson et al. 2007). Also climatic and hydrographic conditions (tides, high temperature, direct exposure to solar radiation and human activities such as fishing and aquatic sports) are factors control coral existence and cover (Perks, 2002 and Mohammed 2003). High latitude (Shippard et al. 1992) and the intensive sandy substrate (Macintyre, 1988; Rogers, 1990 and Mohammed, 2003) are unfavorable for coral existence. Overall the low sedimentation rate (Mohamed, 2003), high light penetration, suitable depth and availability of water exchange that bring nutrients and prevent sediment precipitation on coral colonies are the factors control the existence and well-being of coral species.

The effect of site location, substrate and environmental conditions is obvious on the growth rates of coral species, while a decline was recorded in *Porites lobata* growth rate with increasing latitude at Hawaiian Archipelago (Grigg, 1981; 1982), an inverse relationship between latitude and growth rate for *Pocillopora damicornis* and *Acropora sp.* (Stimson, 1996). On the other hand, Smith (1981) reported that the growth of *Porites sp*. was not depressed at a high latitude site, while changes in the environmental parameters (temperature, salinity, substrate and turbidity) can influence not only growth rate (Crabbe and Smith, 2005) but also abundance and diversity of corals (Lirman, et al, 2003). Environmental conditions are from the important factors that affect the coral growth (Oliver et al, 1983). *Acropoa sp.* may be the most rapidly growing coral in the world in terms of linear extension (Gladfelter et al, 1978). The growth rate compared with number of studies on different species from different localities *Acropora cervicornis* recorded a linear growth of 2.5 $cm.y^{-1}$ at site with high sedimentation rate and 10.95 $cm.y^{-1}$ at less impacted reefs (Crabbe and carlin, 2007). The same species recorded linear extension of 26.4 $cm.y^{-1}$ in Jamaica reefs (Gladfelter et al, 1978). *Acropora sp* had the greatest mean linear extension (16.62 $mm.month^{-1}$) at Australia (Anderson et al, 2012). Harriott (1999) quantified summertime growth rates of 0.46 mm $month^{-1}$ for *A. cytherea* and 0.80 mm $month^{-1}$ for *A. valida* at the Solitary Islands, Australia. Also Anderson (2012) recorded a linear growth rate of 2.15 mm $month^{-1}$ for *Pocillopora venucosa* he concluded that *Pocillopora* is the slowest growing coral species, his hypothesis ascertained by the data reported by Ward (1995) from Rottnest Island, Western Australia, how recoded a linear growth rate ranged between 0.75 and 1.25mm $month^{-1}$.

The Egyptian coral reefs are at risk from human impacts; about 61% of the corals were greatly affected as was estimated by the World Resources Institute (Bryant et al. 1998). The destructive effect of mass tourism on corals was evident at four coral sites near Hurghada that showed a high

physical damage in coral when exposed to mass tourism (Jameson et al. 2007). This damage reflected by lower frequency of hard coral (especially *Acropora*), higher percentage of algae and higher percent of soft coral. Boat anchoring and grounding is one of the serious damage correlated with tourism activities. In Sharm El Sheikh, the dive boats caused a high damage to the reef when increased from 26 at 1988 to 320 at 2000 (Abou Zaid, 2002).

Taba area is characterized by intensive sandy substrate; there were no coral species recorded at the area because the location of the area at high latitude (Shippard et al, 1992) and the intensive sandy substrate that is unfavorable for coral existence

(Macintyre, 1988; Rogers, 1990 and Mohammed, 2003). By introducing Taba Heights Marina to the area as an inland marina it provided a hard substrate represented by the concrete quays constructed as boat berthing facility. Hard substrate is one of the major factors affecting coral status. The coral larvae settlement depends mainly on the existence of hard substrate that suitable for settlement and subsequently coral growth.

The current study aims to evaluate the impact of the existence of hard substrate introduced to a sandy habitat area on the coral communities at the area and the succession of corals over 10 years period from 2007 to 2017.

MATERIALS AND METHODS

Study site

Taba Heights Marina is located at the most Northern tip of the Gulf of Aqaba. It was designed as an inland marina with an approximately 11,500 square meters of water area, with depths of between 2.5 and 4 meters near the main docks. The marina has a wide approaching channel with about 50 meters length, the depth of the channel ranged between 3 and 4 meters deep (Fig. 1).

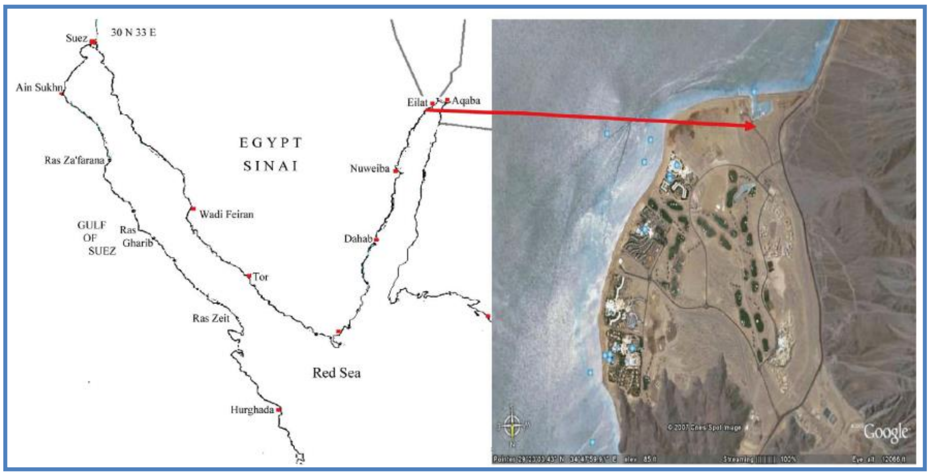

Fig. 1: The study area at Taba city at the northern tip of the Gulf of Aqaba.

Taba Heights is fast becoming the luxury gateway for both land and seafarers. It is the ideal port of call, especially now for seafarers who wish to take a voyage up the Red Sea and cruise the Gulf of Aqaba. Taba Heights marina began to operate at the mid-nineties and granted an International Tourist Marina license in July 2005. The International marina of Taba Heights serve in two directions from Egypt to Jordan and Vice versa.

The marine habitat in front of the marina is sandy habitat, no records of corals dead or live. A weak seagrass bed is found composed of scattered individuals of *Halophilla stipulacea*. This bed accommodate several gastropods and sea urchins, it also help in stabilizing the sediment thus reduce the sediment agitation and movement. Inside the marina the substrate kept its sandy nature, while on the walls of the marina, which are concrete walls a new community has established.

Inside the marina two communities were recorded, a sandy community, which is very weak, composed of scattered individuals of bivalves and fire worms. And a more reach hard substrate community settles on the concrete walls of the marina. This community composed of several organisms with an obvious stratification connected with the water surface. Above the water level established two species (*Pattela* and *chiton)*, these two species tolerate the high temperature and desiccation, and the hard shells of these species enable them to live in these harsh environmental conditions. While just beneath the water surface there were a mixed community of sea urchins, composed of two species (*Diadeima stosum* and *Echinometra mathaei*). At much lower depth found coral species and gastropods *Cerithium ruppilli* and *Engina mendicaria*. All these organisms taking the walls of the marina as their substrate.

Field Survey

Surveys were mostly carried out two times a year the first at January and the second at July from each year at six months interval, at the period from 2007 to 2017. Data collected using Belt transect method (Rogers et al, 1994 and Wilkinson et al, 2003) . In this method, a transect lines were employed to act as guides along which 1 m quadrate was placed every meter continuously. Transects were located parallel to each other and hanging on the quay. The quadrate was made of aluminum pipe and divided into 100 squares with nylon line, and each square therefore represented 1% of the quadrate. The following attributes were recorded in each quadrate: total number of coral species; total number of colonies; percentage cover of each species; living coverage of each species (%); living coverage of hard corals, soft corals.

Growth rate determination

Nine hard coral species were chosen to monitor their growth rates. The colonies of each species were tagged to determine the changes in their growth. Coral colonies were tagged using thin copper threads and the distance between the thread and the tip of the coral branch was accurately measured using caliper or graduated meter for branched corals, while for massive coral the diameter of the colonies were measured by graduated meter. After each time interval, the change in species growth was calculated by repeating the process of measurement. The initial distance was subtracted from the new distance to calculate the growth. The growth rate was then expressed as the number of centimeters gained per time.

Statistical Analysis

We used SPSS statistical program (version 11.5) to carry out the statistical analysis for the obtained data (Noursis, 1990). Statistical analyses were used to examine relationships between the time and percentage cover and time and growth rate of different coral colonies. We used simple linear regression to explore the relationships between the independent variable (time) and the dependent variables (% cover and length).

RESULTS

Taba Heights international marina has three quays; the first is 35 m in length and 4 m depth with a total area of 140 m^2. The second is 94 m in length and 2 m depth with area of 188 m^2, while the third is 70 m in length and 2 m depth with area of 140 m^2. Along the study period (2007-2017), a record of coral species in each quay was recorded and the successions of coral communities were studied.

Coral species diversity

In total, 12 coral species were recorded from all of the surveyed quays during the 10 years period. Nine hard coral species and three soft coral species. The first quay recorded the highest diversity among all; it recorded 12 species, while the second quay recorded 2 soft coral species and 3 hard coral species and the third quay recorded one soft coral species and 3 hard coral species. From the species recorded only the soft coral *Xenia macrospiculata* and the hard corals *Stylophora pistillata*, *Acropora pharaonsis* and *Porites solida* were recorded from all the three quays (Table 1).

Table 1: A comparison of species composition at the different quays at Taba Heights International Marina.

	Quay 1	Quay 2	Quay 3
A-Soft Corals			
Xenia macrospiculata	+	+	+
Sarcophyton trocheliophorum	+	+	
Dindrophyllia robusta	+		
B- Hard Corals			
Stylophora pistillata	+	+	+
Acropora hemperichi	+		
A. humilis	+		
A. pharaonsis	+	+	+
Pocillopora venucosa	+		
Favia favus	+		
Favia pallida	+		
Porites solida	+	+	+
Montasteria annularis	+		
Total	12	5	4

During the first survey at November, 2007 the first quay recorded three soft corals and three hard coral species. The species diversity increased with time, the hard coral species increased to five species at July, 2008, six species at January, 2009, eight species at July, 2010 and nine species beginning from January, 2011. On contrary, the soft coral species recorded three species from the beginning of the survey till July, 2013, decreased to two species at January, 2014 and totally disappeared beginning from January 2016 to the end of the survey. On the other hand, at the second quay the soft corals recorded two species at the beginning of the survey (November, 2007) till July, 2013, decreased to one species at January, 2014, and totally disappeared beginning from January, 2016. The hard coral species firstly recorded from this quay at November, 2007 with two species, increased to three species at July, 2012 to the end of the study. The third quay, recorded one soft coral species at November, 2007 till January, 2013, and then disappeared at the rest of the study. While hard coral species begins with two species at November, 2007 till January, 2011, then increased to three species at July, 2011 till January, 2013, decreased again to two species beginning from July, 2013 till the end of the study.

Coral species percentage cover and succession

The most obvious difference was in the fluctuation of mean percentage cover of hard and soft corals which indicated the status of the corals and the succession between species. At the first quay, the soft coral species were succeeded with the hard coral species. Three soft coral species were recorded at the beginning of the study at November, 2007, *Xenia macrospiculata* recorded a percentage cover of 5%, increased to 8 % at July, 2008, then decreased beginning from January, 2009 (2.6 %) to July, 2015 (0.3 %) until it is totally disappeared at January, 2016 to the end of the study. The same pattern was recorded by the other two soft coral species *Dindrophyllia robusta* and *Sarcophyton trocheliophorum*, which recorded the highest cover at November, 2007 being 4% and 2%, respectively, increased at July, 2008 to 3% and 2.5%, respectively, then decreased at the following periods till they reached its minimum percentage cover at July, 2018 recorded 0.8% and 0.3%, respectively before they completely disappeared at January, 2014. On contrary, the hard coral species began with lower percentage cover increased gradually with successive periods during the study indicating that the hard coral increased with time in the expense of soft coral and replaced them on the quay. The hard coral began at November, 2007 with three branched species *Stylophora pistillata* recorded the highest percentage cover (2.9%), followed by *Acropora pharaonsis* (1.5%) and *A. hemperichi* (0.2%). During the following survey at July, 2008 two species were appended *A. humilis* (0.9%) and *Montasteria annularis* (0.1%) with the increase in percentage cover of the previously recorded three species. Then only one species was added to the coral community during the following three surveys at January, 2009, July, 2009 and January, 2010, this was the massive species *Favia favus*, which recorded a stable cover (0.2%) during the three surveys, with the permanence of the increase in the cover of the previously recorded species. With the continuation of increasing the percentage cover of the previously recorded species at July, 2010, another two species were recorded *Pocillopora venucosa* with a percentage cover of 0.5% and *Favia pallida* with a percentage cover of 0.1%. While at July, 2011 another species *Porites solida* was recorded with a percentage cover 0.1%, at this time the maximum number of species were reached that number continued without increase to the end of the study, only the percentage cover of species were continue increasing (Fig. 2).

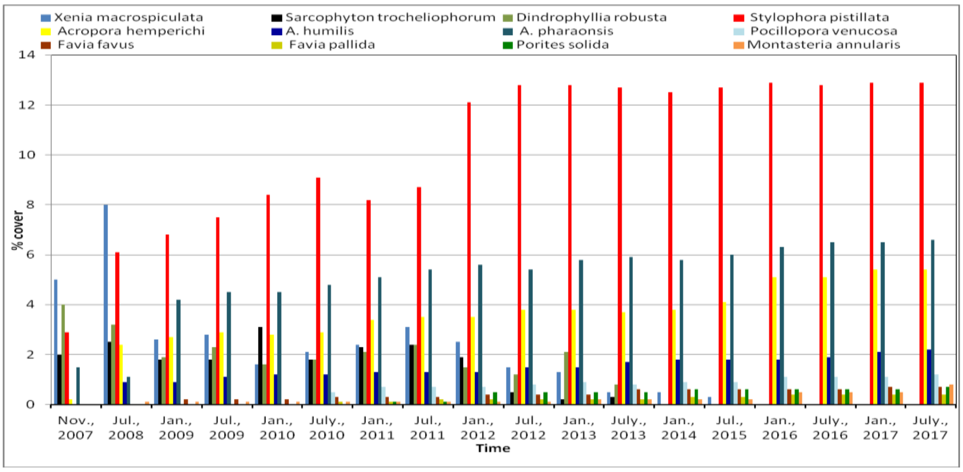

Fig. 2: The percentage cover of hard and soft corals recorded at the first quay during the period from 2007 to 2017.

At the second and third quays the coral species succession was not obvious due to the low diversity and percentage cover of species. At the second quay only five species were recorded two soft corals and three hard corals. The first record of soft corals were *Xenia macrospiculata* and *Sarcophyton trocheliophorum* at November, 2007 with a percentage cover of 9% and 3.9%, respectively, increased during the two following surveys at July, 2008 and January, 2009 to 12% and 12.5% for the former species and 4.6% and 4.9% for the later one. Then both species began to decrease starting from July, 2009 recorded 8.7% and 3.5%. *Sarcophyton trocheliophorum* reached its minimum percentage at July, 2013 recorded 0.9% and then disappeared starting from January, 2014 till the end of the study, whereas *Xenia macrospiculata* took longer time to reach its minimum percentage at July, 2015 then disappeared afterwards at January, 2016 to the end of the study. The hard corals at the quay recorded by two branched species *Stylophora pistillata* and *Acropora pharaonsis* that recorded at the beginning of the study (November, 2007) with a percentage cover of 1.2% and 1%, respectively and one massive species *Porites solida* that recorded much later on at July, 2012 with very small percentage (0.1%). *Stylophora pistillata* recorded its maximum percentage at July, 2010 (2.6%). While both *Acropora pharaonsis* and *Porites solida* recorded their maximum percentages (6.6% and 0.7%, respectively) at July, 2017 (Fig. 3).

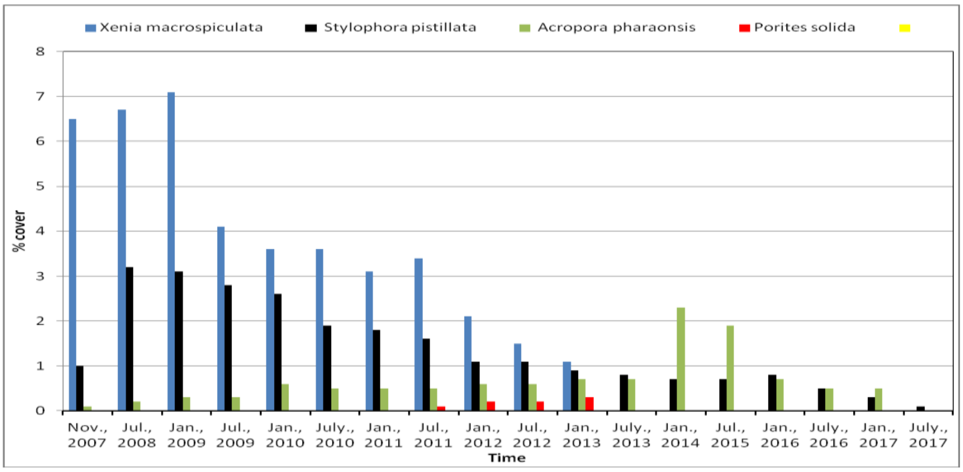

Fig. 3: The percentage cover of hard and soft corals recorded at the second quay during the period from 2007 to 2017.

The third quay recorded 4 coral species, one soft coral and three hard corals. The first record of soft coral was *Xenia macrospiculata* at November, 2007 with a percentage cover of 6.5%, increased during the two following surveys at July, 2008 and January, 2009 to 6.7% and 7.1%. Then it began to decrease starting from July, 2009 recorded 4.1%. *X. macrospiculata* reach its minimum percentage at January, 2013 (1.1%), then disappeared afterwards at July, 2013 to the end of the study. The hard corals at the quay recorded by two branched species *Stylophora pistillata* and *Acropora pharaonsis* that recorded at the beginning of the study (November, 2007) with a percentage cover of 1% and 1.1%, respectively and one massive species *Porites solida* that recorded much later on at July, 2011 with very small percentage (0.1%). *Stylophora pistillata* recorded its maximum percentage at July, 2009 (2.8%). While *Acropora pharaonsis* recorded its maximum percentages (2.3%) at January, 2014, while *Porites solida* recorded its maximium percentage (0.3%) at January, 2013 before it disappeared at July, 2013 (Fig. 4).

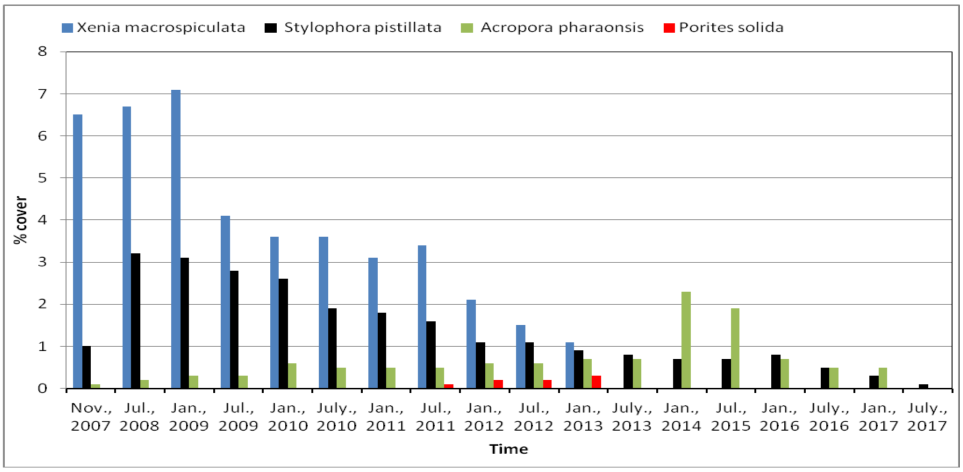

Fig. 4: The percentage cover of hard and soft corals recorded at the third quay during the period from 2007 to 2017.

The statistical analysis for the percentage cover of recorded coral species was tested with time for different species using the regression coeffecient. The analysis showed that the total soft corals recorded were significantly decreased with time at the three surveyed quays, it recorded a significantly decrease with time (β (coefficient of regression)= -0.54) with a percentage of 80% at the first quay, significantly decrease with time (β= -0.37) with a percentage of 34% at the second quay and a significant decrease with time (β= -0.23) with a percentage of 29% at the third quay. On contrary, the percentage cover of total hard coral species showed significant increase with time, it recorded a significantly increase with time (β= 1.24) with a percentage of 80% (R^2 (percentage of variance) **=** 80%**)** at the first quay, significantly increase with time (β= 0.49) with a percentage of 46% at the second quay and a significant increase with time (β= 0.86) with a percentage of 68% at the third quay (Table 2).

Table 2: Regression coefficients between time and % cover of different coral species at different quays at Taba Heights International Marina. β coefficient of regression , R^2 percentage of variance.

Coral	**Quay 1**		**Quay 2**		**Quay 3**	
	β	R^2	β	R^2	β	R^2
	soft coral					
Xenia macrospiculata	- 0.32*	68%	– 0.70*	85%	– 0.44*	88%
Sarcophyton trocheliophorum	- 0.18*	74%	– 0.28*	76%	nr	
Dindrophyllia robusta	-0.20*	83%	nr		nr	
	Hard coral					
Stylophora pistillata	0.52*	81%	– 0.04ns	18%	– 0.15*	70%
Acropora hemperichi	0.22*	84%	0.04ns	3%	0.04ns	12%
A. Humilis	0.09*	87%	nr		nr	
A. pharaonsis	0.25*	74%	nr		nr	
Pocillopora venucosa	0.08*	95%	nr		nr	
Favia favus	0.04*	95%	nr		nr	
Favia pallida	0.04*	95%	nr		nr	
Porites solida	0.05*	87%	0.02*	44%	001ns	0%
Montasteria annularis	0.033*	69%	nr		nf	
Total hard coral	1.24*	88%	0.49*	46%	0.86*	68%
Total soft coral	-0.54*	80%	-0.37*	34%	-0.23*	29%

nr (not recorded) * significant ns not significant

The analysis also revealed that all the relations between the percentage cover of coral species (soft and hard) and time were significant at the first quay. While at the second quay two out of the five species recorded showed non-significant relations between its cover and time those are *Stylophora pistillata* and *Acropora hemperichi*.Where as at the third quay two out of the four recorded species showed non-significant relation, those were *Acropora hemperichi* and *Porites solida* (Figs. 5-10).

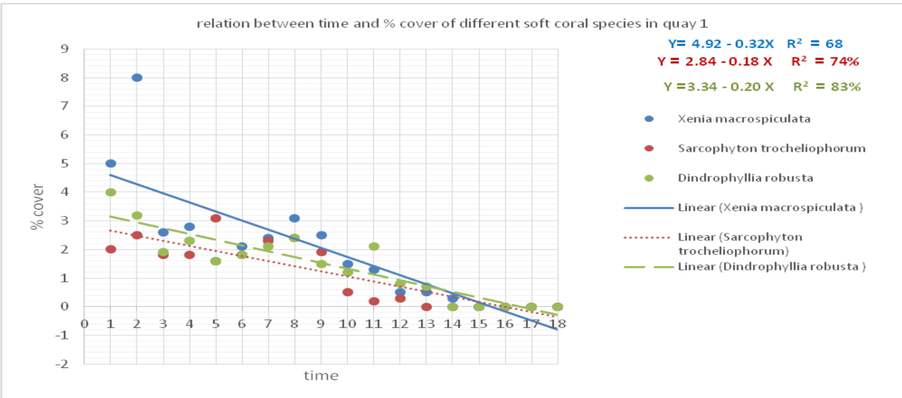

Fig. 5: The regression of coefficient relation (β) and percentage of variance (R^2) between time and % cover of the recorded soft coral species at the first quay.

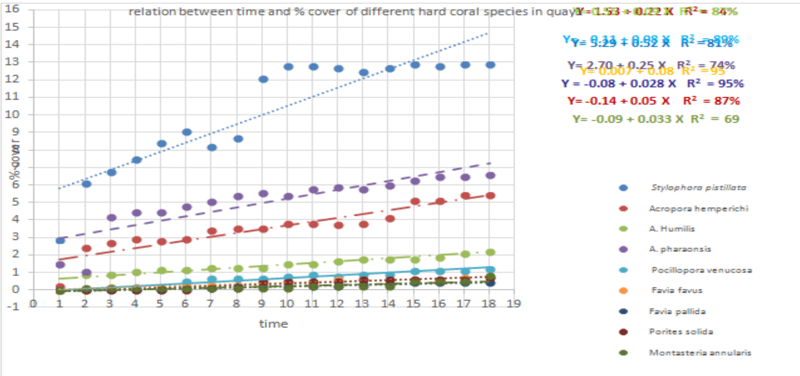

Fig. 6: The regression of coefficient relation (β) and percentage of variance (R^2) between time and % cover of the recorded hard coral species at the first quay.

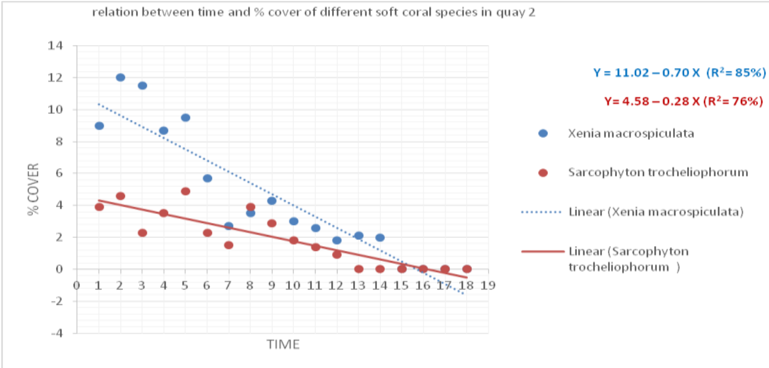

Fig. 7: The regression of coefficient relation (β) and percentage of variance (R^2) between time and % cover of the recorded soft coral species at the second quay.

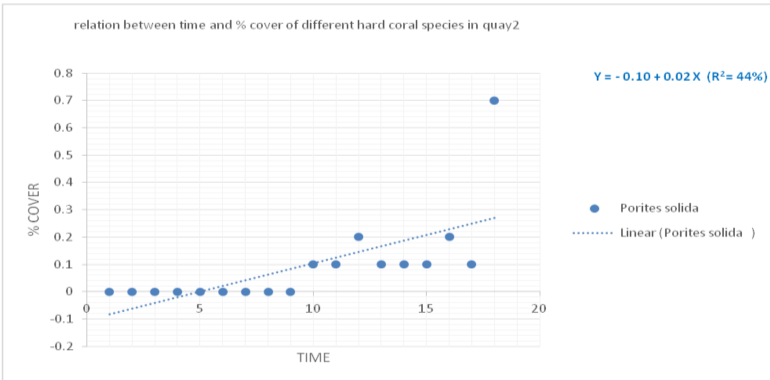

Fig. 8. The regression of coefficient relation (β) and percentage of variance (R^2) between time and % cover of the recorded hard coral species at the second quay.

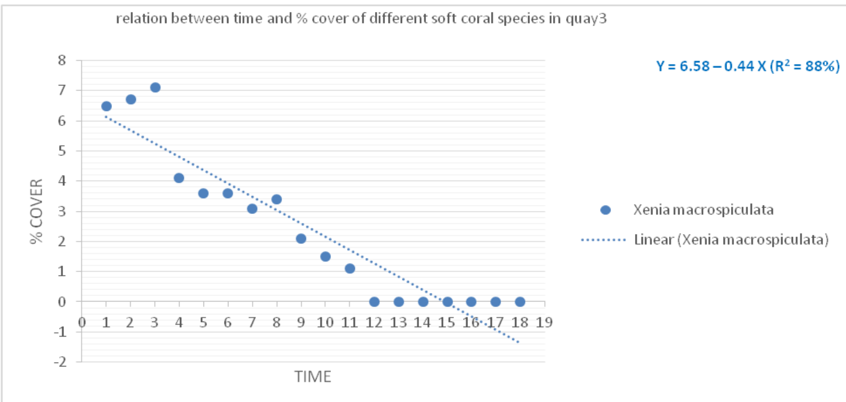

Fig. 9. The regression of coefficient relation (β) and percentage of variance (R^2) between time and % cover aof the recorded soft coral species at the third quay.

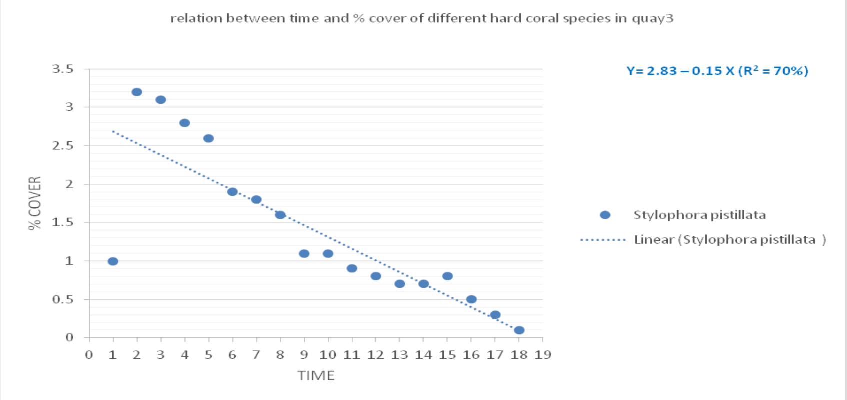

Fig. 10: The regression of coefficient relation (β) and percentage of variance (R^2) between time and % cover of the recorded hard coral species at the third quay.

Coral status

The total area covered by corals was determined at each quay. At the first quay the area covered with coral recorded 2 m^2 from the total quay area (140 m^2) at November, 2007, represented a percentage of 1.4% of the total area. The area covered by hard coral gradually increased during the followed surveys to reach its maximum at January, 2016 recorded 24.5 m^2, represented a percentage of 17.5% from the total quay area. On contrary, the soft coral began with high cover (7 m^2) represented 5% of the quay area, increased only during the followed survey at July, 2008 reached 8.5%, then gradually decreased to only 0.7% at January, 2014 before it completely disappeared beginning from January, 2016 to the end of the study (Fig. 11).

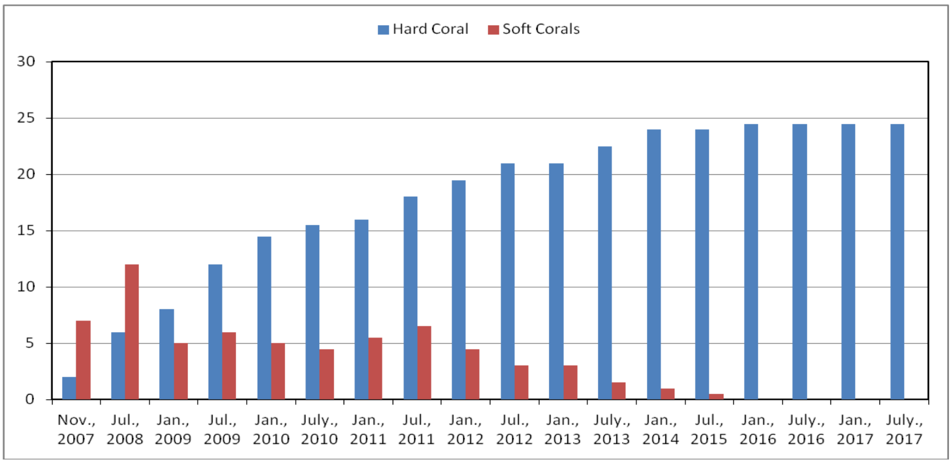

Fig. 11: Succession of hard and soft corals coverage during the period from November, 2007 to July, 2017 at the first quay (area of the quay 140 m^2).

The second quay showed lower percentage cover of hard corals than recorded from the first one and occupied a lower area of the total quay area that reached 188 m^2. At November, 2007 the hard coral area recorded 1.5 m^2, represented by 0.8% of the total quay area, gradually increased during the followed surveys to reach its maximum cover at July, 2015 recorded 15 m^2 with a percentage of 8%, before it decreased again beginning from January, 2016 recorded 5.3% of the quay area and reached its minimum cover beginning from January, 2016 represented 3.2% of the quay area. The soft coral cover at the quay recorded irregular cover, while it recorded a cover of 4.3% at both November, 2007 and July, 2008, it decreased during the followed surveys from 2.1% at January, 2009 to 1.6% at July, 2009, before it increased again during January, 2011 to reach a percentage cover of 4% till January, 2013 with a percentage of 4.9%. Again the study recorded a decrease in area covered by soft corals at the quay beginning from July 2013 (3.9%) and continued till July, 2015 (1.6%) before it completely disappeared beginning from January, 2016 to the end of the study (Fig. 12).

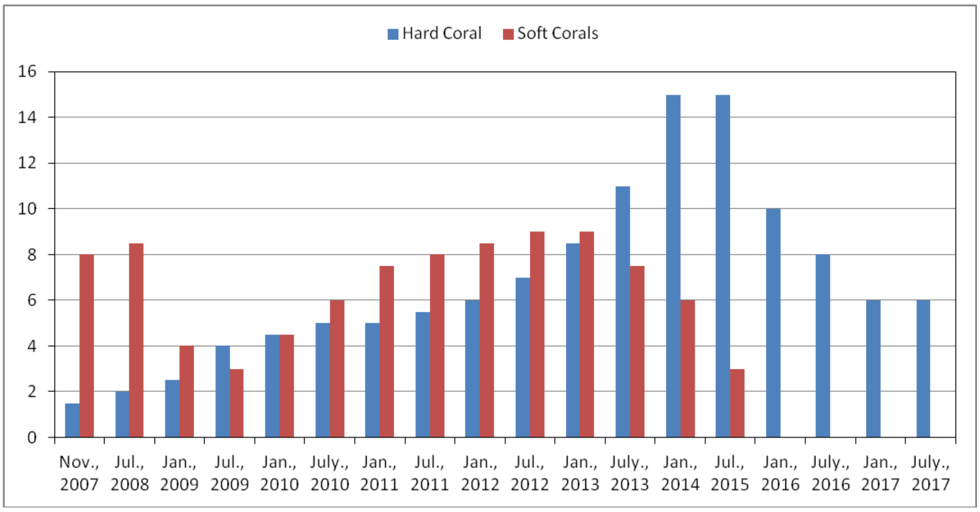

Fig. 12: Succession of hard and soft corals coverage during the period from November, 2007 to July, 2017 at the second quay (area of the quay 188 m^2).

The third quay showed exact the same pattern as the second quay but with lower area covered with corals hard and soft (Fig. 13).

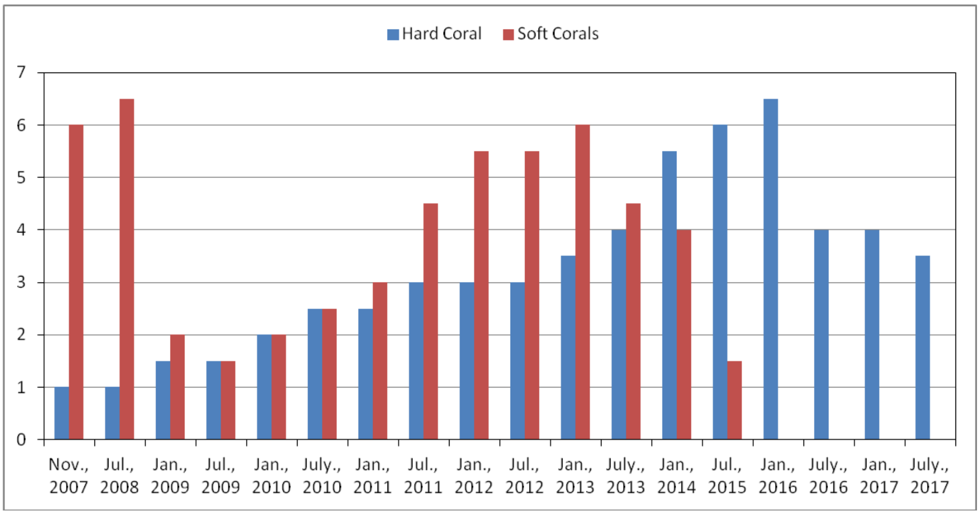

Fig. 13: Succession of hard and soft corals coverage during the period from November, 2007 to July, 2017 at the third quay (area of the quay 148 m^2).

Coral species growth rate

Nine hard coral species were measured for growth rate determination five branched and four massive coral species during the period of study (2007-2017). *Acropora hemperichi* recorded the highest rate of linear extension over the total period of study; the initial branch length was 5.2 cm at November, 2007 reached to 119.6 cm after 10 years at July, 2017. Its mean growth rate was 11.44 $\pm$ 3.1 cm y^{-1}. Followed by *Stylophora pistillata* which increased in length from 4.1 cm at November, 2007 to 79.3 cm at July, 2017. Its mean growth rate was 7.52 cm y^{-1}. On the other hand *Porites solida* showed the lowest growth rate that starts at January, 2011 with radial length of 1.4 cm ended at radial length of 2.1 cm at July, 2017, with radial growth rate of 0.07 cm y^{-1} (Table 3).

Table 3: Growth rate (cm) for different coral species at the period from November, 2007 to July, 2017.

	Jul. 2008	**Jan. 2009**	**Jul. 2009**	**Jan. 2010**	**Jul. 2010**	**Jan. 2011**	**Jul. 2011**	**Jan. 2012**	**Jul. 2012**	**Jan. 2013**	**Jul. 2013**	**Jan. 2014**	**Jul. 2014**	**Jan. 2016**	**Jul. 2016**	**Jan. 2017**	**Jul. 2017**
Stylophora pistillata	5.4	3.4	6.1	5.4	5.7	5.4	7.9	6.7	3.3	3.4	3.4	4.1	3.2	4.1	4.2	2.4	1.1
Acropora hemperichi	3.8	7.2	8.3	8.7	8.6	8.3	7.8	8.5	9.3	6.9	9.7	8	3.9	4.4	3.9	4.1	3
A. humilis	2.1	2.2	3.5	3.4	3.3	4.6	3.6	3.8	4.7	3.4	3.5	4.4	3.8	2.7	3.3	3.1	0.8
A. pharaonsis	2.8	4.7	5.2	5.2	3	2.8	3.2	2.1	1.8	2.9	2.2	4.1	5.3	3.2	2.1	0.9	1.2
Pocillopora venucosa						0.2	0.2	0.4	0.2	0.4	0.2	0.3	0.4	0.4	0.4	0.5	0.1
Favia favus		0	0.1	0.5	0.4	0.5	0.4	0.4	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.1
Favia pallida						0.2	0.4	0.2	0.1	0	0.2	0.1	0.4	0.1	0.1	0	0
Porites solida							0.1	0	0.1	0	0	0.1	0.1	0	0.1	0.2	0
Montasteria annularis		0.6	0.4	0.5	0.3	0.4	0.3	0.4	0.3	0.3	0.4	0.1	0	0.4	0.4	0.1	0

Over the ten years period of study, both linear extension rate per branch for branched corals and radial growth for massive corals showed significant increase with time but with different rates. The coefficient of regression showed that there is significantly increased in length of *Stylophora pistillata* with years by 98% (R^2= 98%), while the remaining 2% attributed to other factors than the time. *Acropora hemperichi* also showed significantly increased in length by the effect of time (98%), while the remain 2% attributed to other factors. The same results were obtained for *A. Humilis*, which showed a significantly increased in length with time by 99% (R^2= 99%), *A. pharaonsis* which showed a significantly increased in length with time by 98% (R^2= 98%), *Pocillopora venucosa* which showed a significantly increased in length with time by 97% (R^2= 97%). Also coefficient of regression for the radial extension of massive coral species showed significant increase as a result of time, but this relation was lower than recorded for the branched coral indicating the growth rate of massive coral species is slower than the branched species. The coefficient of regression showed that there is significantly increased in radial extension of *Favia favus* with years by 87% (R^2=87%), while the remain 13% attributed to other factors than the time. *Favia pallida* also showed significantly increased in growth rate as a result of time (89%), while the remaining 11% was attributed to other factors. The same results were obtained for *Porites solida* which showed a significantly increased in growth with time by 83% (R^2= 83%), *Montasteria annularis* which showed a significant increase in growth with time by 93% (R^2= 93%) while the remaining 7% was attributed to other factors (Table 4 & Fig. 14).

Table 4: Regression coefficients between time and length (growth rate) of different coral species in the studied platforms

Coral	Platform 1	
	β	R^2
Stylophora pistillata	4.68^*	98%
Acropora hemperichi	7.33^*	98%
A. Humilis	3.59^*	99%
A. pharaonsis	3.14^*	98%
Pocillopora venucosa	0.34^*	97%
Favia favus	0.33^*	87%
Favia pallida	0.25^*	89%
Porites solida	0.15^*	83%
Montasteria annularis	0.34^*	93%

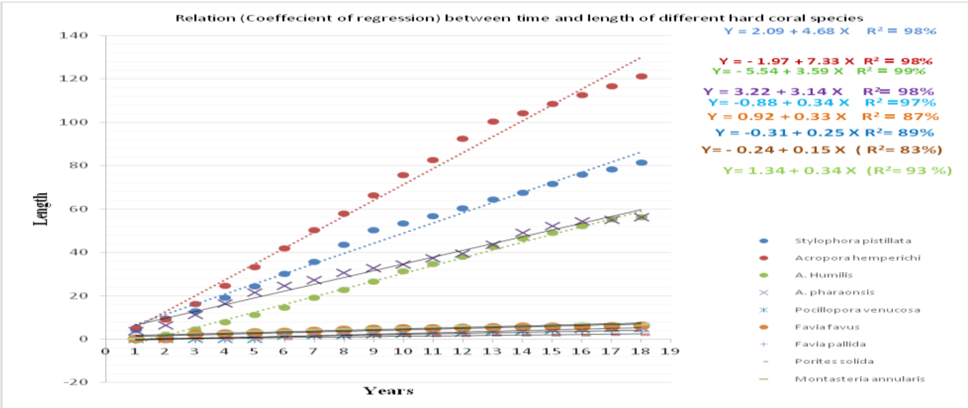

Fig. 14: The regression coeffecient of the growth rate in relation to time for coral specie.

DISCUSSION

In spite of Egyptian coral reefs characterized by astonishing biodiversity and high endemism (Head, 1987), they are at risk from human impacts, about 61% of the corals were greatly affected as was estimated by the World Resources Institute (Bryant et al, 1998). Egyptian Red Sea's live coral cover has been seriously declined over the last two decades (Helmi et al. 2012).

Despite the importance of coral ecosystem, many threats are posing stress on coral reefs. Anthropogenic disturbances caused vast majority of long-term decreases in coral health and cover (Huges, et al. 2003). Human activities have destroyed the coral reef habitats and cause a reduction in coral cover by more than 50 per cent at most reefs (Abdul Razak et al. 2014). If current degradation continues unabated, more than half of the world's coral reefs may be destroyed during the next 30 years (Wilkinson, 2000).

There are aspects of coral biodiversity indicators that can be measured , hard substrates is one of these aspects coral status mainly depends on the availability of hard substrates. The coral larvae settlement depends mainly on the existence of hard substrate that suitable for settlement and subsequently coral growth. The low sedimentation rate (Mohamed, 2003), high light penetration, suitable depth and availability of water exchange that bring nutrients and prevent sediment precipitation on coral colonies is another factors control the existence and well-being of coral species.

Despite the well-known adverse effect of anthropogenic activities, the current case showed one positive effect of these activities. The construction of Taba Heights marina with its three quays provides a hard substrate in the intensive sandy habitat of Taba area. Before the marina constructed, the area was characterized with intensive sandy substrate with seagrass beds, there were no coral species recorded at the area because the location of the area at high latitude (Shippard et al, 1992) and the intensive sandy substrate that is unfavorable for coral existence because sedimentation is dangerous to corals as it ceases coral growth due to decrease in zooxanthellae, which leads to coral tissue lesions (Macintyre, 1988; Rogers, 1990 and Mohammed, 2003).

Taba Heights marina began to operate at mid-nineties and granted an International Tourist marina license in July 2005. The establishment of hard construction (concrete quays) at the area provided a suitable substrate for coral settlement and hence the coral communities' succession began. During more than 10 years that represented the period of study from Nov., 2007 to Jul., 2017, the coral showed an increase in cover and diversity at the quays. The construction of the marina creates a hard substrate at the area and subsequently coral existence began at the quays. The succession began at first with high cover of soft corals, gradually, with the time pass the soft corals decreased and the hard corals existed and increase in cover and diversity at the expense of soft coral. In spite of the soft corals began their existence with 3 species at November, 2007 till July, 2013, it recorded an obvious decrease in percentage cover during this period. Whereas the diversity decreased to two species at January, 2014 and only one species at July, 2014, finally it disappeared completely beginning from January, 2016. On contrary, hard coral began their existence at November, 2007 with very low percentage cover of three species and gradually increase not only in percentage cover but also in diversity to reach 6 species at January, 2009 and continue to increase to reach its maximum diversity recorded 9 species beginning from January, 2011. Whatever, the soft corals are considered as a major space competitors for the hard coral forms and may cause necrosis due to the expulsion of zooxanthellae and prevention of larval settlement (Coll, 1992), eventually the hard coral mange to establish and compete the soft coral at the quays.

The pioneer community began at July, 2007 and represented by 3 soft coral species that recorded a high percentage cover. The soft coral species are opportunistic species that grow rapidly (Fabricius, 1995), and tolerate harsh environmental conditions. Soft corals have a wide and better adaptive to the different specific conditions of light and location on the reef (Borneman, 2001), they have diverse locations and forms covering most shallow water areas with low flat, fingered and encrusting growth forms (Sammarco and Coll, 1987) depending on the large supplemental feedings of the deteriorate water or deleterious effects (Delbeek and Sprung, 1994) and depends on the Bacterio-plankton as food not on zooplankton (Kinsey, 1991). All these factors caused the soft corals to exist first and have high percentage cover as a characteristic species for pioneer stage of succession at the quays. Also during the same period recorded a very low percentage cover of 3 hard coral species *Acropora Pharaonis*, *A. hemperichi* and *Stylophora pistillata*. Acroporid corals are important components of patch reefs. The success of these species in penetrating habitats with extreme environmental conditions is largely due to their rapid growth (Sheppard et al, 1992).

The data collected from the three quays at the marina revealed a different pattern of succession, whereas at the first quay there was a strong and fast succession expressed by a high coral building situation represented by fast increasing in percentage cover and diversity of hard coral accompanied with decreasing in the percentage cover of soft coral. Comparing the coral diversity at the three quays, we recorded nine hard corals and 3 soft corals species at the first quay, while only 3 hard coral species were recorded from the second and third quays. In quays 2 and 3, the shallow depth, which ranged between 1 to 2 m at high tide decreased to 0.2 to 1.1 m in low neap tide leads to the reduction of coral cover and diversity, this explained by the combination between light temperature and solar radiation at the shallow depths especially during the low water at neap tide. There is a relation between coral stresses as bleaching and the combination of high temperature and direct solar radiation stress during the neap tide seasonally (Moustafa et al, 2008). The same conclusion was reached by many other authors as Brown et al. (1996), Brown (1997) and Winter et al. (1998). Climatic and hydrographic conditions (tides, high temperature, direct exposure to solar radiation and human activities such as fishing and aquatic sports) are factors control coral existence and cover (Perks, 2002 and Mohammed 2003). The proximity of second and third quays from the shore increase the sedimentation and algal growth risk, which affect and reduced the coral fauna in these two quays. Sedimentation and increasing algal cover play an important role in coral growth, survival, abundance and degradation (Lapointe et al, 1997). The first quay is far from the shore and facing the entrance of the marina, which create a favorable conditions for coral existence. The current regime inside the marina that the water enter from the Gulf of Aqaba to the mouth of the marina passing the first quay (Hasan, 2014), create a favorable conditions for coral existence at this quay as caused low sedimentation as the sediments washed out by the water movement and high nutrient supply, which is essential for zooxanthellae photosynthesis that provide food for hard coral species.

The growth rate of coral species during the period from 2007 to 2017 were measured for nine hard coral species recorded from the first quay. The data recorded difference in growth rate from species to species due to the different behavior, physiology of the species and tolerability to prevailing environmental condition. *Acropora hemperichi* recorded the fastest growth rate with the highest length it began with 5.2 cm in length at November, 2007 ended with length 119.6 cm at July, 2017. Its growth rate was the highest among the investigated species ranged between 1.1 to 2.1 $cm.month^{-1}$ till January 2014, and the growth rate decreased to 0.3 to 0.7 $cm.month^{-1}$ till July, 2017. The unbranched coral species recorded much lower growth rate ranged between 0.016 to 0.1 $cm.month^{-1}$. The highest growth rate recorded for *Acropora hemperichi* could be explained due to the fact that Acroporid corals are important components of patch reefs. The success of these species in penetrating habitats with extreme environmental conditions is largely due to their rapid growth (Sheppard, et al. 1992). Also the low growth rate of massive corals due to their high sensitivity for environmental conditions.

The coral species at higher latitudes as in the study site that is Taba city, at the most northern tip of the Gulf of Aqaba may suffer from reduced growth rates, lower ability to compete with algae, lower reproductive variability and higher rates of mortality. The effect of site location was obvious on the growth rates of coral species, while a decline was recorded in *Porites lobata* growth rate with increasing latitude at Hawaiian Archipelago (Grigg, 1981; 1982), an inverse relationship between latitude and growth rate for *Pocillopora damicornis* and *Acropora sp.* (Stimson, 1996). On the other hand, Smith (1981) reported that the growth of porites sp. was not depressed at a high latitude site, while changes in the environmental parameters (temperature, salinity, substrate and turbidity) can influence not only growth rate (Crabbe and Smith, 2005) but also abundance and diversity of corals (Lirman, et al, 2003). Environmental conditions is the most important factors that affect the coral growth (Oliver et al, 1983).

The present study showed a high growth rate of corals at both linear growth rate for branched corals and redial growth rate for massive corals, the higher growth rate recorded is attributed to the low sedimentation rate, which fluctuated between 0.2 to 1.9 $mg{\cdot}cm^{-2}.day^{-1}$ (Hasan, 2014). Due to Rogers (1990), the area not subjected to any sedimentation, he stated that the areas recorded sedimentation rate below 7 $mg{\cdot}cm^{-2}.day^{-1}$ consider not subjected to any sedimentation. The other reason for the higher growth rate recorded at the study site is the absence of competition for space as the quay was free of any organisms and a plenty of space on the hard substrate is found, thus the growth wasn't controlled by competition and as a pioneer community according to population ecology concept the population growth of coral species recorded from the study site is density-independent as the quays are first colonized with coral species.

As time passed the species diversity and percentage cover increased the coral ecosystem on the quays heading towards late stages of succession, in this respect the population becomes more crowded, it approaches the quays carrying capacity, thus forcing individuals to compete more heavily for fewer available resources. Under crowded conditions the population experiences density-dependent forces of natural selection called *K*-selectin and the growth rate.decreased from January, 2014 to July, 2017. And as the area is untouched by catastrophic events, detrimental human activities, or other unusual occurrences, the coral ecosystem remain relatively stable as recorded from the study site.

Acropoa sp. may be the most rapidly growing coral in the world in terms of linear extension (Gladfelter et al, 1978). The growth rate compared with number of studies on different species from different localities *Acropora cervicornis* recorded a linear growth of 2.5 $cm.y^{-1}$ at site with high sedimentation rate and 10.95 $cm.y^{-1}$ at less impacted reefs (Crabbe and carlin, 2007).

The same species recorded linear extension of 26.4 $cm.y^{-1}$ in Jamaica reefs (Gladfelter et al, 1978). *Acropora sp* had the greatest mean linear extension (16.62 $mm.month^{-1}$) at Australia (Anderson et al, 2012). Harriott (1999) quantified summertime growth rates of 0.46 mm/month for *A. cytherea* and 0.80 mm/month for *A. valida* at the Solitary Islands,Australia. Whereas the current study recorded a higher growth rate of *Acropora*, that ranged between 11 to 17.5 $cm.y^{-1}$ for *Acropora hemperichi*, 6.9 to 7.9 $cm.y^{-1}$ for *A. humilis* and from 10.1 to 9.4 $cm.y^{-1}$ for *A. pharaonsis*. During the current study *Pocillopora venucosa* recorded linear extension ranged between 0.4 to 0.8 $cm.y^{-1}$, this data is lower than the data obtained by Anderson et al (2012) at Australia who recorded a linear growth of 2.15 $mm.month^{-1}$ and they concluded that *Pocillopora* is the slowest growing coral species, and the data obtained from Rottnest Island, Western Australia (0.75-1.25mm $month^{-1}$) (Ward, 1995).

The radial growth of massive corals showed a much lower growth rate, for instance, *Montasteria annularis* recorded growth ranged between 0.7 to 0.1 $cm.y^{-1}$, this is much lower growth rate than recorded from tropical areas that being 6.55 $cm.y^{-1}$(Weber and White, 1977).

The statistical analysis showed a significant in Regression coefficients between time and % cover and between time and growth rate (length). The analysis revealed that there is a significant increase in the percentage cover of hard coral (1.24*) with time by 88%, on contrary at the same time a significant decrease of soft coral (-0.54*) by 80% with time. These data indicated that hard coral replaced oft corals with time as succession goes further.

Generally, it could conclude that the marina enriched the marine environment of the site by providing a hard substrate favorite for many organisms, especially corals, thus increase the diversity and richness of the site. As International marina has a very good control on the boats using it, no pollution was realized in the area inside or outside the marina, which reduce any impact on the coral species.

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