A PRELIMINARY STUDY OF ALGAL SETTLEMENT POTENTIAL AROUND SHALLOW WATER REEFS AT HURGHADA COAST-RED SEA USING ARTIFICIAL SUBSTRATUM.

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Abstract

The current work was designed to evaluate the role of algal settlement on the available substrate around the coral reef as a preliminary step towards the successive coral settlement in a reef area. The potential of algal settlement around the reef at Hurghada area was measured using glass microscopic slides as artificial substrate. The glass slides were mounted in groups of 10 slides each at five sites. The slides were placed in two groups representing the inner protected reef and the outer exposed one. The slides were collected and examined at 1, 3 and 6 months after installation. The results showed that number of algae species as well as small invertebrates tend to colonize the available space during the first month of installation. The number and intensity of the majority of these species was declined during the course of this study leaving only the slide to be dominated by two encrusting calcareous algae. The results also indicated that the rate of settlement was much lower in the outer reef slides than the inner reef slides, where the slides were almost completely covered with encrusting calcareous algae within 6 months. The statistical analysis of the data also showed significant differences between the localities in their potential of settlement. However, these differences are significantly affected by the time allowed and the site where the substrate is available. The results showed that the area around Hurghada have a high potential for coral settlement if we can create more suitable spaces and allowing the natural course of events to take place.

Introduction

Hurghada is one of the coastal cities which exposed to fast growing unsustainable development during the last decade. The devastating results of this development was obvious in losing about 3000,000 m^2 of its coral reef in one of the largest land filling operation in the History of the Red Sea (GEF, 1998). Such loss of coral reef habitat stopped by the issuing of the environmental law (4/1994), however, the recovery of the reef was not occurring specially in the coastal area despite the fact that substrate was available. The question evolves in such case is do substrate present suitable for coral growth naturally?

It is well known that there a series of events occurred within the coral reef habitat prior to coral settlement and colonization. These events is normally involved a succession process which stepwise changing the pare clean substrate that can not support coral reef to a rigged surface ready to receive the coral larvae (Schuhmacher, 1977). Among the most contributors to this system are the micro

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and macro-algae. Algae especially crustose coralline algae are integral component of the biota of coral reefs. They represent one of the most important frame builders in Cenozoic tropical and sub tropical coral reefs (Kauffman and Fagerstrom 1993).

Odum and Odum (1955) showed that algae are major component of the reef biomass. Where, the smaller turf algae which carpet large areas of the substrate in-between coral colonies play an important role from primary productivity point of view. The role of crustose algae in contributing to the reef as been identified by many authors (Bosence, 1976; Montaggioni, 1979; Bosence, 1985; Freiwald, 1993; Filler and Rasser, 1993; and 1996). This role was known as substrate builder in addition to inducing materials recognized by larvae of a wide variety of marine invertebrate taxa.

The aim of the present work is to evaluate the settlement potential of algae around the coral reef areas at Hurghada applying a simple technique for collecting the data. The study also aims to assess the rate in which crustose algae covers the available substrate which will increase the possibility of coral larval settlement in the Hurghada abused reef areas.

Materials and Methods

The study was carried out in the coastal fringing reefs around Hurghada area during the period 2001-2002. Five sites were selected for the study representing parts of the old fringing reefs. These sites were Marine Institute, Public beach 3, Sheraton. Paradise Hotel, and Oberoi hotel. At each of the selected sites two locations were selected to represent the protected inner reef and the exposed outer reef. The locations of the study sites are indicated in the map Figure (la).

At each of the selected sites 10 Glass microscope slides (0.1 x 2.5 x 7.5 cm) fixed to aluminum holder were used as the artificial substratum because of their chemical inertness. The slides were washed, slightly etched with Hydrofluoric acid vapor and rewashed before being mounted in the aluminum holders using Silicon rubber (Figure 2a). Holding two rows of 5 slides, the holder was tied to living coral branches (usually Pocillopora or Acropora spp.) so that the flat surfaces of the slides were at right angles to the water surface and about 10 cm from the nearest "natural" substrate (Figure 2 B & C). The holders were placed almost at the same depth at five consecutive days at the sites indicated in Figure (1 B & F).

After collection, the slides were immediately preserved in 10% formaldehyde in seawater. In the laboratory t he s tides were examined under a light microscope (Olympus CH40) and the biota was separated into two major groups. The first group included the sessile or those fixed to the substrate. While the second group included the motile forms (mainly animals). Taxa were identify to the nearest taxonomical categories according to Vine (1986). Also the space occupied by algal material was measured and analyzed as percentage of the slide area using (Image- Pro-Plus) computer image analysis soft ware.

Topography of the studied Area

The five selected sites were chosen to represent the different types of reef profiles around Hurghada area. The data in Figure (1, A-F) showed the general location map and the corresponding cross sections of each site.

Site (1) Marine Institute represents a perfect micro-atoll located near the seaward extremity of the lagoon, which is approximately 5-7 m deep in this region. The micro-atoll is about 50 m in diameter and its central pool is about 75 cm deep. Slides were placed at the inside and outside of the micro-atoll approximately 1 m below the reef crest (Figure 1B).

Public Beach 3 (Site, 2) represents a semi exposed fringing reef followed by a wide lagoon leading to outer reef where the depth ranged from 3-7 meters. The slides were placed at 1 meter below the reef edge at inner and outer reefs (Figure 1C).

Sheraton (Site, 3) represents a typical sandy rocky beach leading to a relatively gentle sloping with the reef edge appear at depth 1-2 meters below sea level at 100 meters distance from shore. The slides were fixed at 1 meter depth in the inner and outer edges of the reef (Figure 1 D).

Paradise Hotel (Site, 4) is very close in nature to the previous site except that the rocky beach extended seaward forming a platform to a depth of 2-3 meters where the slope began. The slides at this site were fixed at the bottom of the platform and at the outer edge of the reef slope (Figure 1E).

The fifth selected site was at Oberoi Hotel which represents a typical Red Sea fringing reef with extended reef flat followed by a crest leading to reef wall 6-8 meters high. At the base of the wall area is dominated by sand with few scattered coral batches in front of the reef wall. The slides were fixed in the middle of the reef wall and at the coral batch at depth from 3 meters (Figure 1 F).

Results and Discussion

Over a considerable period of time. glass slides have been used successfully in other studies of marine and freshwater algal communities (Sladeckova, 1962; Littler and Doty, 1975; and Borowitzka *et al*., 1978). The algal coverage of the slides was examined during the study period. The examination of the biota composition showed t hat the three major divisions o f algae w ere p resent o n t he s tide surface. Division Rhodophyta represented by 6 species belonging to 6 genera. Those species were namely *Ceramium rubrum* (Huds.) Ag.; *Hypnea cornuta* (Kutzing) J.Agardh; *Herposiphonia tenella* (Ag.) Nag., *Polysiphonia figariana*, Zanard.; calcareous algae *Lithophyllum Kotschyanum* Unger and *Sporolithon ptychoides* Heydrich. Division Chlorophyta was found to be represented in the slide surface by 2 taxa *Cladophoropsis* zollingen (Kutz.) Boergs and *Enteromorpha flexusa* (Wulf) J,Ag. Division Bacillariophyta represented by only one species belonging to genus *Meiosira* Table (1). Among the branches of the algae several species of animals were found using these algae as shelter and food. These animals included crustacean larvae, bivalves spat, small gastropods, small polycheata, foraminifera, amphipoda juveniles and animals eggs (Table 1 and Plate 1). The communities on the glass slides differed in some aspects from those observed on nearby "natural" substrate some "rare" species were absent from the slides Borowitzka *et al*. (1978). The same results were observed during this study where only few species were recorded on the slide. The most probable cause for this is the small surface area of the slides and their relatively homogeneous surface morphology.

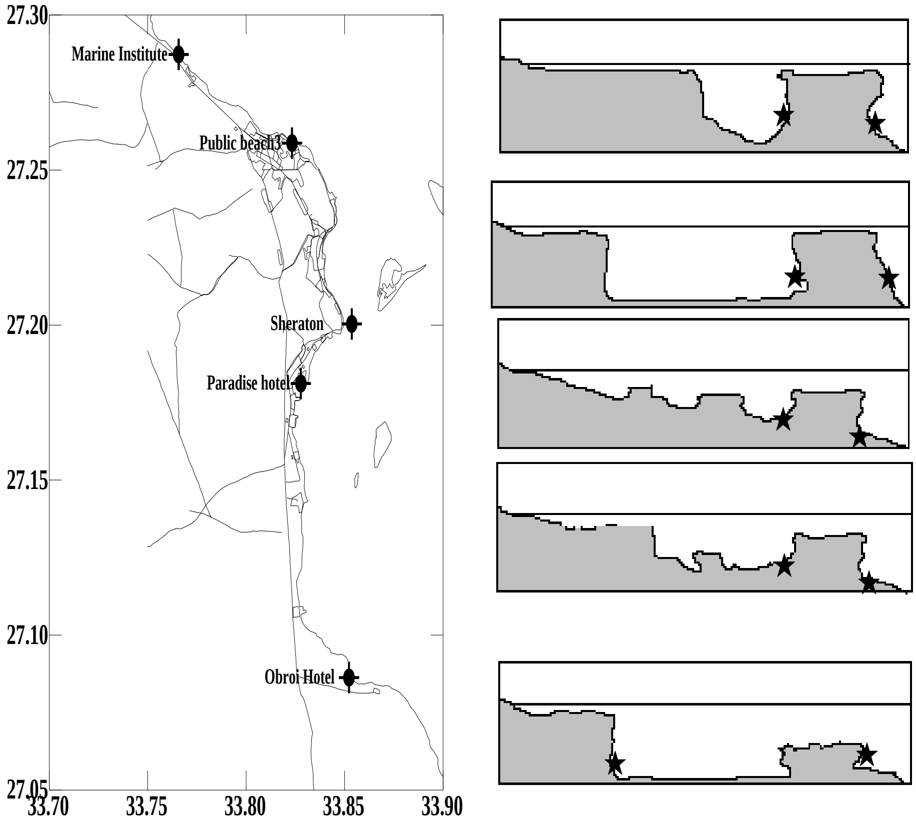

Figure1 (A-F): Map of the Hurgada area showing location and cross-sections at the 5 sites used in the current experiment. (Stars indicating the slides position).

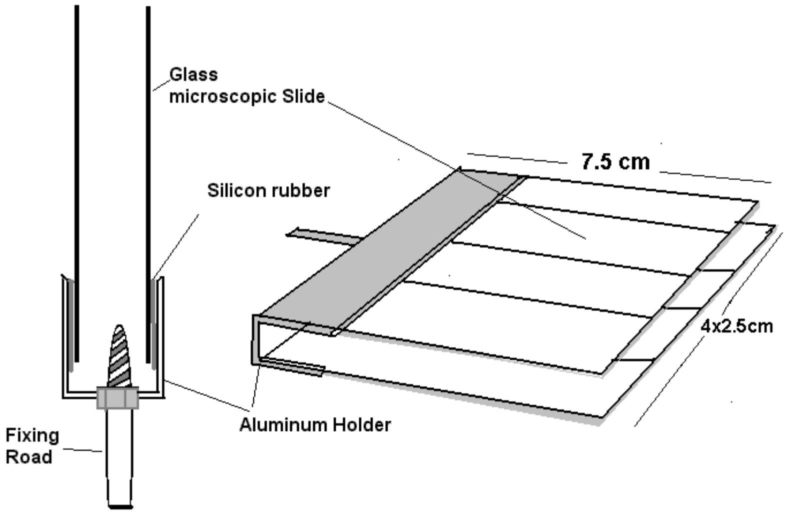

Figure (2 A): Diagram showing the slide holding mechanism.

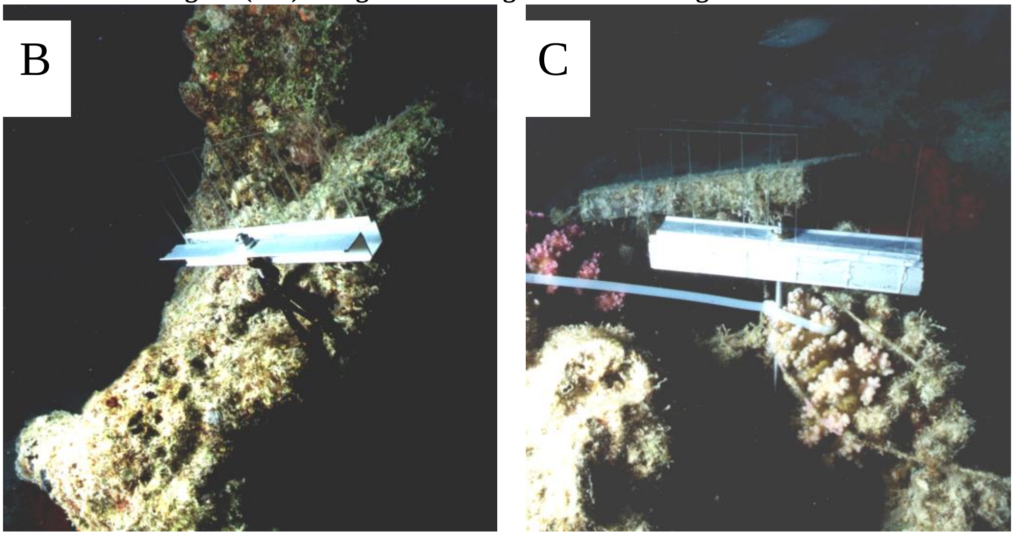

Figure (2 B &C): The slides mounted to the aluminum holders at the start of the experiment under water.

Also, the data in table (1) showed that most of the abundant taxa occupied the slides during the first month after installation tends to be reduced in abundance and/or disappear three months later. This was true for most of the species except for the calcareous algae where their intensity increases with time to reach the maximum at six months period in which the slide surface is almost covered with them. This observation was in conformity with the conclusion reached by Littler and Doty (1975) and Adey and Vassar (1975) found that encrusting coralline algae were the predominant colonizers of the empty spaces in the tropical reef areas.

River and Edmunds (2001) described in details the mechanism in which algae react with corals reef. This mechanism including the covering of the empty spaces with small turf algae for preparation of substrate, this soon encourage the animals grazing in the area leaving a rigged surface for more persistent coralline algae which also supply carbonate source as well as chemical attraction for the coral larvae. Meanwhile, the sequence in which the alga as well as animal materials appear in the slide seems to follow the natural pattern of colonization in coral areas as described by Abelson and Denny (1997) and Figueiredo (1997). Also the same growth sequence occurred on artificial plates placed on the Gulf of Aqaba, Red Sea (Schuhmacher, 1977 & 1988). This finding is in agreement with the present data concerning animal groups, where some of them migrate from the slide specially the motile ones including crustaceans, polycheates and eggs after hatching. For the sessile forms such as bivalve spats and foraminifera the calcareous algae covered them in most cases.

Also, algal colonization on the slide was studied by using computer program which measured and analyzed the dark space (area covered with calcareous algae) and the light space (empty or no algal growth) on the slide as percentage area. The data in table (2) showed that for the outer reef the area occupied on the slides surfaces ranged between 22.55 ± 0.66 to 58.16 ± 0.18 %, with an average of 37.87 ±12.60% during the first month. By the end of the third months the average percentage coverage was 51.80 ± 16.79 % for the five studied sites and the data ranged between 24.77 ± 0.45 to 74.65 ± 0.70%. On the other hand, after six months from installation the slides surfaces coverage ranged between 61.40 ± 0.89 to 89.18 ± 0.37 % with an average of 79.20 ± 9.72 % Plate (2).While, for the inner reef the percentage coverage were significantly higher where the average in the first month was 74.66 ± 6.77% and the data ranged from 62.90 ± 2.18 to 81.07 ± 0.12 %. After 3 months of installation and with the increases in crustose algae the average of the slides surfaces coverage were 89.69 ± 3.33 % and the data ranged from 85.45 ± 0.67 to 95.08 ± 0.22 %. Meanwhile, the data collected after 6 months from installation showed that the average coverage of the slides surfaces were 93.75 ±2.13 % with data ranged from 89.78 ± 0.38 to 95.41 ± 0.64% Plate (3). From the previous data it is clearly verify that the inner reef was more suitable and higher in algal settlement than the outer reef this may be attributed to the protection of the inner reef from wave action.

Table (1) The biotic composition found on the slide surface at different intervals during the period and their relative abundance.

Species (taxa)	***Months***		
	one	***three***	***six***
Ceramium rubrum (Huds.) Ag.	++	+	-
Hypnea cornuta (Kutz) J.Ag.	+++	+	-
Herposiphonia tenella (Ag.) Nag.	+	-	-
Poiysiphonia figahana Zanard	++	+	-
Lithophyllum Kotschyanum Unger	+	++	+++
Sporolithon ptychoides Heydrich.	++	++	+++
Cladophoropsis zoilingeri (Kutz.) Boergs.	-	+	-
Enteromorpha flexusa (Wulf) J.Ag.	+	-	-
Mefosira sp.	+++	+	-
Polycheates	+	+	-
Bivalve spats	++	+	+
Crustacean larvae	++	-	-
Amphipoda juveniles	++	+	-
Foraminifera	-	+	-
Animal eggs	+	-	-

+ = rare : ++ = common, +++ == Abundant.

On the other hand, the results of statistical analysis (ANOVA) (Table, 3) showed that there were highly significant differences between the amounts of calcareous algal growth, represented by the dark coverage, in the selected sites at outer and inner reefs (Plate 2 and Plate 3),with general trend of increasing toward the southern sites.

The distribution of algal growth on the surfaces of the slides indicated that filamentous algae located more or less on the middle and calcareous ones mainly growing near the edges (see Plates 2 and 3). In accordance with this observation North (1971); Foster (1975); Mullineaux (1988) and Morse (1990) they found that the previous type of algal distribution caused by different grazing pressure near the edges comparing with center of flat areas. As well as, the water movement over the edges. Ogata, (1953); Adey and Vassar, (1975) stated that coralline algal spores settles better o roughened surface than on the smooth ones. The same observations were also reported by Filler and Rasser (1993) and Roberts *et al*., (2002).

However, the study of the data representing the monthly rate of change in the percentage coverage of the slide surface (Table, 4) it was clear that the rate of change was different significantly between the two examined zones. For the outer reef zone, three sites showed increase in rate of coverage during the period from the third to the six months, while two showed reduction in rate. On the other hand, all sites showed reduction in the monthly rate of coverage during the same period in the inner reef zone.

Table (2) Percentage coverage of slide surface by Algal material in the five sites during the study period. (Data expressed as Average percentage + SD).

Months	Outer Reef					
	Site 1	Site 2	Site 3	Site 4	Site 5	Mean ± SD
One	22.6±0.7	28.6±0.6	34.9±1.7	45.1±0.1	58.2±0.2	37.9±12.6
Three	44.3±0.5	24.8±0.5	53.6±0.7	74.6±0.7	61.7±0.8	51.8±16.8
Six	61.4±0.9	80.4±0.7	86.6±0.1	89.1±0.3	78.4±0.4	79.2±9.7
Inner Reef						
One	71.3±0.4	79.6±0.5	81.1±0.1	62.9±2.2	78.5±0.5	74.7±6.8
Three	87.5±0.7	91.4±0.7	95.1±0.2	85.5±0.7	89.1±0.3	89.7±3.3
Six	95.4±0.6	89.8±0.4	93.3±1.0	95.3±0.9	94.9±0.3	93.8±2.1

Table (3) Results of two ways analysis of variance (ANOVA) statistical analysis for the coverage data collected from 5 different sites at two zones during the study period.

Source of variation	DF	MS	F	P
Site	4	642.91	1166.8	> 0.001
Months	2	6849.5	12431.02	> 0.001
Zone	1	19909.7	36133.8	> 0.001
Site X Months	8	175.3	318.15	> 0.001
Site X Zone	4	798.95	1450.02	> 0.001
Zone X Months	2	1300.6	2360.55	> 0.001
Site X Months X Zone	8	222.7	404.17	> 0.001
Error	60	0.551		
Total	89			

DF= Degree of Freedom; MS= Mean Square; P= Probability

The sequence recorded in the current study started with filamentous forms and ended with crustose coralline algal domination of the slide surface will most probably play a role in coral larvae settlement as suggested by Morse *et al.*, (1994) where they found that certain chemicals in the crustose coralline algae attract the coral larvae to settle and metamorphose. Also, with the development in analytical methods several algal produced materials were found to represent chemosensory recognition of unique substrata sufficient to induce settlement, metamorphosis and recruitment in the natural environment (Chia, 1978; Crisp, 1984; Morse *et al.*, 1988; Jensen and Morse, 1990; Hadfield and Pennington, 1990; Pawlik. 1990; Morse, 1992; Raimondi and Schmitt, 1992; and Morse *et al.*, 1994).

Plate (2) The Glass slide removed from the holder at outer reef sites after 1 month (1-5), three months (6-10) and six months (11-15).

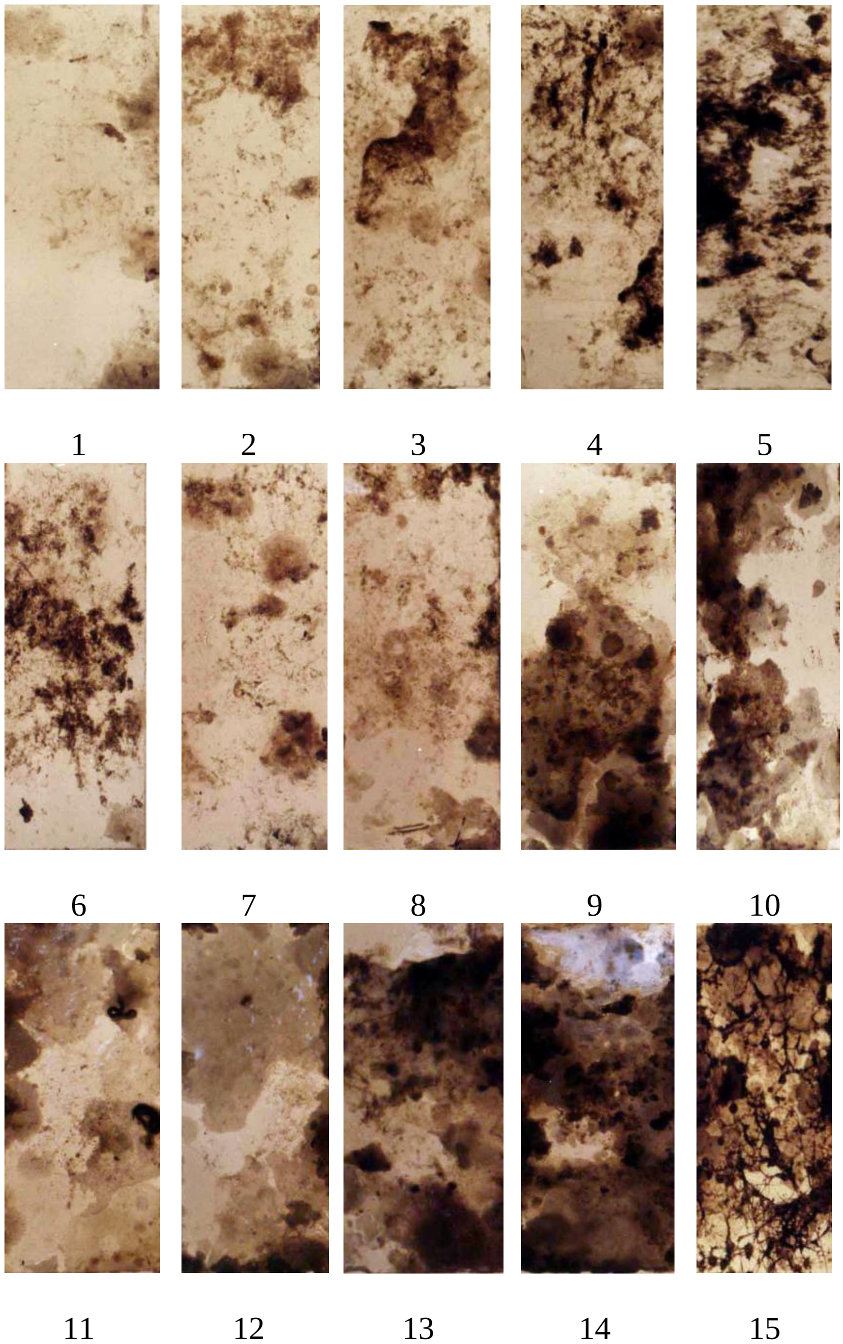

Plate (3) The Glass slide removed from the holder at inner reef sites after 1 month (1-5), three months (6-10) and six months (11-15).

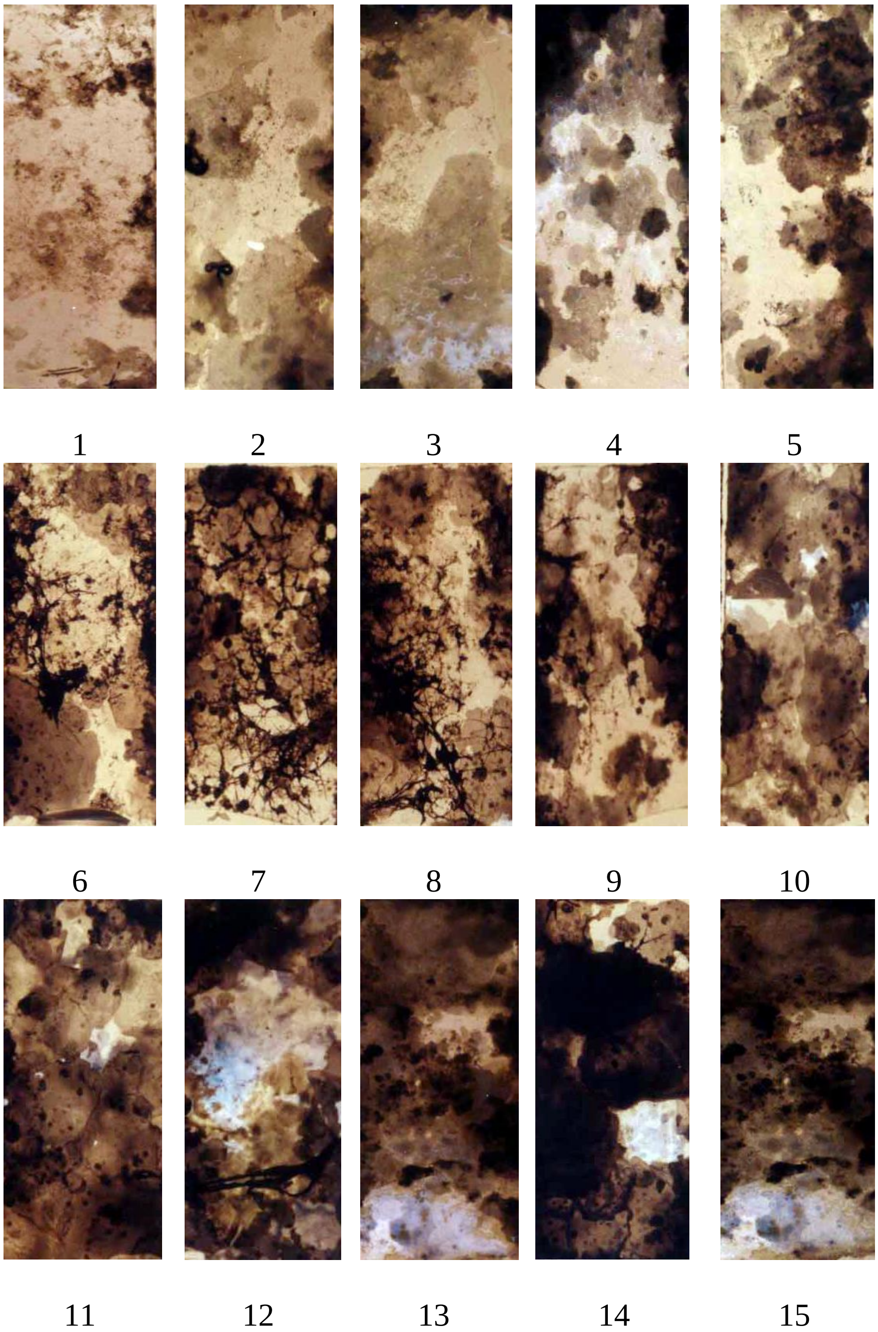

Table (4) The monthly rate of change in algal percentage coverage on the slide surface at the two different zones within the selected localities around Hurghada.

Site	Zone			
	Outer reef		Inner Reef	
	1-3 months	3-6 months	1-3 months	3-6 months
Marine institute	7.25	5.70	5.38	2.65
Public Beach 3	1.27	18.56	3.96	0.55
Sheraton	6.23	10.98	4.67	0.59
Paradise Hotel	9.84	4.84	7.52	3.29
Oberoi Hotel	1.17	5.58	3.53	1.96

Recently, and with the global recognition of the importance of coral reef rehabilitation using artificial substrate several environmental cues included those induced by red algae were recognized to play an important role in the process of coral settlement (Veron, 2000; Mendes & Woodley, 2002 and Ball *et al*., 2002).

In general, glass microscope slides used in the current study proved to be a useful artificial substrate in the study of coral reef algal turf communities. Their major drawback appears to be the hardness of the surface, a feature not commonly found on limestone reefs. This hardness appears to favor crustose coralline algal growth over that of other algae. Many algae could not successfully colonize the slides until their surface had been covered by the coralline algae. Also, the rate of occupation of the available substrate by coralline algae tested in these five areas around Hurghada demonstrated that the area could be rehabilitated if the suitable substrate was available. As well as, on the current rates the preparation of the substrate using the natural sequence will almost take a year and then it will be ready for coral settlement. The same results were recorded by Schumacher (1988); Morse and Morse (1991); Morse *et al*., (1994) and Mendes and Woodley (2002) who suggested that the presence of such crustose coralline algae will help in rehabilitation of the reefs. It seems fair to conclude that, the use of artificial substrate seems to be necessary if detailed manipulative studies of benthic algae on coral reefs are to be carried out.

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دراسه مبدئية لأمكانيه استيطان الطحالب على الأسطح الاصطناعيه بالمناطق الضحله حول الشعاب المرجانيه لمنطقه الغردقة بساحل البحر الأحمر.

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تهدف هذه الدراسه الى تقيم مقدرة استيطان الطحالب على اسطح اصطناعيه حول الشعاب المرجانيه بمنطق الغردقة بساحل البحر الأحمر، مما يعتبر خطوة مبدئية فى طريق استيطان الشعاب الموجودة بالمنطقة. وقد تم قياس مقدرة استيطان الشعاب من خلال أستخدام مجموعات من الشرائح الزجاجية (10 شرائح زجاجية) تم تثبيتها فى خمسة مواقع مختلفه حول منطقه الغردقه. قسمت الشرائح الزجاجية الى مجموعتين رئيسيتين تمثل أحداهما الجزء المحمى من ظهر الشعاب بينما تمثل الأخرى المنطقه المعرضه فى الجزء الأمامى للشعاب. تم تجميع الشرائح وفحصها معمليا بعد شهر، ثلاثه وسته اشهر من تاريخ التثبيت. أوضحت الدراسه نمومجموعه من الطحالب الخيطيه وبعض اللافقاريات الصغيره على السطح الخارجى للشرائح خلال الشهر الأول من التثبيت. كما كشفت الدراسه عن تناقص كثافه الطحالب الخيطيه خلال فترة الدراسة حيث تم استبدالها بنوعين من الطحالب الكلسيه المنبطحه والتى شرعت فى تغطيه السطح الخارجى لشريحه بدءا من الحافه الخارجيه باتجاه الداخل حتى تم كساء الشريحه بأكملها بهذه الطحالب فى غضون الستة أشهر. ويجدر بالذكر هنا أن معدل استيطان الطحالب بالشرائح الممثلة للجزء الأمامى من الشعاب كان أقل من المعدل الخاص بتلك الممثلة للجزء المحمى من الشعاب. أبرز التحليل الأحصائي للنتائج وجود فروق معنويه فى معدل استيطان الطحالب بين المحطات موضع الدراسه وأن الكثافه الطحلبيه تزداد كلما اتجهنا جنوبا. كما بينت الدراسه ان هناك اختلاف ظاهرا داخل المحطه الواحده، فالمناطق المحميه اكثر كثافه طحلبيه من المناطق المعرضه بالجزء الأمامى للشعاب. وبهذا أثبتت النتائج أن المنطقه حول الغردقه تعانى فقط من نقص المساحه المتاحه لتكوين البيئه الملائمه لنمو الشعاب المرجانيه.