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REPRODUCTION AND GROWTH RATE OF TWO SCLERACTINIAN CORAL SPECIES IN THE NORTHERN RED SEA, EGYPT

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ABSTRACT

During the present study three sites were chosen to study reproduction and growth of two dominant coral species, *Acropora humilis* and *Stylophora pistillata*. The gonad development was followed to determine the breeding season in their localities at Hurghada. Their growth rate in the same localities was also studied. Both species are hermaphrodite but the male gonads take shorter time to develop and to release gametes. The polyp number of ova is about 5 in both species for each sex. Breeding occurs in winter months and releasing of gametes in April for *Acropora humilis* and planula releasing is during spring. Planula larva was detected inside *Stylophora* but not in *Acropora*. Growth rate reached the maximum in summer and the least in winter. Higher annual growth rate for *Acropora* (7.5 mm) was recorded at Abu Qalawa, while the highest rate for *Stylophora* (6.68 mm) was recorded at Gotta El-Erg. On the other hand, water currents affect the thickness of *Stylophora pistillata* branches while in case of *Acropora humilis* not affected.

1. INTRODUCTION

The corals of the Red Sea represent the northern part of the subtropical region and considered widely distributed and healthy. They are found off the west of the Red Sea especially along side of the Egyptian Coast (Dar, 2002). *Acropora* and *Stylophora* form the most abundant corals in the Red Sea (Sheppard and Sheppard, 1991). They are branching tree-like and their polyps are small but some of them grow fast (Barnes, 1980). Marshall and Stephenson (1933) claimed that examining the coral gonads periodically could approach the breeding season. Rinkevich and Loya (1979a) studied the reproduction of *Stylophora pistillata* in Aqaba Gulf and reported that, the egg development starts in July preceding the spermaria, which start to develop only in October. The egg fertilization may occur internally to produce larvae by breeding or externally by releasing gametes to produce larvae (Richmond and Hunter, 1990). Tanner (1996) concluded that the seasonal variation in reproduction is related to change in water temperature and the optimum temperature was 26-27ºC at Heron Island in the Great Barrier Reef.

Growth rate of most coral reefs of the branching forms affected by the change in temperature (Dunbar and Wellington, 1981; Kotb, 1996 & 2001), however, the optimum range for coral growth is ranged between 25 and 29°C (Vine, 1986). Muscatine *et al.* (1985), on the other hand, found that growth rate of *Stylophora pistillata* reached 0.013 mm/day at Aqaba Gulf. Later, Kotb (1996) found it in the southern region of the Gulf ranging from 0.017 to 0.025 mm/day, and 0.008-0.025 mm/day for *Acropora formosa.* The aim of the present work is to study the main histological features of the two abundant corals *A. humilis* and *S. pistillata* by following the gonadic changes throughout the year in an attempt to recognize the breeding season of the two species at Hurghada. The other aim is to estimate their growth rate to compare the results with those obtained in other coral regions.

2. MATERIALS AND METHODS

The area of study is located in front of the Marine Biological Station (MBS) of the National Institute of Oceanography and Fisheries (NIOF), about 5 Km north to Hurghada (Fig. 1). The reefs in the vicinity of Hurghada occur along roughly parallel ridges oriented from SSE to NNW (Hodgson, 1983). The first site is Gotta El-Erg at 27°17`N and 33° 46`E. The second site is Abu-Qalawa at 27° 18` N and 33° 48`E; Just outside Abu shar bay, north of shab El-Fanadir. The third site is El- Fanadir which lies at 27° 17` N, and 33° 50` E (Fig. 2). The study began from September 1999 to October 2001. The three sites are Gotta El Erg, Abu Qalawa and El-Fanadir. At the three sites and at 5 m below the sea surface (i.e. at similar light intensity approximately) monthly samples were collected from two branches of each 5 colonies belonging to each of the two species at each of selected site. About 360 coral branches from each studied species were sampled throughout the whole study period from all stations to study the breeding season and gonads formation. Fixation was found best in 6% formalin. The method of decalcification by Rinkevich and Loya (1979a) was adapted to study the histological structure and gonadic changes in the two corals. Sections of 8μm thick were stained by Haematoxylin and Eosin.

For the growth rate, five colonies of each of *A. humilis* and *S. pistillata* were chosen and marked at each site at 5 m depth. Five branches from each colony were tagged by plastic string about 1.5-2.0 cm apart from the tip of the branch. The increase of the branch length and diameter was determined seasonally (every 3 successive months). Some physico-chemical parameters were measured at the place of sampling.

3. RESULTS

Temperature, pH and salinity were nearly similar in the three locations. The ranges were; temperature from 18.1 ºC in January to 28.8 ºC in August, pH from 8.62 to 8.85 and salinity from 39.1 ppt. to 40.95 ppt. and dissolved oxygen from 4.4 mg/l to 6.29 mg/l.

3.1. Polyp structure and reproduction

Acropora humilis and *Stylophora pistillata* have a similar description and structure with the exception of some differences in the origin. Where, in *A. humilis*, polyp is elevated outside the branch (Figure 3a), while in *S. pistillata*, the polyp is immersed inside the branch (Figure 5a) except the anterior portion of the oral disc which protruded externally. Both of the two species have a cylinderical shape with a mouth opening on the oral disc leading to a tube called actinopharynx, which ended by enterostome followed by coelenteron (entron). The present mesenteries are of the primary (perfect) type. They are derived from the body towards the actinopharynx and united with the coelenteron forming mesenterial chambers. Numbers of mesenteries are 6 pairs without presence of mesenterial filaments in both species. Moreover, the posterior portion of mesenteries is not joined and floated into the body cavity. The gonads are found on the mesenteries. The general histological structure of both species shows a similar structure of the gastric portion, tentacles, nematocysts, mucous gland, body wall, actinopharyngeal wall, mesenteries, body cavity and gonad position. The difference between them is in their thickness, where *A. humilis* is thicker than *S. pistillata*. On the other hand, gonads are extent into the half of *S. pistillata* tentacles while *A. humilis* not extend.

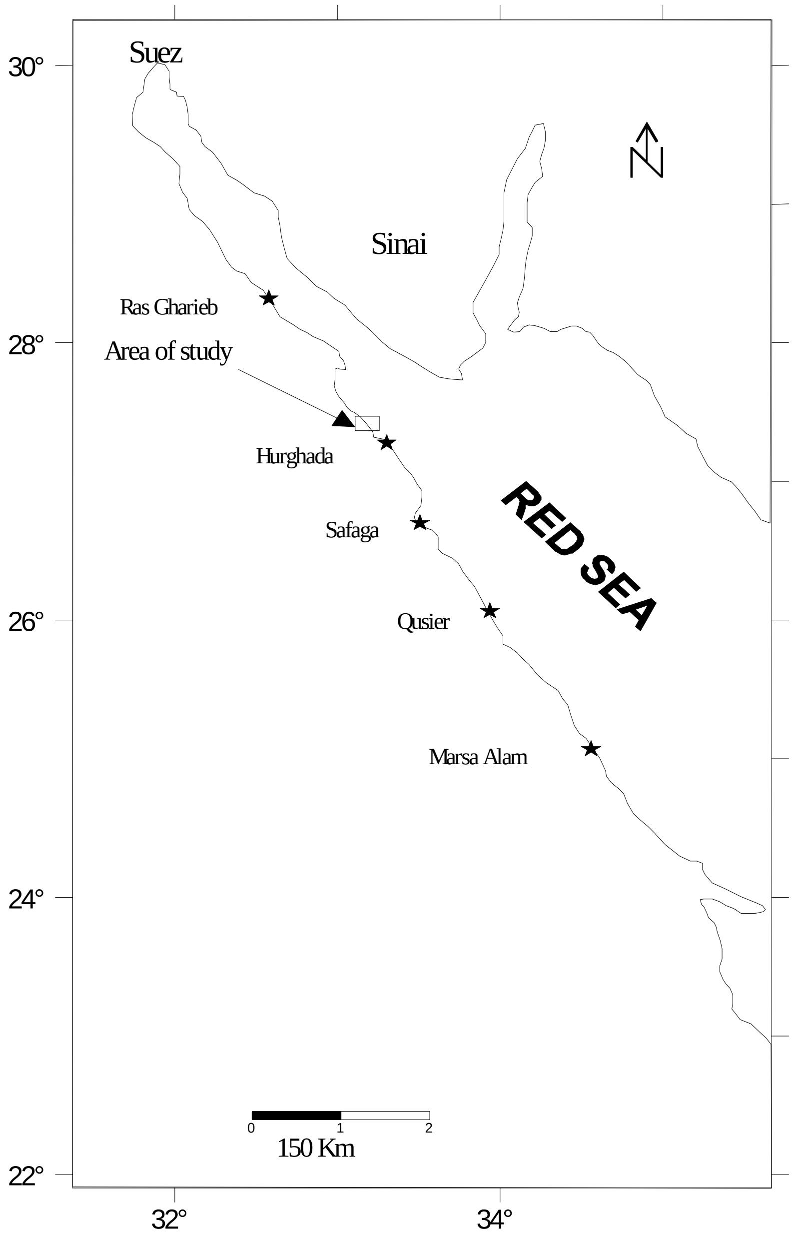


Figure (1): The Egyptian coast of the Red Sea

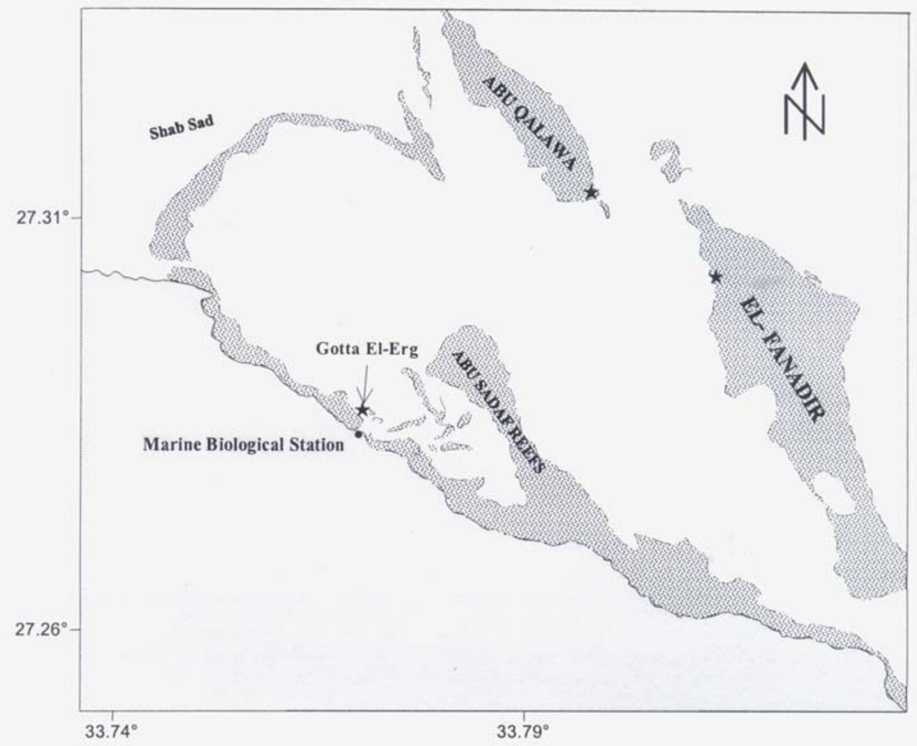
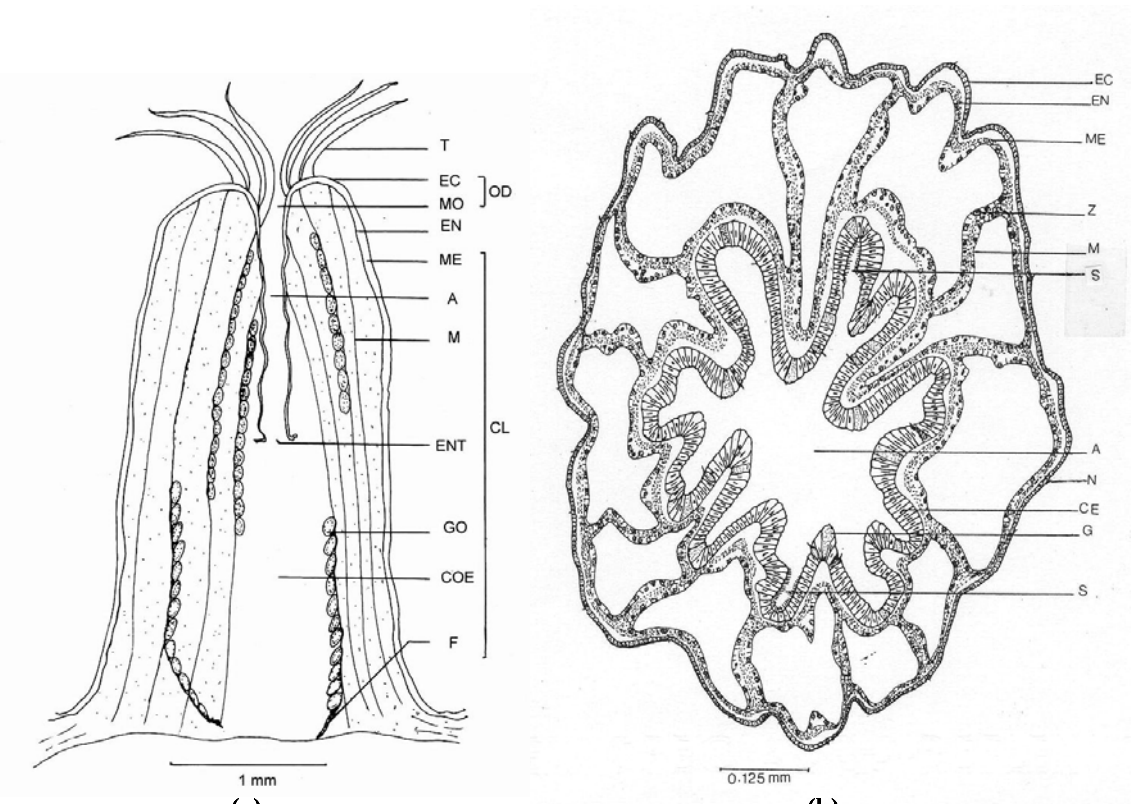
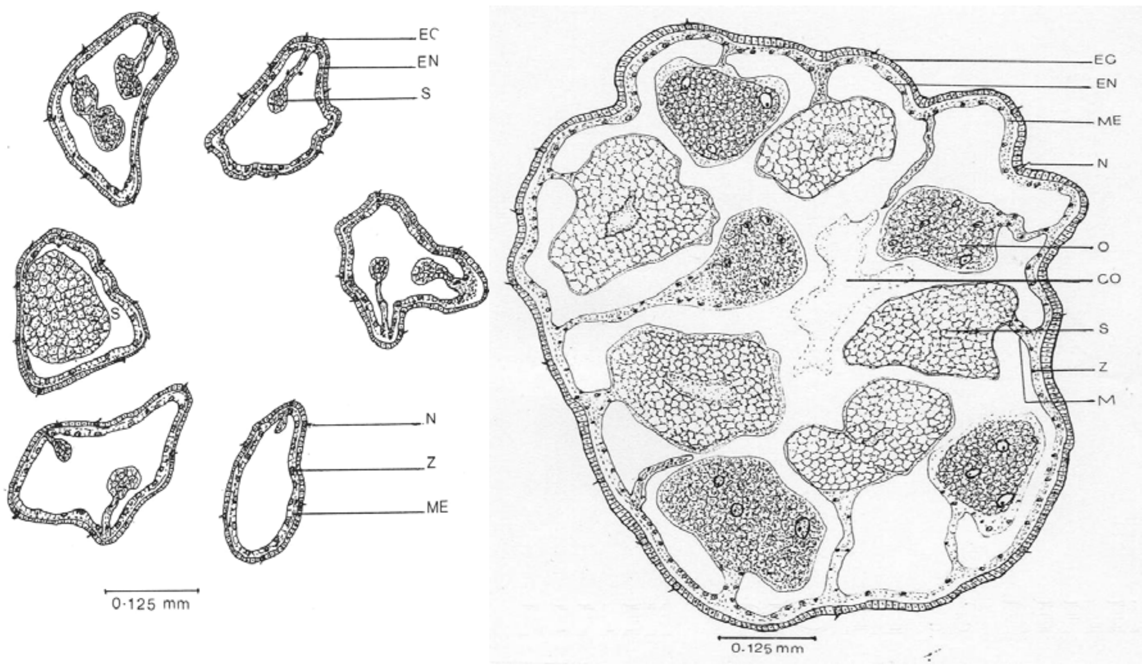


Figure (2): Positions of the three studied sites El-Fanadir, Abu-Qalawa and Gotta El-Erg at Hurghada reefs



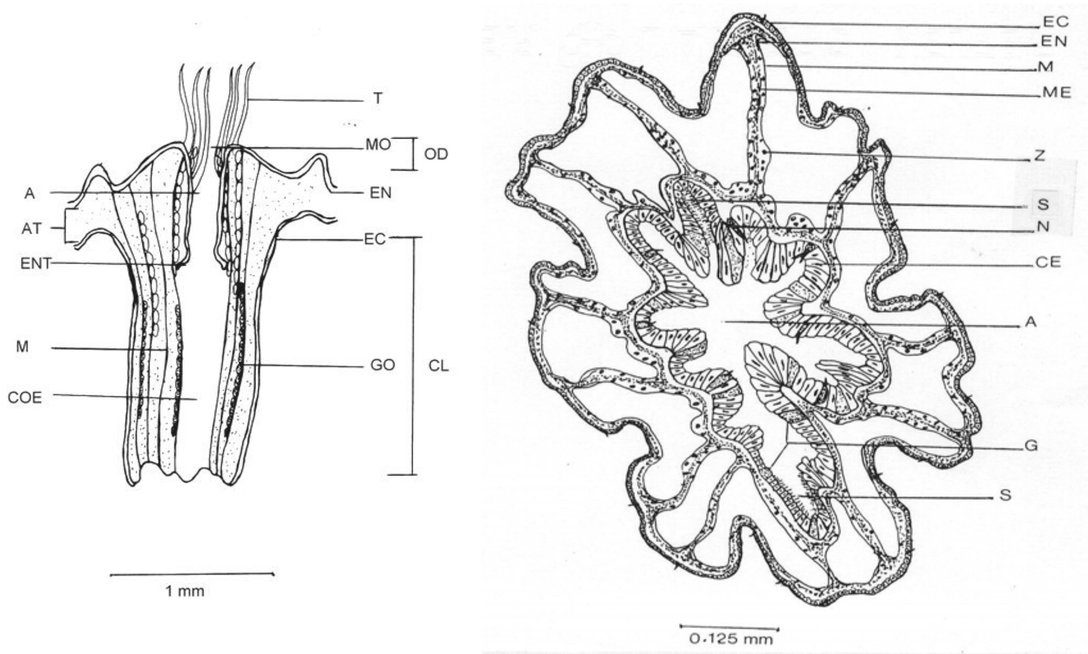
(a) **(b)**

Fig. (3): A. humilis; (a) diagram showing the general shape and structure of the polyp and (b) a general histological structure (T.S.) of the polyp in the stomodael portion. A., actinopharynx; AT, attachment part of another polyp; CE., columnar epithelial cells; CL., column; COE., coelenteron; EC., ectoderm; EN., endoderm; ENT., enterostome; F., filament-like structure; G., glandular cell; GO., gonads; M., mesentery; ME., mesogloea; MO., mouth; N., nematocyst; OD., oral disc; S., siphonoglyph; T., tentacle; Z., zooxanthella.



(a) ***(b)***

Figure (4): *A. humilis*: (a) transversal section in the base of tentacles to show the extension of gonads on upper portion of mesenteries and (b) a transverse section of the lower part of a mature hermaphrodite polyp showing the developing gonads filling all the cavities. CO., coelenteron; EC., ectoderm; EN endoderm; G., gland cell; M., mesentery; ME., mesogloea; N., nematocyst; O., female gonads; S., male gonad; Z., zooxanthella.



(a) **(b)**

Figure (5): *S. pistillata*: (a) General diagram showing the shape and some internal structures of a polyp and (b) Cross section showing the histological structure of the polyp. A., actinopharynx; AT., attachment part of another polyp; CE., epithelial cells; CL., column; COE., coelenteron or gastrovascular cavity; EC., ectoderm; EN., endoderm; ENT., enterostome; G., glandular cell; GO., gonads; ME., mesogloea; M., mesentery; MO., mouth region; N., nematocyst; OD., oral disc; S., siphonoglyph; T., tentacle.: Z., zooxanthella.

3.2. *A. humilis*

Polyp base diameter range was 1.23-2.17 mm and that of its length was 4.4-4.9 mm. Six tiny yellow to green tentacles surround the mouth. It possesses two siphonoglyphs and 5 paired perfect mesenteries (Fig. 3b). Gonads are globular and extend anterior into the mesenteries and not more the tentacles base (Figure 4a and b). *A. humilis* is hermaphrodite but male gonads were thicker 450-600 µm while the female gonads were 180-245 µm. The male developed in winter (January/February) when the polyp was about 2.37 mm thick. It was not possible to detect the process of shedding.

Female gonads developed before those of male, from October to April and gametes were observed in all cavities of the polyps, but concentrated in the lower parts of the mesenteries (Fig. 4b). In each mature polyp there were 4-5 gonads of each sex and the numbers of ova formed were 4-8 for each polyp. The male gonad (spermaria), by successive development, gives rise to the gonads containing spermatids and spermatocysts. Which increase in size by more divisions and filled up with spermatogonia, finally they became densely packed with sperms. The oocytes were formed from primordial female cells, where each young female gonad contained 4-8 oocytes. Only one or two large oocytes may remain in each female gonad because most of the oocytes were disappearing during their growth. Each oocyte has a spherical, ovoid or sometimes less regular shape. An oval nucleus was found in the oocyte and situated nearly in the center of the immature egg, but after maturation it was found in the periphery of the egg. The eggs become elongated and their membrane disintegrates and disappears gradually where it apparently becomes ready for fertilization. No planula larva was detected inside the polyp, which suggests that fertilization may be happened externally. After April the release of both male and female gametes was accomplished and polyps become empty in the subsequent months.

3.3. *S. pistillata*

The base diameter of the polyp is smaller than that of *A. humilis* and it ranged from 0.61 to 1.1 mm (Figure 5a). Its length reached 2.2 mm and its colour changed from dark brown, purple, brownish and yellow to pale pink. Similar to *A. humilis,* six tentacles and 6 perfect pair of mesenteries are present (Fig. 5b). This species is also hermaphrodite and five gonads of each sex were found extending along the whole mesentery (Fig. 6a) and penetrate into the middle portion of tentacles approximately (Fig. 6b). Male gonads developed from October to December while the female developed from July to December and the mature oocyte ranged between 195-225 µm in diameter. Fertilization takes place internally, where, many planula larvae were observed during several sections of the polyp (Fig. 7 and 8) during the breading months (March to June). Planula larva was detected inside the sections of polyps collected from March to June, which seemingly represent the breeding season. Presence of larva inside polyp indicated that fertilization is internal. The planula appeared made of two ciliated layers of cells, a less organized gastrodermis, and a thin mesogloea.

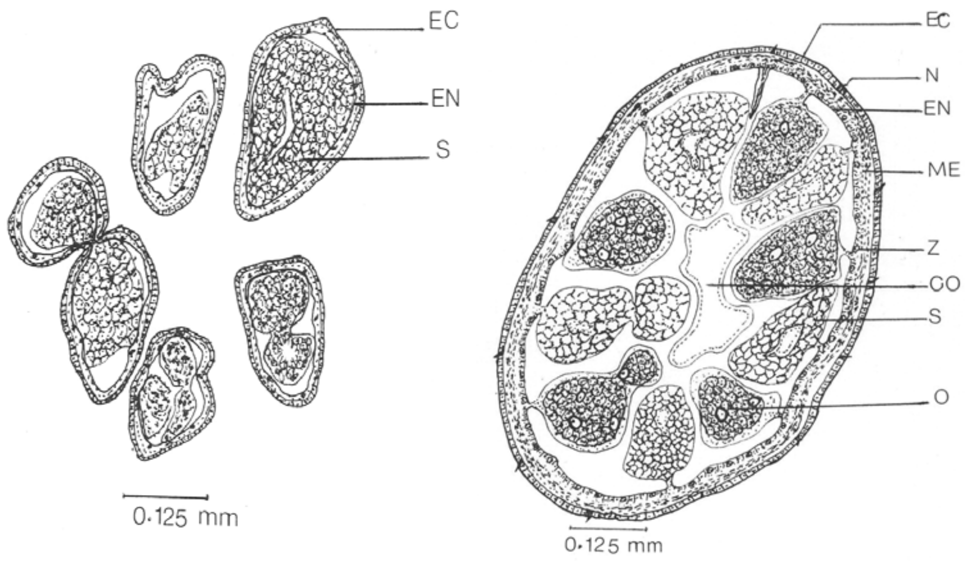


Figure (6): ***S. pistlliata*: (a) T. S. in the middle part of the hollow tentacles to show the penetration of gonad cells and (b) Lower part of a hermaphrodite polyp showing the developing gonads filling all the cavities of the polyp. CO., coelenteron (gastrovascular cavity); EC., ectoderm; EN endoderm; ME., mesogloea; N., nematocyst; O., female gonad; S., male gonad; Z., zooxanthella.**

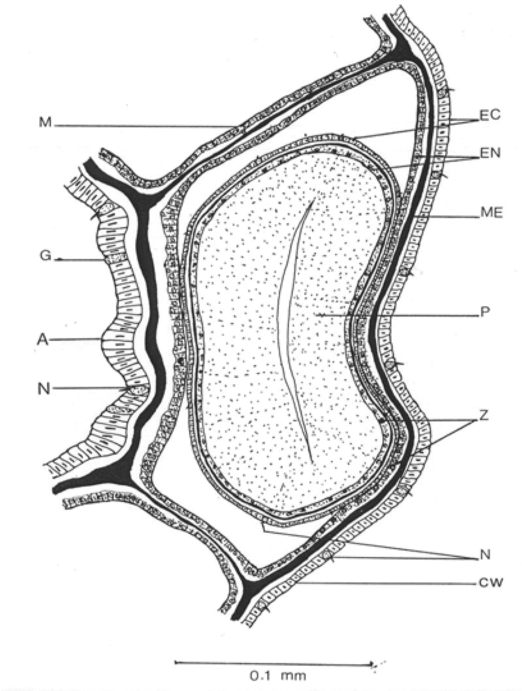


Fig. (7): *S. pistlliata*. Appearance of planula larva inside the inter-mesenterial chamber of polyp. A., actinopharynx; CW., column wall; EC., ectoderm; EN endoderm; M., mesentery; ME., mesogloea; N., nematocyst; P., planula larva; Z., zooxanthella.

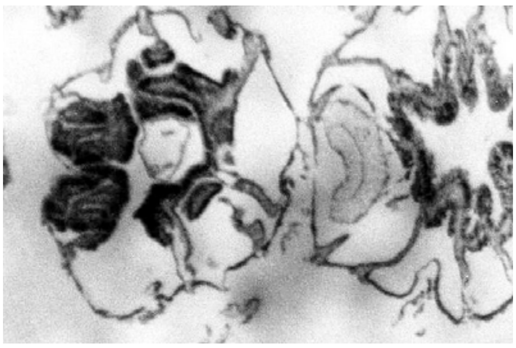


Fig. (8): The appearance of gonads and a part of planula larvae in the transverse section of *S. pistlliata*

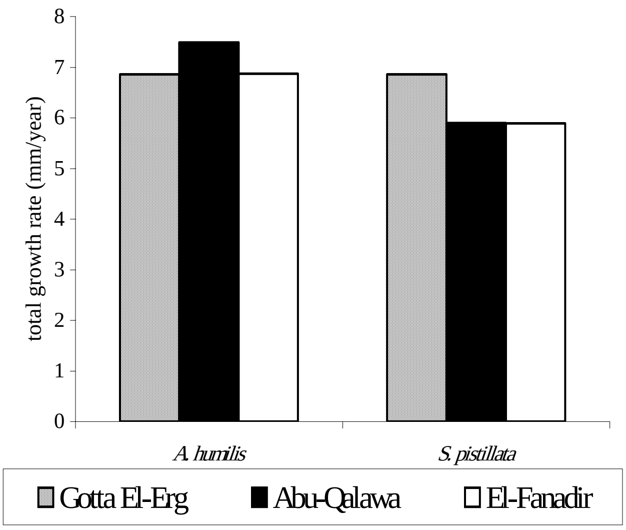


Fig. (9): The annual growth rate (mm/year) for acropora humilis and Stylophora pistillata at the study sites.

3.4. Growth rate

Obviously the growth rates of both *A. humilis* and *S. pistillata* reached its maximum values during summer months, and the contrary occurred in winter. Table (1) shows clearly that the growth rate can be arranged for both species in the four seasons follows: Summer> Spring> Autumn> Winter. The values per season for *Acropora* are 2.04, 1.97, 1.59 and 1.44 mm respectively. While they are for *Stylophora*; 1.7, 1.65, 1.46 and 1.38 mm respectively. These values pointed to the increase of the growth rate of *Acropora* compared to that of *Stylophora*.

Cumulatively the growth rate during the whole year (Fig. 9) reached the highest value at Abu Qalawa for *Acropora* (7.45 mm) while at both Gotta El-Erg and El-Fanadir the growth rate was nearly the same. In case of *Stylophora* the growth was promoted more at Gotta El-Erg and reached 6.86 mm while it was nearly the same at the other two sites. Growth rate per day ranged between 0.024 mm for *A. humilis* in summer at Abu Qalawa and 0.014 mm for *S. pistillata* at the same site in winter (Table 1) and it followed the trend of the annual growth rate for both species.

Corals diameter are approximately similar for *A. humilis* (Table 2) at the different localities and ranged between 10.6 and 14.5 mm (at El-Fanadir), between 9.30 and 14.20 mm (at Abu-Qalawa) and between 9.60 and 13.70 mm (at Gotta El-Erg). On the other hand, a big difference was obtained for *S. pistillata* between the sheltered and exposed stations. At Gotta El-Erg the branches diameter were much lower than those of Abu-Qalawa and El-Fanadir. At El-Fanadir the diameter ranged between 8.80 and 14.90mm and between 8.90 and 13.50 mm at Abu-Qalawa; while at Gotta El-Erg it ranged between 5.70 and 7.50 mm.

Table (1): The means of daily growth (mm/day), seasonally growth (mm/season) and annual growth (mm/year) rates of the studied coral species.

Sites		Gotta El-Erg	Abu-Qalawa	El-Fanadir	Gotta El-Erg	Abu-Qalawa	El-Fanadir
Species		*A. humilis*			*S. pistillata*		
Spring	mm/season	2.04	2.04	1.84	1.85	1.57	1.54
	mm/day	0.0227	0.0224	0.0204	0.0205	0.0173	0.0171
Summer	mm/ season	1.98	2.13	2.02	1.80	1.68	1.66
	mm/day	0.0220	0.0236	0.0224	0.0200	0.0187	0.0183
Autumn	mm/season	1.44	1.82	1.52	1.67	1.38	1.35
	mm/day	0.0160	0.0200	0.0168	0.0186	0.0151	0.0149
Winter	mm/season	1.34	1.50	1.49	1.54	1.27	1.34
	mm/day	0.0149	0.0166	0.0164	0.0167	0.0140	0.0145
Annual growth rate mm/year		6.86	7.49	6.87	6.86	5.90	5.89

Table (2): The variation between the branch diameters (mm) in the different sites

Site	Species	branch1	branch2	branch3	branch4	branch5	Average
El-Fanadir	*A. humilis*	11.30	14.50	12.50	12.30	10.60	12.24
Abu-Qalawa		10.90	14.20	12.10	9.70	9.30	11.24
Gotta El-Erg		13.70	9.60	11.00	10.50	11.00	11.16
El-Fanadir	*S. pistillata*	11.00	9.33	14.90	11.50	8.80	11.11
Abu-Qalawa		10.00	13.50	12.10	8.90	10.80	11.06
Gotta El-Erg		5.90	7.50	7.00	5.70	7.50	6.72

4. DISCUSSION

Although *A. humilis* and *S. pistillata* belong to two different families; Acroporidae and Pocilloporidae, their growth and histological structures are similar in many details. The numbers of tentacles, mesenteries and siphonoglyphs are the same in both forms which points to the consistent structure of the coral polyps in general presence of gonads on the mesenteries is also a common feature in these animals (Rinkevich and Loya, 1979a). However, maturation period was slightly different in the two species, female gonads of *Stylophora pistillata* needs 6 months to be mature (July-December) and the female gonads of *Acropora* becomes mature in colder 5 months (October-February).

The male gonads maturation happens in shorter period in both species; *A. humilis* male gonads matured in two months (January – February) and the male gonads of *S. pistillata* matured in 3 months (Oct.- Dec.). Similarly, it is probably common among corals to form ova before sperms (Duerden, 1902 and Rinkevich and Loya, 1979a & b). This also confirmed in the present work. Surprisingly, despite the presence of six pairs of gonads, extending along the mesenteries the gametes appeared few and only about 5 ova were produced by each polyp. *Montipora* and *Porites* similarly produce few eggs, but much larger number of eggs are formed by *Pavona* and *Pocillopora* (Stimson, 1976 and Rinkevich and Loya, 1979a). This decrease in fecundity may be in contrast to the overwhelming spread of the two studied species in Hurghada. Rinkevich and Loya (1979a & b) mentioned that the species with small sized polyps produce fewer eggs than those with large polyps such as *Favia*. Apparently the tiny polyps, present in spreading corals, produce few ova, while others are large polyps, present in less spreading corals, produce greater number of ova. It is thus a more or less an ecological compensation state. Moreover, a comparison of egg sizes illustrates, the branching coral forms produces small sized eggs compared with the massive and encrusting forms (Table 3). Planula larva has not been detected in the polyp of *A. humilis*, which means that it is a spawning species as indicated by Schlesinger and Loya (1985). It differs from *S. pistillata*, which is a brooder species because the planula was detected in the latter coral, which is also considered as such by Richmond and Hunter (1990).

Evidently temperature influences the growth rate of corals, particularly in the Red Sea (Sheppard and Sheppard, 1991 and El Samman, 2000). At Hurghada, the growth of both *A. humilis* and *S. pistillata* is promoted in summer, while it is almost crippled in winter. One may suggest the growth may be detained in winter due to the devotion of a large part of metabolism to reproduction rather than to growth. Table (4) shows the values of growth rate of some corals in different parts of the world including Hurghada. It seems that, these values are limited. The difference between corals growth rate in different localities may be mainly due to local changes such as water motion and depth. This may explain why the growth rate of *A. humilis* at the site Abu Qalawa is higher than that at Gotta El-Erg, which is more protected and characterized by slow water, motion. Tunnicliffe (1983) reported that, the species of the Acroporidae family generally have high linear extension rates compared with the other scleractinian corals. This meets the illustrated results of the present investigation in which *A. humilis* recorded higher growth rate than *S. pistillata.*

Water circulation and currents play a vital role in the branch and polyp thickness. In the present studied localities, *A. humilis* shows no vital variation in the branch diameters relative to the hydrodynamic conditions of the investigated sites. The average diameters of the branches recorded in the exposed sites (El-Fanadir and Abu Qalawa) to the hard wave action and water movements are varying between 12.24 and 11.24 mm, while in the sheltered site (Gotta El-Erg), this average is about 11.16 mm. While, *S. pistillata* is highly affected by the variations in the hydrodynamic conditions in the different sites. However, in the sheltered sites, the branch diameters appear thinner than those in the exposed sites. The recorded data is completely agreed with those reported by Jokiel (1978) who argued that, the main structure of the coral colony is helping the coral branches to survive during the strong currents. He added that, the branch thickness is related to the local hydrodynamic conditions (intensive wave action and water movements.

Table (3): Comparison between some recorded egg diameters of different species and that of the present study.

Coral species	Coral form	Egg diameter (μm)	Reference	Location
Favia doreyensis	Massive	374		
Lobophyllia sp.	Massive	350	Marshall and Stephensone (1933)	Great Barrier Reef
Symphyllia recta	Massive	335		
Montipora sp.	Encrusting	280		
Porites lobata	Massive	120		
Porites copressa	Branching	120	Stimsom 1976	Caribbean Sea
Pocillopora damicornis	Branching	30		
Pocillopora meandrina	Branching	30		
Pocillopora meandrina	Branching	100	Grigg 1976	Caribbean Sea
Stylophora pistillata	Branching	230	Rinkevich and Loya 1979 a	Gulf of Aqaba (Red Sea)
Acropora humilis	Branching	180-245	The present study	Hurghada
S. pistillata	Branching	195-225	The present study	(Red Sea)

Table (4): A comparison of the growth rate of some corals using different methods.

Locality	Depth (m)	Growth rate mm/y	Species	Method	Author
Caribbean Sea	4–11	3.6– 28.8	*A. formosa*	Linear growth and real time field	Buddemeier & Kinzei (1976)
Caribbean Sea	2	2 – 13.3	*A. humilis*	Linear growth by Alizarin- Red	Davies (1989)
Southeastern coast of Sinai	5	8.59	*S. pistillata*	Linear growth by Alizarin- Red	Kotb (1996)
peninsula.		6.05	*A. granulosa*		
Northern Red Sea	5	9.24	*S. pistillata*	Linear growth by Alizarin- Red	Kotb (2001)
		6.336	*A. granulosa*		
Hurghada	5	3-7	*A. humilis*	Transplanting	Ammar *et al.* (2000)
		3-5	*S. pistillata*		
Hurghada	5	6.83 - 7.42	*A. humilis*	Linear growth and	The present study
		5.89 - 6.86	*S. pistillata*	direct measurement	

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