Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(4): 249 – 266(2020)
www.ejabf.journals.ekb.eg

Reproductive traits and Microstructure of skeleton in both of *Acropora digitifera* and *Acropora gemmifera* (Scleractinia, Anthozoa) inhabiting the Northern Red Sea (Hurghada, Egypt)

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ARTICLE INFO
Article History:
Received: June 3, 2020
Accepted: June 19, 2020
Online: June 25, 2020

Keywords:
Scleractinian corals
Acropora
Micro-structure
Reproduction
Broadcasting Spawning
Red Sea

ABSTRACT

Reef-building scleractinian corals proliferate and maintain their populations, in part, through sexual reproduction. They typically reproduce sexually as either gonochoric (separate male and female) or hermaphroditic (producing both eggs and sperm) colonies. Both types of sexual reproduction achieved as spawning processes that take place once a year and this process affected by environmental conditions such as temperature, photoperiod and pH level. In relation, the current study was designed to explore the reproduction patterns of two Acroporoid coral species; *Acropora digitifera* and *Acropora gemmifera*, which inhabiting the northern Red Sea (Hurghada, Egypt). A scanning electron microscope (SEM) was used to identify both coral species and to obtain their microstructure details. For reproduction study purpose, gonads maturity status and spawning timing of both studied species were noticed, either by direct field observations, during the study period including two consecutive spawning seasons, or observed in aquaria, by taking live coral colony samples for watching their specific spawning release.

Results indicated that both investigated species are hermaphroditic broadcasting spawner (release buoyant egg-sperm bundles) and showed gradual gonads maturity development begin from October until their spawning time in late April. All polyps became empty from egg sperm bundles in early May. There was a clear relationship between the spawning time of the two coral species and the lunar cycle, temperature, and photoperiod. Spawning of study species occurred on nights (nearly 3-4 hours after sunset) during the new moon and full moon phases. The present study concluded that *A. digitifera* and *A. gemmifera* spawned before April full moon within two days.

INTRODUCTION

Coral reefs are reproductive species characteristic with a highly diversity which provide a shelter for an extraordinary biodiversity and support economics of many island and coastal communities **(Connell, 1978** and **Moberg & Folke, 1999)**. Coral reef ecosystems are

threatened by several factors; world widely, climate change, pollution and overexploitation **(Hughes *et al.*, 2003** and **Lough, 2008)**. The existence of healthy reef and the recovery reef species are controlled by several environmental disturbance which dependent on gametes production, success fertilization, development of offspring, and survival of the new population **(Richmond, 1997)**. All of these pathways are different and influenced by the interaction between coral biology and fluctuation in the environment **(Tomascik & Sander, 1987; Harrison & Wallace, 1990; Richmond & Hunter, 1990; Szmant & Gassman, 1990; Hughes *et al*., 2000** and **Baird *et al.*, 2009).**

There are two different primary modes of development in corals: broadcast spawning is the dominant way of sexual reproduction in reef building scleractinian corals **(Harrison & Wallace, 1990** and **Baird *et al*., 2009)**. Broadcast spawner species can be gonochoric or hermaphroditic and release their gametes. About 65% of the scleractinian coral reef species are hermaphroditic broadcast spawners **(Richmond & Hunter, 1990; Guest *et al.*, 2008** and **Baird *et al.*, 2009a & 2009b)**. Most of these species are released their gametes as a positively buoyant egg-sperm bundles **(Arai *et al.*, 1993** and **Kinzie & Buddemeier, 1996)**. Once the egg-sperm bundles have reached the sea surface, it's breaks within 10-35 minutes, where the external fertilization takes place. This in contrast to the brooder coral reef populations which can also be gonochoric or hermaphroditic, where the internal fertilization takes place inside the coral polyp and well-developed larvae are released **(Harrison & Wallace, 1990).**

Reproduction of coral reef is controlled by different environmental factors as temperature, photoperiod and salinity that have been suggested to be cues to the corals to spawn simultaneously **(Babcock *et al*., 1986; Oliver & Babcock, 1992** and **Bacock*et al.*, 1994)**. However, many conflicting evidences are still unexplained. Corals in the Conzinct Island, Western Australia, as example experience about similar annual temperature and photoperiod cycles to those in the magnetic Island, Great Barrier Reef. However, they reproduce at six months different seasons **(Simpson, 1985** and **Babcock *et al.*, 1986)**. **Bachtiar (2001)** demonstrated that corals growth take place in summer temperature for four months before they reproduce, spawn at the same time as corals grown in the ambient temperature, as well as corals grown in the shifted photoperiods.

The present study was aimed to determine the spawning season of two coral species in the Red Sea, Egypt. Also, this study provides some basic information on the reproductive cycle of broadcaster reef-building scleractinian corals in Red Sea water that are not available in a recent publication.

MATERIALS AND METHODS

Study area:

Stony corals are sensitive to environmental conditions and non-favorable conditions are likely to suppress their growth and reproduction, which in turn could lead to incorrect assumptions about their gametogenic development. So, after several prospections on different

localities, we chose our two study area according to the health status of the coral reef community that have fewer pollutants. Two similar replicate sites were chosen in the Hurghada, Red Sea area including the coral reef habitat next to Remevyera resort shore (site, I) and Small Giftun Island shore (Site, II). In both selected sites, the two target species; *Acropora digitifera* and *Acropora gemmifera* occurred together with moderate coverage of coral reef patches **(Fig. 1)**.

Site I: Remevyera resort (Co-ordinates: 27°09'99"N & 33° 85'24" E). Remevyera resort, (13km South East to small Giftun Island, East to Hurghada Port) is a rocky site located east to Hurghada Port. This site surrounded with fringing reef with narrow reef flat. The reef slope extends almost vertically down to about 10m depths followed by a sandy bottom with relatively abundant coral patches. Coral coverage on this island exceeds 40% and our studied species are well represented there.

Site II: Small Giftun Island (Co-ordinates: 27° 11'09"N &33°58'53" E). Small Giftun Island is a rocky island located east to Hurghada Port. The island surrounded with fringing reef with narrow reef flat. The reef slope extends almost vertically down to about 19m depths followed by a sandy bottom with relatively abundant coral patches. Coral coverage on the island exceeds 60% and considered as high coverage site. This site faces high human impact in compare with the first site.

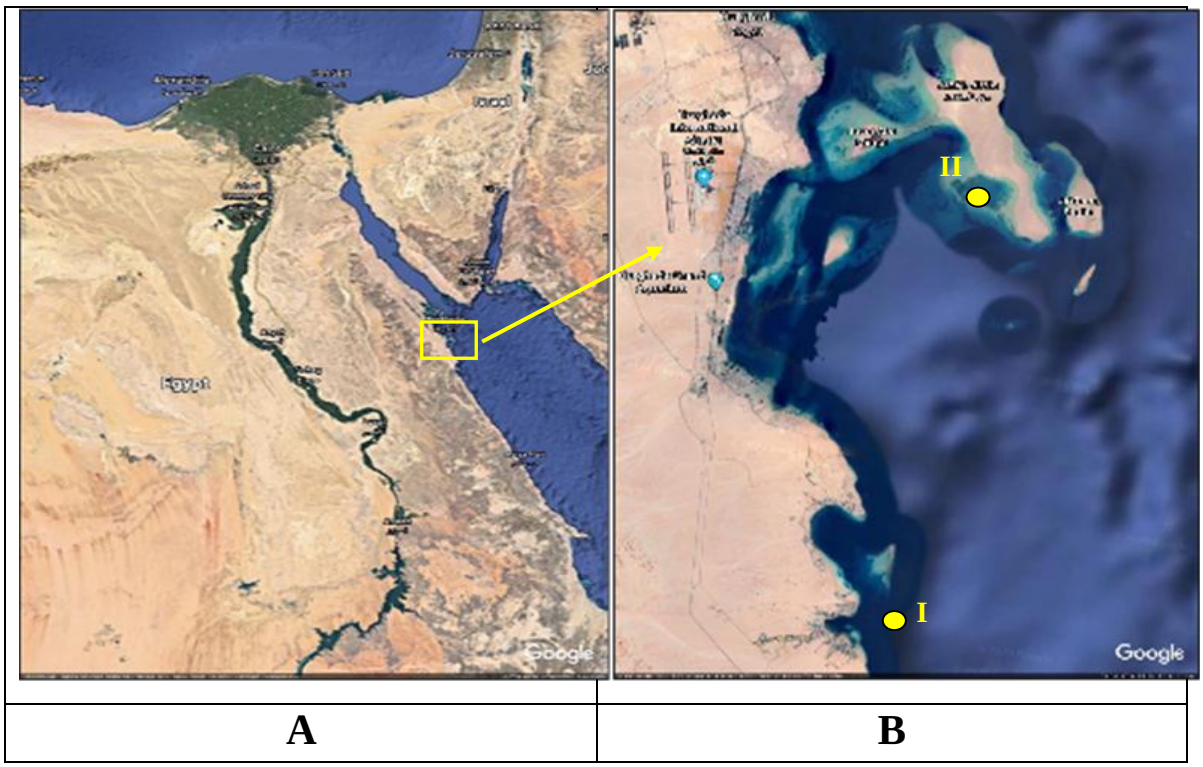

Fig. (1). (A) A map of the study area on Red Sea. (B) Enlarged subset of map A showing studying sites; site (I): Remevyera resort, site (II) Small Giftun Island.

Sampling and Identification of studied coral species:

The two target species in this study from genus *Acropora* were identified firstly from the external shape, color and then we use the dissecting microscope to obtain features and ratio differences in the axial corallite, axial polyp and other taxonomical features according to **Veron (2000)** which used here as a guide for corals identification. Ten colonies from each species were chosen in both sites and tagged at the start date of the current study to investigate their spawning time and their mode of reproduction. The size of tagged *A. digitifera* and *A. gemmifera* colonies were chosen to be more than 30 cm in diameter but no much bigger, making sampling repetition is possible. Samples from different three branches (>5cm length) were taken monthly from each tagged colony during the study period to see the coloration of the egg during maturation before releasing of gametes.

Corals skeleton microstructure:

For more accurate identification for target coral species *A. digitifera* and *A. gemmifera* used Scanning Electron Microscope (SEM) as a very effective tool in coral identification. So samples of both coral species polyps as well as hard skeleton were prepared for SEM investigation.

***Polyp preparation*:** Specimens of live control and treatment corals were chopped off and immediately fixed in 4% formaldehyde 1% glutaraldehyde (4F1G), phosphate buffer solution (pH 7.2) at 4°C for 3 hours. Polyp samples were washed in the buffer and dehydrated at 4 °C through a graded series of ethanol. These specimens were then post fixed in 2% OSO4 in the same buffer at 4°C for 2 hours, then washed in the buffer solution, dehydrated at 4°C in a graded series of ethanol and dried by the critical point method.

***Skeleton preparation*:** Colonies of *A. digitifera* and *A. gemmifera* were immersed in commercial bleach (12% NaOCl) at 60 °C for 30 min. After that the specimens washed in running tap water and rinsed several times in distilled water to remove the overlying soft tissues and other organic matter. The resultant whitened skeletons were then dried at room temperature until constant weight.

***Microstructure investigation*:** The prepared samples and bleached skeletons were mounted using carbon paste on an Al-stub and coated with gold up to a thickness of 400Å in a sputter- coating unit (JFC-1100E). Investigations of the samples were performed in a JEOL JSM-5300 Scanning Electron Microscope (SEM) operated between 15 and 20 KeV (kilo electron volt) according to **Thomas (1962)** and **Tooze (1964)**.

Environmental Measurements:

The reproduction of corals and the maturation of its gonads affected by different environmental factors such as temperature, day-length, lunar cycle (before getting spawn). So, different environmental parameters were measured in the present study.

HANNA GPS Multiparameter Meter (HI 9829) was used to obtain monthly measurements of water temperature, PH, Dissolved Oxygen, and salinity at the 4 m depth

contour, which was in the middle of the depth zone where specimen collection was carried out at the study sites. The logging probe was lowered to 1 m of the bottom to avoid damage and blockage of the sensors due to sediment-suspension at the water-seabed interface.

Also, the day length (photoperiod from sunrise time to sunset time) was calculated in the sample day from the city calendar. Full moon status was determined in the day of the spawning of every selected colony of both studied species.

Reproduction and spawning traits of *A. digitifera* and *A. gemmifera*:

Through regular field trips to both study sites, we checked the maturation of the oocytes, spawning timing, and modes of reproduction for different 10 separate colonies in every study site using SCUBA diving. Regular field observations with colonies sampling involved in the current study at least one time per month around the full moon date. In the months of spring season, we checked the colonies daily for each species from day five prior the full moon time and three days after.

To determine the maturation status, we had a monthly dive trip at the two study sites to see the target coral reef colonies and determined its oocyte maturation which carried out by recording the oocyte coloration through the period of the study.

As when colonies so close to spawning the mature egg-sperm bundles it's obvious on the corallite opening (calcia), the colonies release the egg-sperm bundles have a broadcasting mode of reproduction, while the colonies that release planula larvae they have broadening mode of reproduction.

RESULTS

Morphological description of study species:

The collected colonies of *A. digitifera* and *A. gemmifera* were solid, very porous, and branching. The individual coral animal is called the polyp (axial and radial). The skeleton deposited by an individual polyp within a colony is the corallite which composed of calcium carbonate. These colonies of *A. digitifera* (**Dana, 1846**)have two colors; brown color with purple branched tips and yellow color with creamy branched tips. As it have identical colony growth form (corymbose to digitate) with small terete branches. Branches are usually 1cm in diameter; axial corallites are large, up to 4mm wide. Radial corallites are about 1mm in diameter, have thick lips on their lower side, and are aligned in rows. Colonies of *A. gemmifera* (**Brook, 1892**), are digitate. Branches are thick, tapering to small axial corallite. Radial corallites are of two sizes, usually in rows. The large sized corallites increase in length towards branch bases, where incipient axial corallites are common. *A. gemmifera* colonies are usually purple, blue, cream or brown, with blue or white branch tips. Generally axial corallites are larger than radial corallites and all the corallites of a colony are closely interconnected **(Fig. 2)**.

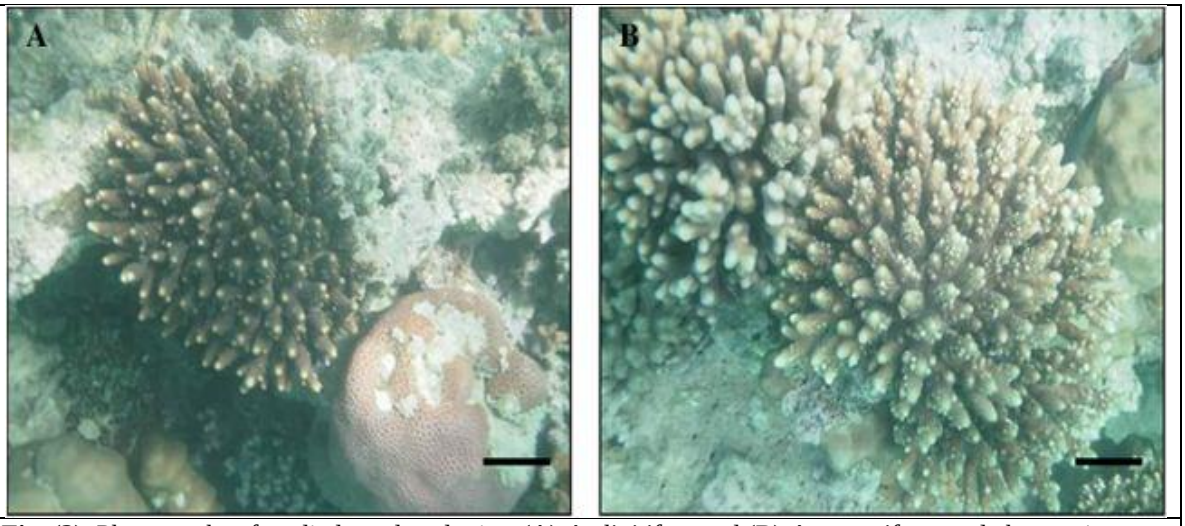

Fig. (2). Photographs of studied corals colonies; (A) *A. digitifera* and (B) *A. gemmifera*, scale bare = 1cm.

Microstructure of *A. digitifera* and *A. gemmifera:*

As shown in **Figure 3** (A1, B1, B2), the individual branch of both *A. digitifera* and *A. gemmifera* respectively is formed of an axial polyp and many radial polyps. The axial and radial corallites are the skeletons of the polyps (**Fig. 3** A1, A2, B1, B2). The corallite is defined by two regions, the calice and the theca. The upper oral surface of a corallite is the calice which opens to outside by a large opening known as calice opening or mouth opening which is large in *A. digitifera* (range from 0.96 to 1.5 mm in diameter), while that of *A. gemmifera* range from (0,75 to 1mm in diameter). The calice opening is surrounded by a circle of sclerosepta arranged in two different level first six primary septa extend to the centre of the calcia and six secondary septa smaller than the primary ones. The theca is the wall of the corallite which consists of vertical rods arranged in concentric rings and horizontal radial and tangential bars. The radial bars form the sclerosepta along with the vertical units (the rods). The tangential bars are synapticulae that connect adjacent sclerosepta to one another (**Fig. 3** A3, A4, B3, B4).

Reproduction traits of *A. digitifera* and *A. gemmifera*:

In situ examination of colonies, during which two studied coral *Acropora* species were sampled in both years (2018 and 2019), showed that both of the two species in 2018 and 2019 clearly synchronized. Oocytes maturation was recorded in *A. gemmifera* and *A. digitifera*, where both followed the same color regime during the maturation process with no significant difference in gonad coloration trend, in which oogenesis was accompanied by color change in developing oocytes. It colored white or pale white in immature stages, and changed during the maturation stages from light cream to pink just before spawning (**Table 1** and **Figs. 4 & 5**). Such gonad data were quite evident that our studied species are hermaphrodites, contained oocytes and spermaries in the same polyp but in different mesenteries.

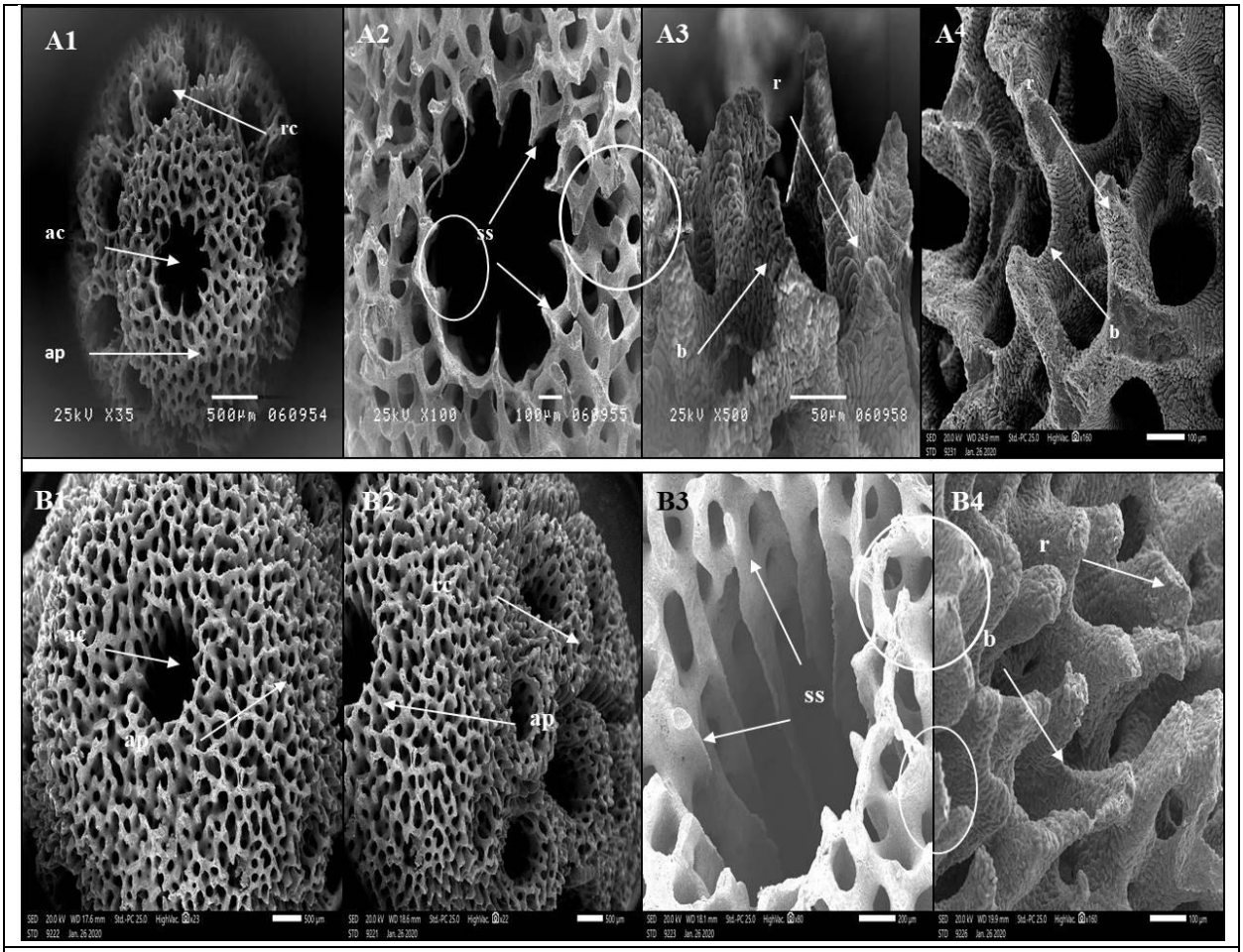

Fig. (3). Scanning electron micrographs of *A. digitifera* (A) and *A. gemmifera* (B). (A1) upper view for both axial and radial skeleton branches; (A2) upper view of the axial corallite showing rods and bars (circle); (A3,A4) rods and bars of axial corallite; (B1) upper view for individual branch showing axial corallite and axial polyp; (B2) lateral view of branch show the radial corallite and radial polyp; (B3) upper view for axial corallite with its sclerosepta showing rods and bars (circle); (B4) rods and bars of axial polyp. Abbreviations: ac, axial corallite; ap, axial polyp; rc, radial corallite; rp, rdaial polyp; ss, sclerosepta; r, rods; b, bars. Scale bar: A1, B1, B2 (500µm); B3, 200µm; A2, 100µm; A4, B4 (100µm); A3 (50µm).

Table (1) shows the common coloration trend of oocytes in both synchronized spawner species under investigation. This color trend was recorded as a result of daily observation during the active gametogenesis process and during the mass spawning event period. The time of the maximum occurrence of each of the oocytes color ranked as days prior to spawning event and indicated that the active gametogenesis process commonly occurred within a month before spawning. The vitallogenesis process took less than 4 weeks where gonad color changed from light cream to cream to pink. It seemed that the rhythm of changes in oocytes coloration between different studied species occurred between cream to light pink coloration (vitallogenesis stage), while mostly all of the studied species reached to ripe or fully mature oocytes (Pink color) at the same time at maximum 4 days before spawning **(Figs. 4&5)**.

Table (1). Oocytes coloration during the different stages of maturation of both studied *Acropora* species.

Oocytes Status	Immature	Premature Stage I	Premature Stage II	Premature Stage III	Mature
Oocytes colour	White	Light Cream	Cream	Light pink	Pink

Fertile colonies are found in the population of *A. digitifera* and *A. gemmifera* from collected samples in (March, April 2018 and February, March 2019) at both study sites **(Tables 2 & 3)**. Consequently, after spawning time, and for three months later spawning, gonads are empty or not big enough to be obvious and it is not observed. From October to January there is a reduction in the proportion of fertile colonies which gradually increase, return to be mature and the reproductive synchrony is relatively take place between both current studied species with fertile colonies over 90% in March before full moon month (April) with 100% maturity percentage **(Figs. 6 & 7)**.

The surface sea water temperature increases gradually with monthly means range from 22.30 to 24,89^{o}C between March 2018 and May 2018, and in the same period there's increase of photoperiod (day length) and no clear significant in the PH level as shown in **(Table 4)**. Sea water temperature increase during October 2018 leads to develop in the gonads maturation. Consequently, the current study showed that eggs in *A. digitifera* develop very slowly from July to September 2018, and then they develop very rapidly from October 2018 to March 2019 **(Fig. 6)**. While, eggs in *A. gemmifera* develop very slowly from July to October 2018, then they develop very rapidly from November 2018 to March 2019 **(Fig., 7)**. All colonies spawn one time a year in April full moon. However, some colonies were also found to have ripe oocytes before full moon of January 2019 suggesting that some colonies in the population may have spawning before the spawning peak in April 2019 for both study species. On the other hand, testes of both *A. digitifera* and *A. gemmifera* develop after the full moon of November 2018. Before the full moon of April 2018 and March 2019 most of colonies contained ripe testes **(Tables 2 & 3)**. These results suggested that most colonies in this population ready to spawn prior to the full moon of April 2018.

Regarding to spawning synchronization of corals in the two different study sites, results in **Tables (3&4)** indicated that *A. digitifera* and *A. gemmifera* at both study sites show high degrees of synchrony on their reproductive cycles whereas the peak of spawning season of this coral is likely before the full moon of April. At all, colonies of *A. digitifera* and *A. gemmifera* spawn between the first and second day before April full moon. It was found that in the 28th of April 2018 (two days before the full moon), fresh broken colonies in the both study sites contained pinkish eggs **(Table, 5)**. The following day (just before the full moon), pinkish eggs were found in some colonies at both study sites which indicate that the spawning extend to the full moon time. The ripe colonies were tagged at this time. In the next day after the April full moon, there were no longer eggs in the tagged colonies suggesting that the spawning had taken place.

Table (2). Monthly field observation detection of oocytes and spermaries occurrence in *Acropora digitifera* colonies at two different studied sites.

Months	Site (I)			Site (II)		
	Cl–Ooc.	Cl–Sp.	Ooc. Color	Cl–Ooc.	Cl–Sp.	Ooc. color
Mar-18	**10**	**10**	pale cream to light pink	**10**	**10**	pale cream to light pink
Apr-18	**10**	**10**	light pink to pink	**10**	**10**	light pink to pink
May-18	**0**	**0**	Empty	**0**	**0**	Empty
June-18	**0**	**0**	Empty	**0**	**0**	Empty
July-18: Sep-18	**NS**	**NS**	NS	**NS**	**NS**	NS
Oct-18	**6**	**0**	light white	**6**	**0**	light white
Nov-18	**8**	**1**	light white	**7**	**1**	light white
Dec-18	**8**	**4**	light white	**8**	**4**	light white
Jan-19	**9**	**6**	light white to white	**9**	**5**	light white to white
Feb-19	**10**	**7**	white to pale cream	**10**	**7**	white to pale cream
Mar-19	**10**	**10**	pale cream to cram	**10**	**10**	pale cream to cream

Cl–Ooc.: number of colonies observed have oocytes; Cl–Sp.: number of colonies observed have sperms; Ooc. Color: oocytes color that observed after cross section is taken in the colony; NS: not observed.

Table (3). Monthly field observation detection of oocytes and spermaries occurrence in *Acropora gemmifera* colonies at two different studied sites.

Months	Site (I)			Site (II)		
	Cl–Ooc.	Cl–Sp.	Ooc. Color	Cl–Ooc.	Cl–Sp.	Ooc. color
Mar-18	10	10	Pale cream to cream	10	10	Pale cream to cream
Apr-18	10	10	Cream to pink	10	10	Cream to pink
May-18	0	0	Empty	0	0	empty
June-18	0	0	Empty	0	0	empty
July-18: Sep-18	NS	NS	NS	NS	NS	NS
Oct-18	5	0	light white	5	0	light white
Nov-18	6	1	light white	5	1	light white
Dec-18	7	2	light white	7	2	light white
Jan-19	9	5	light white to white	8	5	light white to white
Feb-19	10	7	white to pale cream	10	6	white to pale cream
Mar-19	10	10	pale cream to cram	10	10	pale cream to cream

Cl–Ooc.: number of colonies observed have an oocytes; Cl–Sp.: number of colonies observed have an sperms; Ooc. Color: oocytes color that observed after cross section is taken in the colony; NS: not observed.

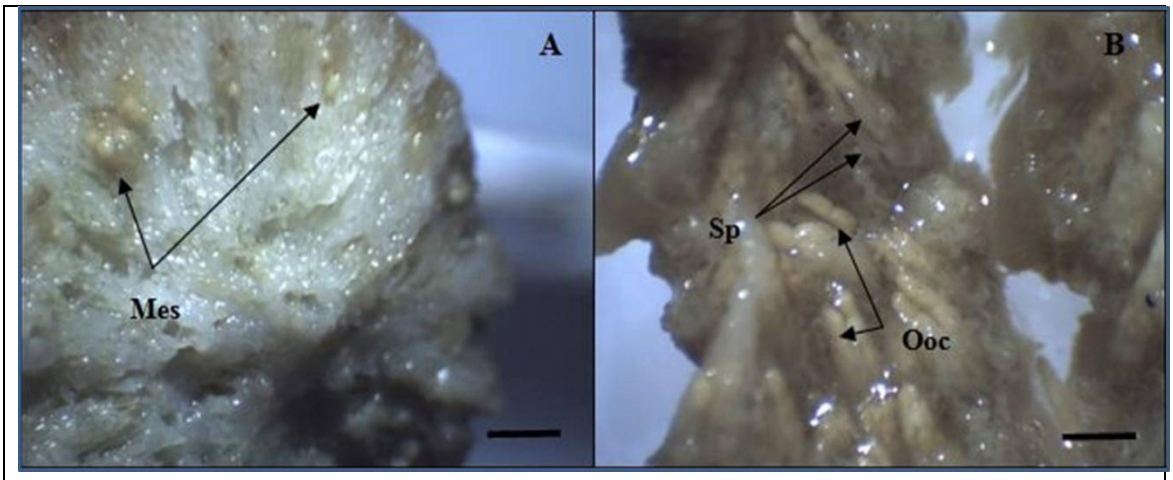

Fig. (4). Photograph showed the branch of *Acropora digitifera* with mesentries containing oocyte (A), and soft tissue after decalcification show the mesentries which contain both of oocyte and spermaries (B). Mes: Mesentries; Sp: Sperms; Ooc: Oocyte (Scale bar = 500µm)

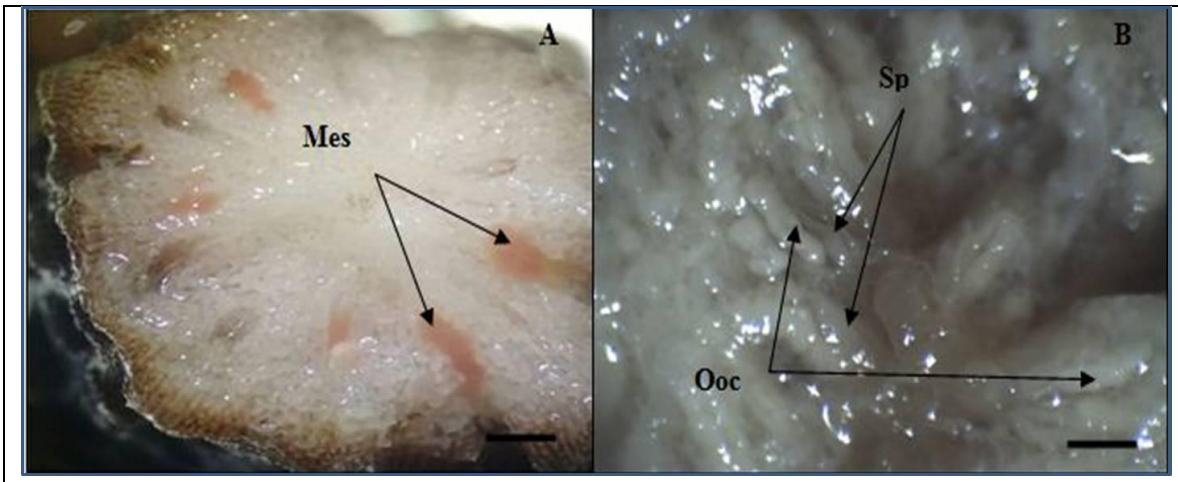

Fig. (5): Photograph showed the branch of *Acropora gemmifera* with mesentries containing oocyte (A), and soft tissue after decalcification show the mesentries which contain both of oocyte and spermaries (B). Mes: Mesentries; Sp: Spermaries; Ooc: Oocyte (Scale bar = 500µm)

Table 4. Monthly average values of day light and water parameters in the study area.

Months	T (°C)	Day L (h)	Salinity (‰)	pH	DO (mg/L)
Mar-18	22.30 ± 0.15	12.01 ±0.25	40.2 ± 0.01	8.072 ± 0.009	7.175 ±0.019
Apr-18	22.8 ± 0.45	12.82 ± 0.22	40.25 ± 0.014	7.76 ± 0.010	7.135 ± 0.033
May-18	24.89± 0.79	13.49 ± 0.17	40.245 ± 0.01	8.073 ± 0.0084	7.097 ± 0.013
June-18	26.67± 0.39	13.82 ± 0.05	41.26 ± 0.093	8.208 ± 0.016	6.82 ± 0.094
Oct-18	27.21± 0.137	11.29 ± 0.08	40.218 ± 0.019	8.21 ± 0.01	6.53 ± 0.018
Nov-18	26.23± 0.133	10.66 ± 0.005	40.091 ± 0.083	8.21 ± 0.01	6.948 ± 0.0155
Dec-18	21.94±0.242	10.42 ± 0.005	40.445 ± 0.031	8.11 ± 0.013	7.256 ± 0.020
Jan-19	22.45± 0.217	10.72 ±0.055	40.446 ± 0.02	7.977 ± 0.008	7.194 ± 0.015
Feb-19	22.15 ± 0.184	11.36 ± 0.08	40.467 ± 0.015	8.101 ± 0.012	7.22 ± 0.027
Mar-19	22.71± 0.137	12.16 ± 0.08	40.321 ± 0.0285	8.08 ± 0.007	7.177 ± 0.012

Table 5. Spawning timing of studied coral species.

Acropora spp.	Spawning slicks observed	Full moon date	Nights before (-) or after (+) full moon
A. *digitifera*	28 April 2018	30 April 2018	**-2**
A. *gemmifera*	28 April 2018		**-2**

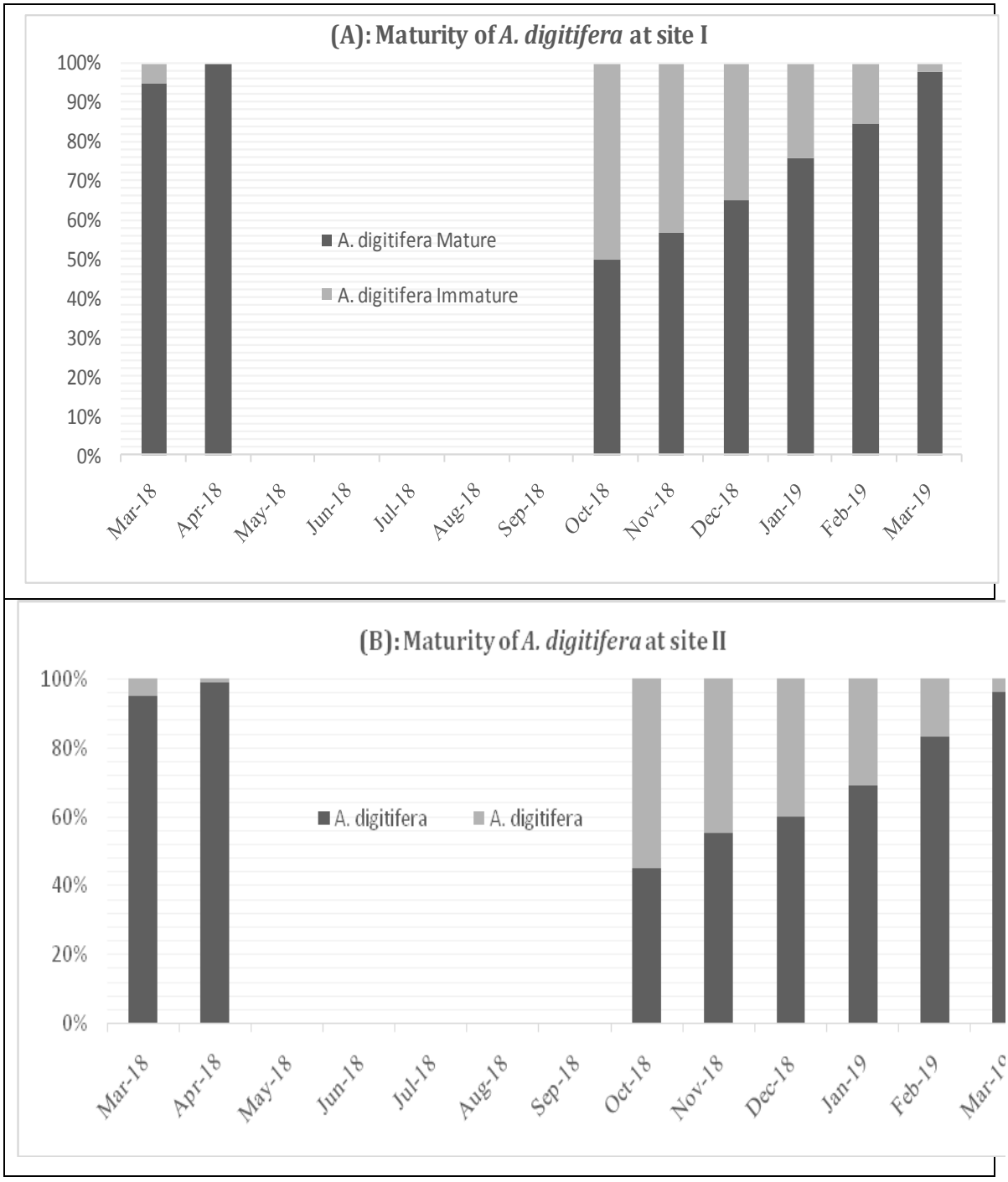

Fig. (6). Monthly immature and mature colonies percentages (%) of *A. digitifera* at site I (A) and site II (B) during study period.

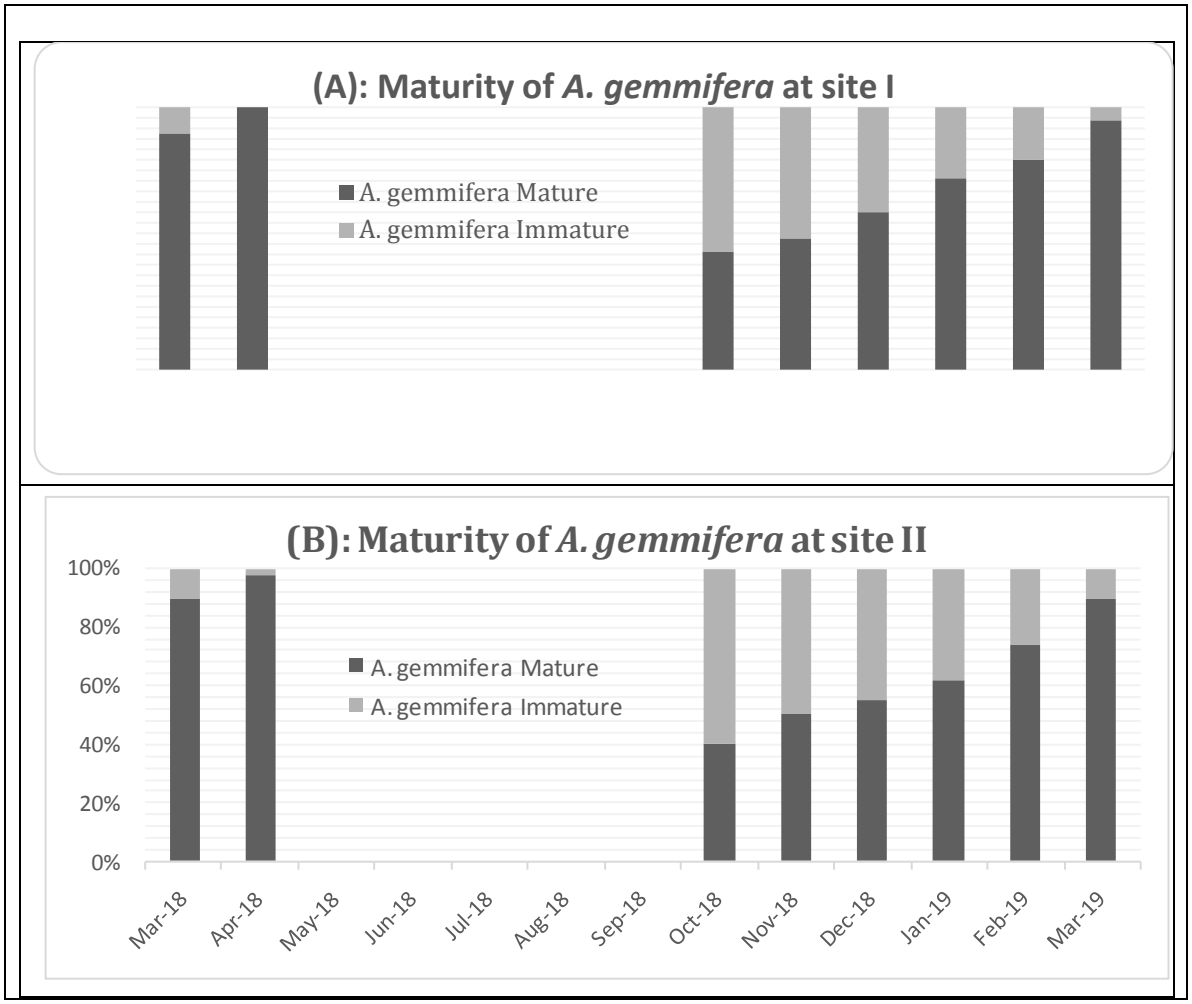

Fig. 7.Monthly immature and mature colonies percentages (%) of *A. gemmifera* at site I (A) and site II (B) during study period.

DISCUSSION

Genus *Acropora* is one of the widest spared genera around the world comprises 182 species recorded in different reefs around the world with about 42 species recorded in the Red Sea (**Wallace, 1999** and **Veron, 2000**). *Acropora* spp. are hermaphroditic, which produce both male and female gametes in the polyps of the colonies, and there is no evidence that members of this genus had a gametes maturation spike but had a single annual gametogenic cycle (**Wallace, 1985; Szmant, 1986; Mangubhai & Harrison, 2008a & 2008b; Rosser & Gilmour, 2008**). Among present observations in the Hurghada waters in Red Sea, it was cleared that *Acropora digitifera* and *Acropora gemmifera* are not exception and the present study ensured that both species are hermaphroditic broadcasting spawners in which process it observed release their buoyant egg-sperm bundles.

In the present work, Synchrony in gamete maturation of two corals, *A. digitifera* and *A. gemmifera*, assemblages at these Red Sea sites is among the highest ever recorded. The proportion of mature colonies in this season at these sites (99% of colonies mature at both study sites Hurghada in April 2018) is higher than for *Acropora* on the Great Barrier Reef, where, for example, values for the proportion of colonies with mature oocytes in the weeks preceding the mass spawning period (**Willis *et al*., 1985**) in 1999 were 72% in the central Great Barrier Reef and 63% in the northern Great Barrier Reef (**Baird & Marshall, 2002**). Similarly, the proportion of *Acropora* colonies breeding in a typical Western Australian mass spawning period was 66% depending on direct observation by (**Babcock *et al*., 1986)**. In the same way, the proportion of *Acropora* species breeding is similar to that on these Australian reefs by (**Penland *et al*., 2004),** (86% in the central Great Barrier Reef, 65% in the northern Great Barrier Reef and 95% in Western Australian).

In the present study, both *A. digitifera* and *A. gemmifera* are likely to have only one gametogenic cycle per year as their colonies spawned before March full moon 2018. **Bachtiar (2001)** suggested that low synchrony in the spawning of the corals *A. nobilis, A. cytherea* and *Hydnophora rigida* in the Gili Trawangan and Gili Meno, Indonesia is likely owing to the low variation on environmental factors (Temperature, Photoperiod) that may constrain and limits the stages of reproductive cycles. In the Red Sea water temperature is nearly always warm at most of the time. Because broadcasting corals require external fertilization, responding similarly to specific environmental signals to ensure conspecific reproductive synchrony (in the order of minutes, e.g. **Levitan *et al*.. (2004**) is probably of prime importance to ensure high fertilization rates. Thus, one of the most possible hypotheses explaining multi-species spawning is that species respond similarly but independently to timing cues to synchronize spawning within populations (**Bachtiar, 2001)**, resulting in many species having short overlapping spawning periods. No coastal location is truly seasonal, even equatorial reefs experience marked rhythmic changes in sea surface temperature. Consequently, mass spawning is just as likely to occur on the Red Sea reefs as it is at higher latitudes; indeed, this remarkable phenomenon is probably a feature of all species coral assemblages.

There's no indication here for the biannual gametogenic cycle for both coral species. The biannual gametogenic cycle has been reported to takes place in the corals *Montipora digitata, Montipora aequituberculata,* and *Montipora platiformis*in the Great Barrier Reef (**Wijayanti*et al*., 2019**). Multiannual gametogenic cycle has also been found in the *A. pallifera* species in Papua New Guinea (**Randall *et al*., 2020**). In the *A. pallifera* gametogenic process takes place continuously and overlapping each other. The biannual gametogenic cycle may give benefit to the coral increase reproductive output, particularly for corals with low local population density.

The spawning season within population of the two studied corals is restricted during the particularly full moon in the middle of the spring season over only one month. Most corals close to equatorial may have spawning season spread over several months, as in Palau, for example, in which spawning of 13 corals spread over more than three months (**Kenyon,**

1995). Corals which have narrow spawning time (in mass spawning event) in the Great Barrier Reef, they spawn in several months when they live in equatorial region of Papua New Guinea (**Oliver *et al.*, 1988**). The same phenomenon is not likely to occur in the two corals, although the present study hasn't revealed clearly the length of the spread spawning season. The spread of the spawning season has been thought to have some disadvantages to the coral reproductive success, to oppose the synchronous spawning. The spread of the spawning season may reduce the chance of the sperm to fertilize the eggs and may reduce survivorship of planula larvae from predatory (**Oliver & Babcock, 1988**).

Many previous studies interested by coral spawning prediction(based on available evidence) indicated that reproductive conditions can be estimated based on the visibility and color of developing oocytes (**Baird & Marshall, 2002**). Visible pigmented oocytes are mature and most likely will be released around the next full moon (**Willis *et al*., 1985; Babcock *et al*., 1986** and **Oliver *et al*., 1988**). Visible white oocytes are close to maturity and are likely to be spawned within 1–3 months. Colonies in which oocytes are not visible either have recently spawned or are unlikely to do so for at least 3 months (**Harrison *et al.*, 1984; Baird & Marshall, 2002** and **Guest *et al.*, 2005a & 2005b**). None of these previous studies concerned the detailed changes in color of oocytes during the active gametogenesis of the corals. The present study gives a detailed investigation on the using of oocytes colorations for the examination and prediction of spawning time of *Acropora* spp. in the Red Sea. The oocytes colors were white and light cream during immature and early premature stages (more than 4 weeks) prior to the spawning time. At the vitellogenesis stage the color changes from light cream to cream to light pink and reach the pink color at the fully mature stage few days prior to spawning days.

All the previous studies which used the same method of oocytes color to predict the time of coral spawning did not record the phenomena of oocytes coloration at the field and mentioned only the pigmentation of oocytes prior to spawning time. However, **Babcock *et al.*, (1986)**, studied the spawning of 105 scleractinian coral species on the Great Barrier Reef, and found that the oocytes color of *A. cythera*, *A. formosa*, *A. gemmifera*, *A. humilis*, *A. selago*, and *A. tenuis* at the spawning time were pink which agree with this study, and the oocytes color of the most of the others *Acropora* spp. were pink or red (**Babcock *et al.*, 1986**) which are in coincidence with the present findings that, the color scheme which stated in this study can be used in other places around the world.

In the Red Sea temperature and solar irradiance remain within ranges that are suitable for spawning of corals to occur elsewhere (e.g., **Hayashibara *et al.*, 1993; Babcock *et al.*, 1994** and **Penland *et al.*, 2004**). In other words, conditions are suitable for breeding all year round, so it seems unlikely that the timing of reproduction in any scleractinian is limited to certain times of the year by resource availability. It is not clear whether there is an adaptive (ultimate) advantage to spawning when environmental conditions are likely to be "optimal" for fertilization, larval development, survival and settlement. As the environmental condition

reach the suitable level for spawning, mean temperature was 22.8± 0.45 ^{o}C and photoperiod was 12.82± 0.22 hr that was optimal condition for spawning of two study species.

The knowledge of spawning times in coral can be a good indicator for reproduction in other groups. Also, knowing the timing and synchrony of coral spawning can help in explaining the success or failure in annual coral replenishment due to corresponding climatic conditions (**Mendes & Woodley, 2002**). Knowing the time of reproductive events can also allow for more effective management of pulse impacts from coastal development on coral reef ecosystems (**Richmond, 1997**). Based on the results of the present study we concluded that the spawning peak of the two study species take place before April 2018 full moon with two days, as the gonads reached their maturation in optimal environmental condition for both *A. digitifera* and *A. gemmifera* in this time. The seasonal nature of coral spawning around the globe affords environmental managers the opportunity to place temporal restrictions on human impacts that undermine the early development of coral larvae (**Guest *et al.*, 2005b**).

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الملخص العربي

السمات التناسلية والتركيب المجهري للهيكل في كلاً من *Acropora digitifera* و *Acropora gemmifera* (المراجين البانية للشعاب) قاطنة شمال البحر الأحمر (الغردقة، مصر)

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المراجين البانية للشعاب تنمو وتحافظ علي بقاء أفرادها من خلال عملية التكاثر الجنسي كأحد أهم خياراتها، وتتنوع طرق التكاثر الجنسي لهذه المراجين فهي اما منفصلة الجنس أو خنثي تحوي بداخلها كلا من البويضات والحيوانات المنوية، وفي كلا الحالتين يتم التكاثر مرة واحده كل عام. و تتأثر عملية التكاثر الجنسي ونضج المناسل وتوقيت اطلاق الأمشاج أو اليرقانات بالعوامل البيئية مثل درجة الحرارة وطول فترة النهار وقيمة الأس الهيدروجيني للماء... الخ.

في الدراسة الحالية، تم ملاحظة خصائص التكاثر والبنية المجهرية للهيكل الصلب لنوعين من المراجين بانية الهيكل من جنس *Acropora* (*Acropora digitifera* و*Acropora gemmifera*) وذلك في مياه الجزء الشمالي للبحر الأحمر (الغردقة، مصر). تم استخدام الميكروسكوب الألكتروني الماسح للوصول إلي التركيب الدقيق لكلا النوعين محل الدراسة للتأكد من صحة تصنيفهما والصفات المعلمة لكلا النوعين. حيث يهدفالبحث الى دراسة التكاثر تم تسجيل حالة نضج المناسل ووقت التكاثر في كلا النوعين عن طريق الملاحظة البيئية المباشرة خلال زيارات منتظمة لبيئة المستعمرات طوال فترة الدراسة والتي تضم موسمين متتالين لموسم التكاثر (من مارس ٢٠١٨ إلي مارس ٢٠١٩).

تشير النتائج إلي أن كلا النوعين محل الدراسة خنثي (مزدوجي الجنس) وأنه عند التكاثر تخرج حزم طافية من البويضات والحيوانات المنوية. وتوضح النتائج التطور التدريجي للمناسل في المستعمرات من شهر أكتوبر حتي وقت اكتمال النضج الجنسي و اطلاق حزم الأمشاج وقت التكاثر في أخر شهر إبريل. وتصبح كل مكونات المستعمرات خالية من البويضات والحيوانات المنوية في أول شهر مايو. كما بينت النتائج أن هناك علاقة بين وقت التكاثر في كلا النوعين وبين دورة القمر، درجة الحرارة، طول فترة النهار. كما أن التكاثر لكل من النوعين محل الدرسة حدث خلال الليل (تقريبا بعد ٣ أو ٤ ساعات من غروب الشمس) خلال الطور الجديد الطور المكتمل للقمر. وقد خلصت الدراسة الحالية الى أن تكاثر كلا من *Acropora digitifera* و *Acropora gemmifera* يحدث قبل طور القمر المكتمل لشهر إبريل بيومين.