# Patterns of fertility in the two Red Sea Corals *Stylophora pistillata* and *Acropora humilis*

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**Abstract.** *Ammar MSA Obuid-Allah AH, Al-Hammady MAM. 2012. Patterns of fertility in the two Red Sea Corals* Stylophora pistillata *and* Acropora humilis. *Nusantara Bioscience 4: 62-75.* Patterns of fertilities (total testes and total eggs) for the hermatypic coral *Acropora humilis* were lower than those in *Stylophora pistillata* at the four studied sites. Site 3 (El-Hamraween harbor), the site impacted with phosphate, recorded the highest annual mean of testes number and egg number in the two studied species *Acropora humilis* and *S. pistillata*. However, site 1, the site impacted with oil pollution and fishing activities, recorded the lowest annual mean of testes number, total testes, egg number and total egg for the two studied species. Thus, phosphorus enrichment seems to be considerably less destructive than oil pollution, and thus may represent an 'eco-friendly'. Testes were observed full of sperms during winter season in the sectioned polyps of *A. humilis,* while eggs were detected during autumn and winter. However, the lack of eggs in *S. pistillata* occurred only during spring season at all the studied sites. In the studied coral species, the ova were developed first before spermeria. The breeding season of coral reefs differs in both different localities and different species extending from December to July in the northern Red Sea, Gulf of Aqaba and Southern Red Sea (the present study). While in *A. humilis,* the breeding season extend from February to June in the Great Barrier Reef, in the Gulf of Aqaba and in Hurghada (the present study). Tough control, public awareness and continuous shore patrolling to the activities of oil pollution and fishing activities at the vicinity of site 1 (Ras El-Behar) are urgent. Although existing corals may continue to grow and survive in an area with elevated nutrients levels, it is essential to maintain water quality on coral reefs within ecologically appropriate limits to ensure successful reproduction of coral and provide recruits for the long-term maintenance and renewal of coral populations.

**Key words:** fertility, Red Sea, corals, *Stylophora pistillata, Acropora humilis*

**Abstrak.** *Ammar MSA Obuid-Allah AH, Al-Hammady MAM. 2012. Pola kesuburan pada dua karang dari Laut Merah* Stylophora pistillata *dan* Acropora humilis. *Nusantara Bioscience 4: 62-75.* Pola fertilitas (testis total dan telur total) untuk karang hermatypic *Acropora humilis* lebih rendah daripada *Stylophora pistillata* di empat lokasi penelitian. Situs 3 (Pelabuhan El-Hamraween), lokasi yang terdampak dengan fosfat, tercatat memiliki rata-rata tahunan tertinggi jumlah testis dan jumlah telur pada dua spesies yang dipelajari *A. humilis* dan *S. pistillata*. Namun, situs 1, lokasi yang terdampak dengan pemcemaran minyak dan kegiatan penangkapan ikan, tercatat memiliki rata-rata tahunan terendah dari jumlah testis, testis total, jumlah telur dan telur total untuk dua spesies yang dipelajari. Dengan demikian, pengayaan fosfor tampaknya jauh kurang destruktif daripada pemcemaran minyak, sehingga dapat dianggap 'ramah lingkungan'. Testis yang diamati penuh sperma selama musim musim dingin pada polip *A. humilis* yang dibelah, sedangkan telur terdeteksi selama musim gugur dan musim dingin. Namun, ketiadaan telur pada *S. pistillata* hanya terjadi selama musim semi di semua lokasi penelitian. Pada spesies karang yang diteliti, ovum terbentuk lebih dahulu sebelum spermeria. Musim perkembangbiakan terumbu karang berbeda baik katrena perbedaan lokasi maupun spesies, terjadi dari Desember hingga Juli di Laut Merah bagian utara, Teluk Aqaba dan Laut Merah bagian selatan (lokasi penelitian ini). Sementara pada *A. humilis*, musim perkembangbiakan terjadi dari Pebruari hingga Juni di Great Barrier Reef, Teluk Aqaba dan di Hurghada (lokasi penelitian ini). Kontrol yang ketat, kesadaran masyarakat dan patroli pantai terus menerus terhadap kegiatan pencemaran minyak dan penangkapan ikan di sekitar lokasi 1 (Tanjung Ras El-Behar) sangat mendesak. Meskipun karang yang ada dapat terus tumbuh dan bertahan hidup di daerah dengan tingkat nutrisi yang meningkat, adalah penting untuk mempertahankan kualitas air pada terumbu karang dalam batas-batas ekologis yang tepat untuk menjamin keberhasilan reproduksi karang dan memberikan sumber bibit untuk pemeliharaan jangka panjang dan pembaharuan populasi karang.

**Kata kunci:** kesuburan, Laut Merah, karang, *Stylophora pistillata, Acropora humilis*

## INTRODUCTION

Studies of reproduction in hermatypic corals have largely provided information on the sexual biology (Fadlallah 1983; Harrison and Booth 2007; Kenyon 2008) and life history of coral (Harriott 1983; Moorsel 1983; Babcock 1984; Kojis 1984; Chaves-Romo and Reyes-Bonilla 2007; Glynn and Colley 2009). Few researchers have studied deleterious environmental factors affecting coral reproduction (Loya and Rinkevich 1979; Markey et al. 2007; Mangubhai and Harrison 2009; Vize 2009), but none have examined the natural variability of coral

fecundity. Relatively few studies have concentrated on quantitative data on reproductive output, usually expressed as potential fecundity (Ward and Harrison 2000; Goffredo et al. 2006).

Recent research on sexual reproduction in scleractinian corals has been instrumental in the reconsideration of a number of hypotheses which attempted to relate the mode of coral reproduction to habitat (Stimson 1978; Harrison and Both 2007; Cairns 2007), coral morphology (Rinkevich and Loya 1979b; Flot et al. 2008) and ecology (Loya 1976). However, only a few workers have attempted to assess the effects of anthropogenic activities on coral reproduction (Loya and Rinkevich 1979; Markey et al. 2007; Humphrey et al. 2008; Randall and Szmant 2009) or to provide comparative data on natural variability of coral fecundity (Kojis and Quinn 1984). Furthermore, most of these studies have been restricted to the effects of oil pollution (Peters et al. 1981; Negri et al. 2005; Markey et al. 2007) and thermal stress (Jokiel and Guinther 1978; Glynn et al. 2008; Glynn and Colley 2009) on the reproductive biology of the corals.

More studies on real or potential fecundity at all levels within and between populations are therefore needed to assess the suitability of fecundity as an index of stress in corals. Reduced fecundity is a form of partial reproductive failure. Several mechanisms have been demonstrated in corals to date, including oocyte abortion (Loya and Rinkevich 1979; Kenyon 2008), planula abortion (Jokiel 1985; Harrison 2006; Graham et al. 2008), and incomplete spawning followed by rapid oocyte resorption of unspawned oocytes (Rinkevich and Loya 1979b; Kenyon 2008). Of these studies, only that of Rinkevich and Loya (1979c) observed reproductive failure in a natural situation of ill-defined stress.

Various forms of reproductive failure (oocyte abortion, planula abortion, reduced fecundity, etc.) can be induced in corals by stress (Harrison and Wallace 1990; Krupp et al. 2006; Yakovleva et al. 2009). Therefore, it has been suggested that variation in fecundity could be useful as a measure of sub-lethal stress on reefs (Harrison and Wallace 1990). Measures of fecundity such as the number of eggs or the number of planulae per polyp can provide a useful index of reproductive effort and useful indicator of the health of a coral (Kojis and Quinn 1984; Harrison and Wallace 1990). Consequently, changes in these measures can be an indication of sublethal stress in corals. However, fecundity alone can underestimate the reproductive effort of corals and is better combined with other reproductive measures such as size of eggs and the volume of testis material (Harrison and Wallace 1990; Bassim and Sammarco 2003; Fabricius 2005).

Waller and Tyler (2005) reported two main reproductive patterns in marine invertebrates, the production of small numbers of large oocytes, and the production of large numbers of small oocytes. Scleractinian corals have a similar pattern of gametogenesis to that of other cnidarians (Giese and Pearse 1974; Gorbunov and Falkowski 2002; Holstein et al. 2003), and either broadcast spawn gametes for external fertilization and development or brood larvae within polyps, and may be hermaphroditic

or gonophoric (Fadlallah 1983; Harrison and Wallace 1990; Huang et al. 2009; Baird et al. 2009). In hermaphroditic coral species, eggs and spermaries may develop on the same mesenteries (as in the faviids and mussids), on different mesenteries within the same polyp (most pocilloporids and acroporids), in different polyps within the same colony, or rarely, at different times within the same colony (Fadlallah 1983; Harrison and Wallace 1990; Harrison 2006; Harrison and Hakeem 2007).

The breeding season of coral reefs differs in both different localities and different species (Nozawa et al. 2006; Mezaki et al. 2007). It extends from December to July in the northern Red Sea, Gulf of Aqaba (Shlesinger and Loya 1985). While in *Acropora humilis*, the breeding season extends from February to June in the Great Barrier Reef (Bothwell 1981), in the gulf of Aqaba (Shlesinger and Loya 1985). However, Baird et al. (2010) conclude that the major spawning season of corals on shallow-inshore reefs in the Dampier Archipelago is autumn, although taxa that spawn in spring and summer include *Porites* spp., *Acropora* spp., possibly *T. mesenterina* that are numerically dominant at many of these sites. Consequently, management initiatives to limit the exposure of coral spawn to stressors associated with coastal development may be required in up to five months per year. The gonads development in *Stylophora pistillata* is differing from *A. humilis*. However, female gonads in *S. pistillata* need approximately six months for maturation (July to December) while male gonads require only three months (October to December) (Baird et al. 2010). Hunter (1989) reported that the reproduction process in *A. humilis* and *S. pistillata* in the Red Sea occurs during spring and summer. However, corals in the inner and eastern Gulf of Thailand spawned following the full moons of February/March, whereas spawning in the southwestern Gulf of Thailand and the Andaman Sea occurred 1 month later following the full moons of March/April (Kongjandtre et al. 2010). In Western Australia, coral spawning occurs predominantly in the austral autumn in contrast to the Great Barrier Reef on Australia's east coast where most spawning occurs in spring (Baird et al. 2010).

Shlesinger and Loya (1985) found that the female gonads require about five months (October to February), while the male gonads require only two months (January and February) for maturity. The same authors also reported that *A. humilis* release gametes during late spring and early summer. Guest (2004) and Waller et al. (2005) have sequential patterns of egg and sperm development in *Diploastrea heliopora*. Kongjandtre et al. (2010) illustrations partially conflict that, the male gonads of *A. humilis* starting their development at the end of January and February and completed their development in April, while female gonads started their development at the end of October before the male gonads become well developed at April. However, Glynn et al. (2011) repeated that reproduction of corals takes place mainly from March to May when seasonally high sea temperatures and rainfall prevailed in the Galápagos Islands.

The aim of the study is to examine the fertility patterns as biomonitors for environmental threats on the two Red

Sea corals *A. humilis* and *S. pistillata*, outlining the degree of harm of each impact, the possibility of recovery and putting the possible scientific solutions.

## MATERIALS AND METHODS

All fieldwork was performed using SCUBA diving equipment, throughout the period from December 2007 to January 2009.

### Study area

A preliminary visual survey of the Egyptian Red Sea coast, using snorkeling and SCUBA led to selection of four sites at four widely geographically separated areas along the western coast of the Red Sea (Figure 1). These sites are Ras El-Behar (northern Hurghada), Middle reef (Hurghada), Kalawy bay (Safaga) and El-Harnraween harbor (El-Quseir). Three of these sites are subjected to

different human activities and the fourth one is considered as a control site. Ras El-Behar (Site 1) lies at the northern part of the Red Sea, at a distance of about 60 km northern to Hurghada city, between latitudes 27° 43' 12" N and 27°43' 51" N and longitudes 33°33' 12" E and 33°33' 04" E. This site is impacted by petroleum oil pollution coming from the nearby petroleum fields and oil tankers. Furthermore, commercial fishing activities are impacting the same site. Middle Reef (Site 2) is located 200 m offshore between the northern reef and crescent reef, directly in front of National Institute of Oceanography and Fisheries (NIOF). This location is about 5 km northern to Hurghada city, between longitudes 27°17.13' N and 27°17.09' N and latitudes 33 °46.43' E and 33 °46.47' E. The middle reef is situated in the area that has been subjected to landfilling which is associated with high sedimentation rate. El-Hamraween harbor (Site 3) is located about 60 km south of Safaga 20 km northern of
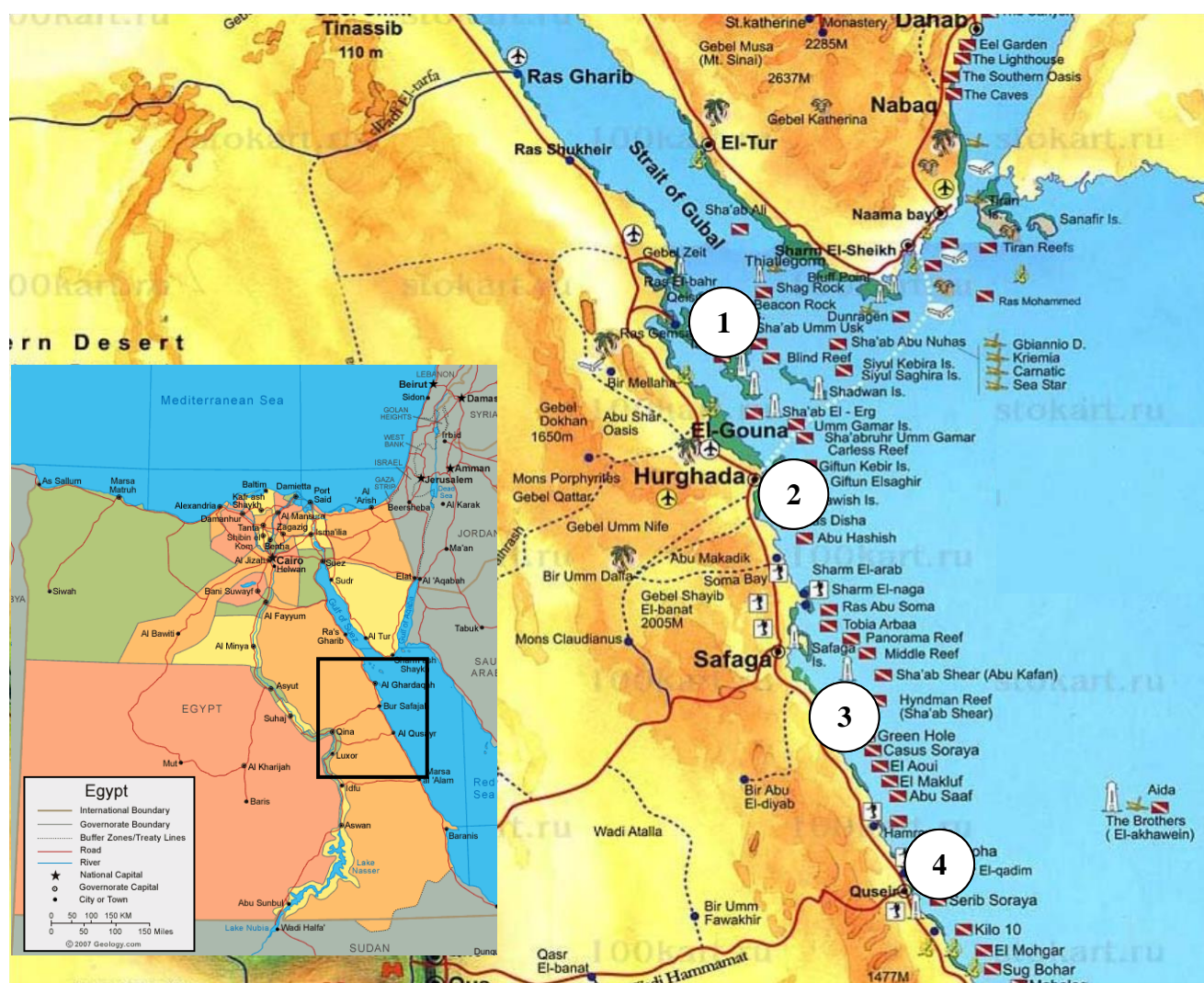


**Figure 1.** Location map of the studied site: 1. Ras El-Behar (northern Hurghada), 2. Middle Reef (Hurghada), 3.Kalawy bay (Safaga) and 4. Al-Hamraween harbor (El-Quseir).

El-Qusier City and about 120 from the Capital City of the Red Sea governorate (Hurghada). It is dominated between latitudes 26°15' 02" N and 26°15'17" N and longitudes 34°12' 07" E and 34°12'00" E. The site is impacted by heavy load of phosphate due to preparation and shipment operations of phosphate are in El-Hamraween harbor. Kalawy area (site 4) lies between latitudes 26°30'32" N and 26°30' 35"N and longitudes 34°03' 59" E and 34°04' 00" E. It lies about 30 km south Safaga City. This site is a pristine area, difficult to be accessed by fishermen because of the heavy wave breaking in addition to the tough patrolling in the area, thus it is considered as a control site in this study.

**Selection of studied species**

Two coral species from two families commonly dominating coral assemblages in the Red Sea were chosen for this study; *S. pistillata* (Esper 1795) and *A. humilis* (Dana 1846). The choice of coral species was mainly based on morphological and behavioral properties. The studied species have a digitate to branching growth form and comparable size of polyp (1-2 mm diameter). The use of branching rather than massive growth forms ensure that a small branch can be removed easier from the mother colony without damaging neither the corals living tissue nor the remainder of the colony or other reef benthos. The choice of the studied species has proved useful for examining patterns of fertility.

**Field sampling and maintenance**

Skirt fragments (<5 cm fragment) from three separate colonies of the studied species were seasonally collected at each of the three depth zones (reef flat, 3 m depth and 8 m depth). Only one terminal portion of the branch was sampled per coral colony, using a long-nosed bone cutter.

Samples were divided into two portions. The first part of sample was kept in the dark by wrapping them in aluminum foil and placed in whirl-package under water. On the deck, water was removed from the bags and immediately transferred to foam box filled with ice waiting for transportation to NIOF laboratories for analysis of chlorophyll concentration and zooxanthellae densities. The second part of the collected samples was stored in 10% formaldehyde in seawater for histological investigations. More than 128 polyps of *A. humilis* and *S. pistillata* ranging between 1.2 mm to 2.2mm in diameter were investigated histologically.

**Fertility measurements**

After 24 h in 10% formaldehyde sea water preservation, in the laboratory, pieces from the preserved branches were rinsed under the tap water for 15 min then decalcified with a solution of formic acid and sodium citrate for about 24-48 hours. The formic acid and sodium citrate were made up by adding the same volume of both formic acid and distilled water to make the formic acid solution, then sodium citrate salt was made up by dissolving 20 g of sodium citrate in 100 ml of distilled water. Finally, the two solutions were mixed in a ratio of 1:1. The mixed solution was poured into a beaker containing the samples until the decalcification process was completed. This method was preferred, since it was faster and easier to handle (Rinkevich and Loya 1979b). The decalcification process was continued until no skeletal materials remained. Samples were then preserved in Bouin's solution (Humason 1972) in plastic vials.

For histological analyses, tissue samples (0.75 to 1.5 cm$^2$) were taken from mid-branch (Rinkevich and Loya 1979b). All tissue samples were dehydrated in an ethanol series (Humason 1972), cleared in toluene and embedded in tissue prep. The prepared blocks were sectioned horizontally (i.e., parallel to the surface) at 10µm using an automatic microtome instrument. All tissue sections were stained with Harris Hematoxylin and counterstained with Eosin.

**Procedures of staining**

The sections were passed throughout the following stages: Xylene-1 10-12 min, Xylene-2 5 min, 100 %, 90%, 80%, 70% ethyl alcohol 5 min each, distilled water 1-2 min each, haematoxylin (HX) 3 min, distilled water 2 min, eosin 3 min, 80%, 90% and 100 alcohol 3 min each, 100% Butyl alcohol 3 min, Xylene-3 min. Mounting using Canada balsam or DPX on the section and cover the slide and put in oven at 60-70˚C.

*Hematoxylin (HX) staining.* HX 0.5 g, mercuric oxide 0.25 g, glacial acetic acid 4 ml, potas. alum 10 g, absolute alcohol 5 ml, distilled water 100 ml, dissolve the HX in alcohol, and the Pots. Alum in water, then mix them and heat to boiling, then add the mercuric oxide. When the solution becomes deep purple, stop heating, then cool and add the acetic acid to be used after 24 hours.

*Eosin.* Eosin yellow 1 g, distilled water, 100 ml, glacial acetic acid 0.5 ml. Each polyp was histologically examined under stereo binocular microscope (X20) then photographed using microscope camera. Finally, the eggs and testes sizes were measured by microscope eyepieces.

For the quantitative analyses, six pairs of mesenteries were exposed. Six mesenteries contained strings of eggs and six mesenteries developed testis, the number, and size of eggs were scored. Two measurements were taken for each egg, a "length" and a "width" measurement using a calibrated eyepiece micrometer in the dissecting microscope. The egg size was the mean of these two measures. The polyp egg size was the mean of the individual egg sizes. "Egg total" was calculated by adding all the individual egg sizes (or by multiplying the polyp egg size by the polyp egg number). Testes were counted for the testes number. The length and width of each testis were measured and the mean of these measurements was called the testes size. Total testes were calculated by multiplying the polyp testis size by the polyp testes number.

## RESULTS AND DISCUSSION

Both of *A. humilis* and *S. pistillata* are simultaneous hermaphroditic species has appeared in the sections (Figure 2). Each of the male gonads (testes) and female ones (ova) are located in the same polyp. Testes and ovaries develop
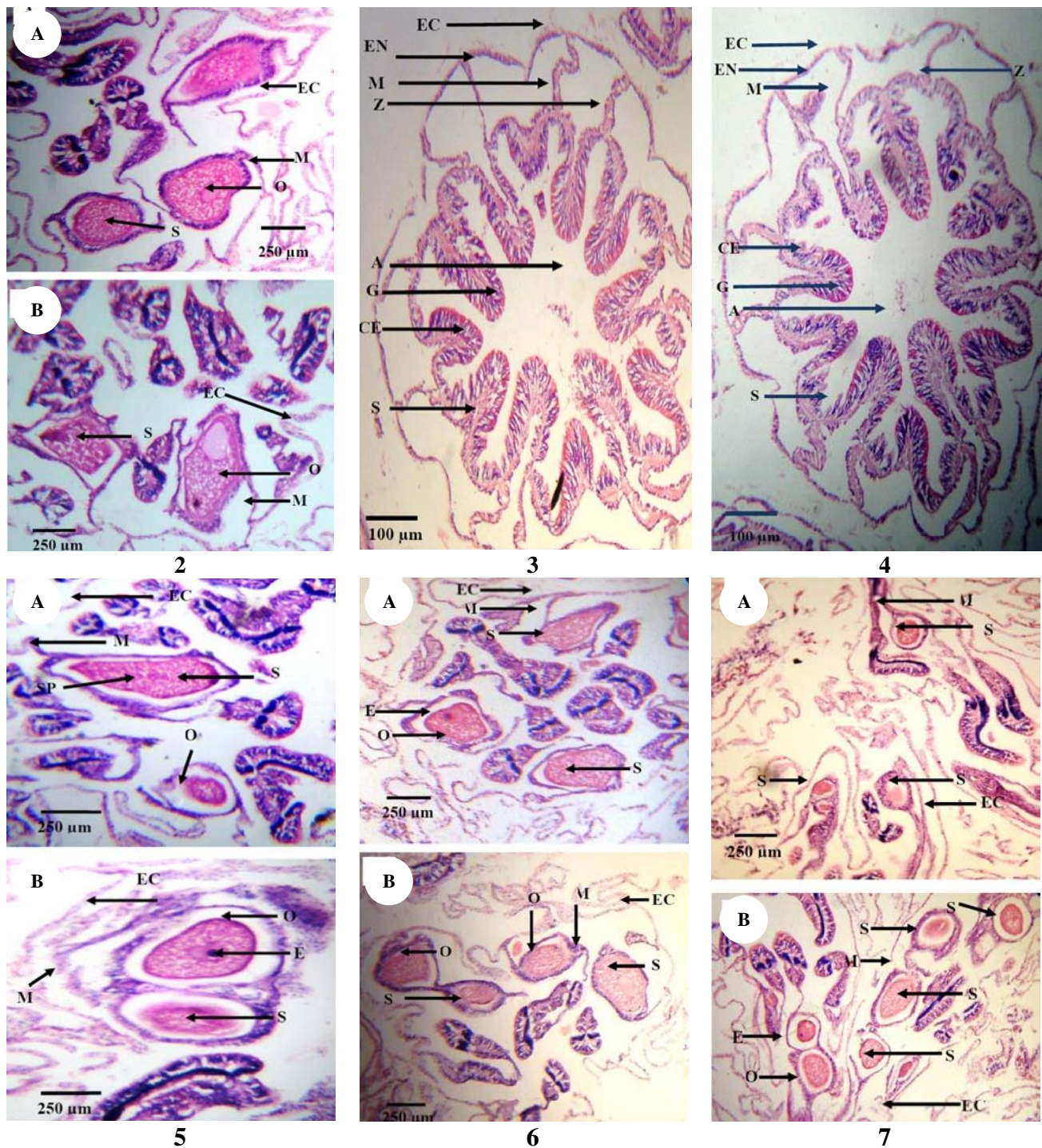
**Figure 2.** Transverse section of the lower part of a mature hermaphrodite polyp showing male and female gonad in one polyp. A). *S. pistillata. B). A. humilis*; EC ectoderm; M mesentery; O female gonad; S male gonad.

**Figure 3.** A general histological structure of *A. humilis* polyp in the stomodael portion showing six pairs of mesenteries: A. actinopharynx; CE columnar epithelial; EC ectoderm; EN endoderm; G glandular cell; M mesentery; S siphonoglyph; Z zooxthanthela.

**Figure 4.** A general histological structure of *S. pistillata* polyp in the stomodael portion showing six pairs of mesenteries: A. actinopharynx; CE columnar epithelial; EC ectoderm; EN endoderm; G glandular cell; M mesentery; S siphonoglyph; Z zooxthanthela.

**Figure 5.** Transverse section of *A. humilis* (A): Male and female gonads during summer season at site 1. (B). Female gonad containing mature egg during Winter season at site 1. EC, ectoderm, M mesentery, O, female gonad, S, male gonad, SP, sperm, E, egg.

**Figure 6.** Transverse section of *A. humilis,* (A): Testes full of sperms and ovary containing egg during winter season at site 2. (B). Testes and ovary during Summer season at site 2. EC ectoderm, M mesentery, O female gonad, S male gonad, E egg.

**Figure 7.** Transverse section of *A. humilis* (A): Testes during autumn season at site 3. (B). Male gonad and female one containing mature egg during winter season at site 3. EC ectoderm, M mesentery, O female gonad, S male gonad, E egg.
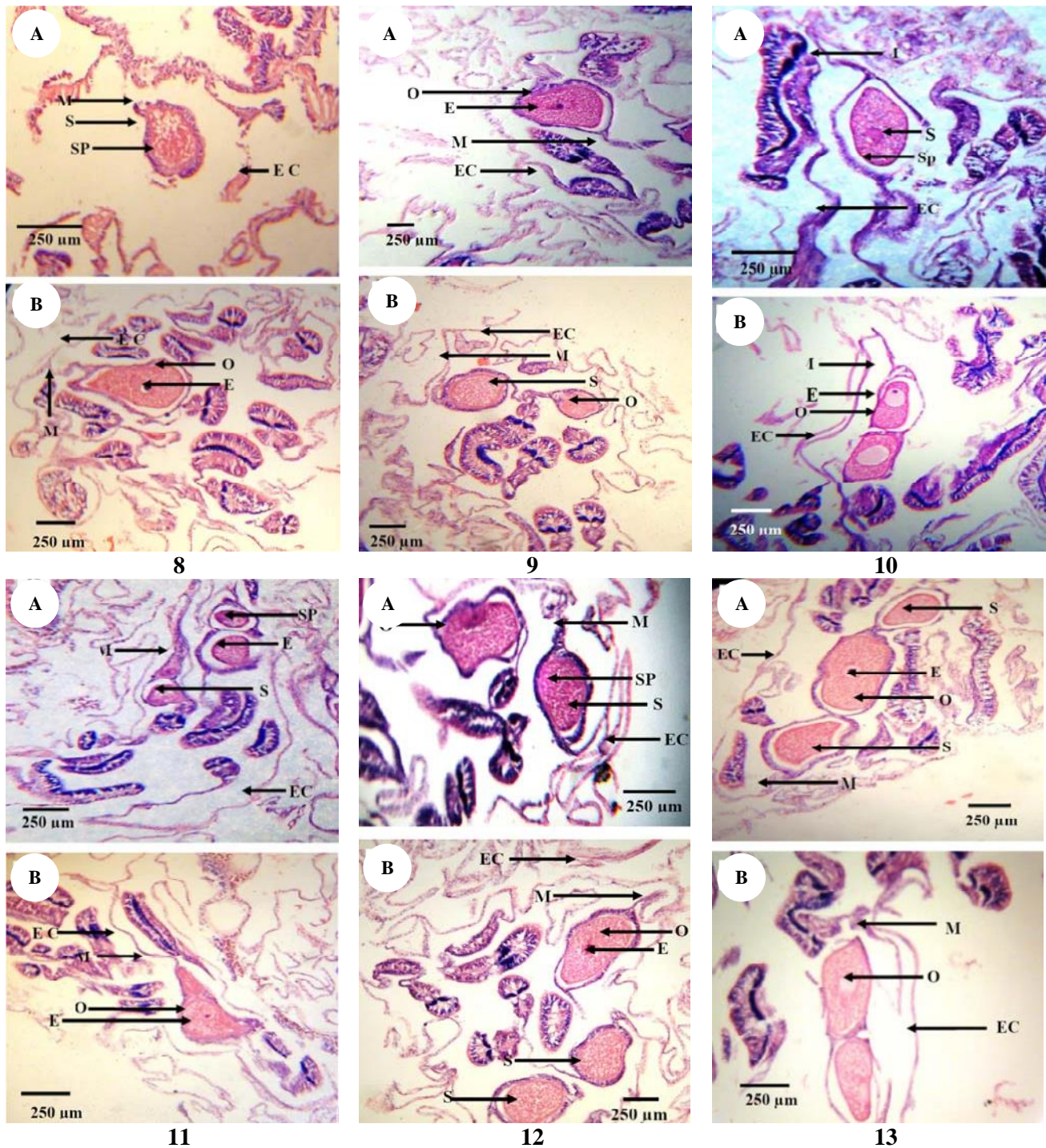
**Figure 8.** Transverse section of *A. humilis* (A): Testes full of sperms during winter season at site 4. (B). Female gonad containing mature egg during winter season at site 4. EC ectoderm, M mesentery, O female gonad, S male gonad, Sp sperm, E egg.

**Figure 9.** Transverse section of *S. pistillata* (A): Female gonad containing mature egg during winter season at site 1. (B). Male gonad and Female gonad during spring season at site 1. EC ectoderm, M mesentery, O female gonad, S male gonad, E egg.

**Figure 10.** Transverse section of *S. pistillata* (A): Testes full of sperms during winter season at site 2. (B). Female gonad containing mature egg during winter season at site 2. EC ectoderm, M mesentery, O female gonad, S male gonad, Sp sperm, E egg.

**Figure 11.** Transverse section of *S. pistillata* (A): Testes full of sperms during winter season at site 3. (B). Female gonad containing mature egg during winter season at site 3. EC ectoderm, M mesentery, O female gonad, S male gonad, Sp sperm, E egg.

**Figure 12.** Transverse section of *S. pistillata* (A): Testes full of sperms during winter season at site 4. (B). Female gonad containing mature egg during spring season at site 4. EC ectoderm, M , mesentery, O female gonad, S male gonad, Sp sperm, E egg.

**Figure 13.** Transverse section of *S. pistillata* (A): Ovary containing Mature egg and Testes full of sperms during winter season at site 4. (B). Female gonad having no egg during summer season at site 4. EC ectoderm, M mesentery, O female gonad, S male gonad, E egg.

**Table 1**. Annual means of total testes (µm) and total eggs of the two studied species *A. humilis* and *S. pistillata* at the four studied sites.

| Species | Sites | Testes number | Testes size | Total testes | Egg number | Egg size | Total eggs |
|---|---|---|---|---|---|---|---|
| *A. humilis* | Site 1 | 1.37±0.71 | 222.73±103.34 | 331.45±227.67 | 0.562±0.81 | 64.5±86.58 | 95.65±137.47 |
| | Site 2 | 1.75±1.29 | 249.37±150.28 | 588.18±567.81 | 1.5±1.75 | 91.4±95.26 | 281.4±338.86 |
| | Site 3 | 3.31±1.92 | 233.15±76.72 | 880.53±622.79 | 2.12±2.14 | 51.03±53.06 | 220.15±258.29 |
| | Site 4 | 2.68±1.07 | 324.53±11 | 960.4±691.06 | 1.31±1.77 | 86.78±102.29 | 269.34±377.42 |
| *S. pistillata* | Site 1 | 1.5±0.96 | 254.65±118.64 | 450.65±330.24 | 0.87±1.02 | 86.65±93.37 | 158.75±208.87 |
| | Site 2 | 2.12±1.2 | 370.06±112.93 | 844.71±594.17 | 1.81±1.51 | 119.34±88.73 | 330.46±300.77 |
| | Site 3 | 3.4±1.29 | 289.79±38.37 | 1021.67±490.83 | 2.75±2.14 | 78.9±55.68 | 320.96±262.36 |
| | Site 4 | 2.37±1.31 | 408.68±143.67 | 1106.03±813.03 | 1.68±1.66 | 147.03±121.23 | 366.9±94.44 |

**Table 2**. Seasonal testes number, testis size (µm) (testis length x testis width) and total testes of *A. humilis* at the studied sites respectively (X`±SD).

| Seasons | Sites | Egg number | Egg width | Egg length | Egg size | Total eggs |
|---|---|---|---|---|---|---|
| Autumn | Site 1 | 1.5±0.577 | 199±10.42 | 215±14.44 | 207±12.36 | 310.25±121.15 |
| | Site 2 | 1.25±0. 95 | 164±109.38 | 171±114.07 | 167.5±111.72 | 280.375±216.8 |
| | Site 3 | 1.5±1.29 | 142±95.31 | 145.25±97.31 | 143.625±96.3 | 292.375±258.49 |
| | Site 4 | 2±0.81 | 218.75±16.37 | 182.75±105.38 | 200.75±59.18 | 397.25±210.9 |
| Winter | Site 1 | 1.75±95 | 331.25±33.78 | 353.75±37.24 | 342.5±35.5 | 583±266.48 |
| | Site 2 | 3.25±0.95 | 419±13.49 | 453±9.3 | 436±7.03 | 1412±397.29 |
| | Site 3 | 5.75±0.5 | 302.75±51.37 | 301.5±6.65 | 302.125±25.12 | 1742.375±256.43 |
| | Site 4 | 4.25±0.5 | 445.5±45.58 | 525.25±62.56 | 485.375±46.1 | 2053.37±197.18 |
| Spring | Site 1 | 1.25±0.5 | 256.75±8.22 | 264.5±7.41 | 260.625±6.82 | 326±131.5 |
| | Site 2 | 1.75±0.95 | 286.5±8.88 | 294.25±10.99 | 290.375±9.84 | 506.875±279.64 |
| | Site 3 | 4±0.816 | 262.5±24.11 | 272±19.51 | 267.25±21.68 | 1056.875±146.77 |
| | Site 4 | 2.5±0.577 | 340.75±16.62 | 352.25±13.17 | 346.5±14.76 | 860±164.2 |
| Summer | Site 1 | 1±0.81 | 145.25±97.003 | 96.25±111.15 | 80.83±61.029 | 113.33±110.5 |
| | Site 2 | 0.75±0.95 | 103.5±119.68 | 103.75±119.95 | 103.625±119.82 | 153.5±192.5 |
| | Site 3 | 2±0.81 | 215.25±15.77 | 224±14.94 | 219.625±15.22 | 430.5±148.74 |
| | Site 4 | 2±0 | 262±26.64 | 269±24.58 | 265.5±25.57 | 531±51.15 |

**Table 3.** Seasonal egg number, egg size (µm) (egg length x egg width) and total eggs of *A. humilis* at the studied sites (X`±SD).

| Seasons | Sites | Egg number | Egg width | Egg length | Egg size | Total eggs |
|---|---|---|---|---|---|---|
| Autumn | Site 1 | 0.75±0.95 | 69.25±79.98 | 77.75±89.82 | 75.75±87.68 | 111.75±139.37 |
| | Site 2 | 2.25±0.95 | 159.25±9.06 | 174.25±10.93 | 166.75±9.91 | 381.375±174.55 |
| | Site 3 | 3±0.81 | 92.5±4.9 | 100.25±2.21 | 96.375±3.14 | 287.5±71.2 |
| | Site 4 | 1.25±0.95 | 132.25±88.32 | 136.5±91.01 | 134.375±89.64 | 225.125±174.41 |
| Winter | Site 1 | 1.5±0 .57 | 173.75±7.71 | 190.75±6.39 | 182.2±7.02 | 270.87±96.87 |
| | Site 2 | 3.75±0.95 | 188.75±7.58 | 209±5.35 | 198.87±5.49 | 744.25±183.18 |
| | Site 3 | 5.5±0.57 | 105.25± 9.77 | 110.25±9.74 | 107.75±9.75 | 593.125±87.98 |
| | Site 4 | 4±0.81 | 204±6.05 | 221.5±4.79 | 212.75±4.94 | 852.25±180.58 |
| Spring | Site 1 | 0 | 0 | 0 | 0 | 0 |
| | Site 2 | 0 | 0 | 0 | 0 | 0 |
| | Site 3 | 0 | 0 | 0 | 0 | 0 |
| | Site 4 | 0 | 0 | 0 | 0 | 0 |
| Summer | Site 1 | 0 | 0 | 0 | 0 | 0 |
| | Site 2 | 0 | 0 | 0 | 0 | 0 |
| | Site 3 | 0 | 0 | 0 | 0 | 0 |
| | Site 4 | 0 | 0 | 0 | 0 | 0 |

**Table 4**. Seasonal testes number, testis size (µm) (testis length x testis width) and total testes of *S. pistillata* at the studied sites (X`±SD).

| Seasons | Sites | Egg number | Egg width | Egg length | Egg size | Total eggs |
|---|---|---|---|---|---|---|
| Autumn | Site 1 | 1.25±1.25 | 190.75±127.26 | 197±131.33 | 193.875±129.28 | 324.625±329.65 |
| | Site 2 | 1.75±0.95 | 386.25±16.007 | 406.5±8.81 | 396.375±12.37 | 695.375±386.3 |
| | Site 3 | 2.75±0.95 | 259.5±10.47 | 267.25±10.68 | 263.375±10.56 | 718.25±224.68 |
| | Site 4 | 2±0.81 | 418±19.91 | 435.5±17.36 | 426.75±18.63 | 843.75±311.72 |
| Winter | Site 1 | 1.75±1.25 | 290± 199.28 | 330± 223.035 | 310±210.98 | 709.125±481.58 |
| | Site 2 | 3±0.816 | 519.75±12.25 | 535.5±8.18 | 527.625±8.11 | 1584±432.52 |
| | Site 3 | 4.75±0.5 | 323.5±7.76 | 378.25±13.59 | 350.875±6.38 | 1667.875±191.23 |
| | Site 4 | 4±0.81 | 553.5±21.7 | 591±8.3 | 572.375±14.9 | 2296.37±507.93 |
| Spring | Site 1 | 1.75±0.95 | 257 9.83±9.83 | 267.5±6.55 | 262.25±7.96 | 453.25±234.07 |
| | Site 2 | 2.75±1.25 | 318.75±28.33 | 333±24.46 | 325.875±26.27 | 872.125±360.85 |
| | Site 3 | 4.25±0.5 | 287.75±11.87 | 307.25±5.85 | 297.5±8.86 | 1263.125±136.91 |
| | Site 4 | 2.25±0.95 | 390±20.7 | 421.25±17.74 | 405.625±19.06 | 901.125±360.77 |
| Summer | Site 1 | 1.25±0.5 | 245.75±4.03 | 259.25±2.87 | 252.5±1.22 | 315.62±126.255 |
| | Site 2 | 1±0.81 | 223±16.57 | 237.75±14.45 | 230.375±14.77 | 227.375±176.34 |
| | Site 3 | 2±0.7 | 249.25±5.49 | 259.5±2.69 | 254.375±3.89 | 506±172.19 |
| | Site 4 | 1.25±0.95 | 220.75±147.26 | 319±159.63 | 230±153.39 | 382.875±292.62 |

**Table 5**. Seasonal egg number, egg size (µm) (egg length x egg width) and total eggs of *S. pistillata* at the studied sites (X`±SD).

| Seasons | Sites | Egg number | Egg width | Egg length | Egg size | Total eggs |
|---|---|---|---|---|---|---|
| Autumn | Site 1 | 1±0.81 | 123.25±82.5 | 129.5±86.43 | 126.375±84.43 | 166.625±131.62 |
| | Site 2 | 3±0.81 | 163.5±4.79 | 168.5±5.06 | 166±4.77 | 495.25±122.2 |
| | Site 3 | 4±0.81 | 115.25±6.94 | 119.5±4.65 | 117.375±5.76 | 466.25±75.31 |
| | Site 4 | 1.75±0.95 | 145.5±5.91 | 150.25±7.27 | 295.75±13.14 | 509.75±257.19 |
| Winter | Site 1 | 1.75± 1.25 | 156.25± 104.44 | 161± 112.41 | 158.87± 107.3 | 376.75± 260.29 |
| | Site 2 | 3.25±0.5 | 212.75± 9.77 | 220.25± 6.18 | 216.5± 7.87 | 700.87± 81.2 |
| | Site 3 | 5±0.81 | 116.25± 5.43 | 130.5±4.04 | 123.37±4.71 | 619.37± 123.29 |
| | Site 4 | 4±0.81 | 208.75±5.43 | 219± 6.05 | 213.87±5.67 | 853.62± 160.43 |
| Spring | Site 1 | 0 | 0 | 0 | 0 | 0 |
| | Site 2 | 0 | 0 | 0 | 0 | 0 |
| | Site 3 | 0 | 0 | 0 | 0 | 0 |
| | Site 4 | 0 | 0 | 0 | 0 | 0 |
| Summer | Site 1 | 0.75±0.95 | 59±68.17 | 63.75±73.61 | 61.375±70.88 | 91.625±116.16 |
| | Site 2 | 1±0.81 | 92.25±61.57 | 97.5±65.01 | 94.875±63.28 | 125.75±100.87 |
| | Site 3 | 2±1.41 | 72.25±48.47 | 77.5±51.9 | 74.875±50.18 | 198.25±137.79 |
| | Site 4 | 1±0.81 | 76.75±51.33 | 80.25±53.61 | 78.5±52.47 | 104.25±84.19 |

within mesenteries between the retractor muscle and mesenterial filaments. The mesenteries were all perfect and arranged in up to 6 pairs (12 mesenteries) (Figures 3 and 4). Some mesenteries of polyp were unpaired. Testes usually consist of one to six spermaries, each spermary being separated from the others by a thin membrane, probably of mesogleal origin. The ovaries usually contain one ovum at maturation that is surrounded by a thick endodermal layer during early oogenesis.

Annual patterns of fertilities (average of the four seasons are shown in Table 1. Generally, the annual patterns of fertilities (total testes and total eggs) of the hermatypic coral *A. humilis* were lower than those in *S. pistillata* at the four studied sites. However, site 3 (El-Hamraween harbor), the site impacted with phosphate, recorded the highest annual mean of testes number and egg number in the two studied species *A. humilis* and *S. pistillata*. On the other hand, the highest annual mean of total testes of *A. humilis* and *S. pistillata* were recorded at site 4 (control site), having value of 960.4±691.06 µm and

1106.03±813.03 µm for both species respectively. The highest annual mean of total eggs of *A. humilis* was recorded in site 2 (281.4± 338.86 µm) while that of *S. pistillata* was found in site 4 (366.9±94.44 µm). The present study detected that site 1, the site impacted with oil pollution and fishing activities, recorded the lowest annual mean of testes number, total testes, egg number, and total egg for each of the two studied species.

**Fertility patterns of *A. humilis***

Data concerning the average seasonal testes number, total testes (µm) (testis length x testis width), egg number and total eggs (µm) (egg length x egg diameter) in for *A. humilis* at the study sites are shown in Tables (2, 3). The seasonal mean of testes number, testes size, and total testes at site 1 (Ras El-Behar) recorded their highest value in winter while the lowest values were recorded during summer. During the winter season, testes were observed fully of sperms in the sectioned polyps of *A. humilis* (Figure 5). Male gonads of *A. humilis* started their

development at the end of January and February and completed their development in April, while female gonads started their development at the end of October, becoming well developed in April. Eggs were detected only during autumn (average egg number = 0.75±0.95, egg size = 75.75±87.68 µm and average total eggs = 111.75±139.37 µm) and winter (average egg number = 1.5±0.57, egg size = 182.2±7.02 µm and average total eggs = 270.87±96.87 µm) at site 1.

At site 2 (Middle reef - NIOF) the maximum average of each of testes number, testes size and total testes of *A. humilis* were recorded during winter season, while the minimum values were recorded during summer season (Table 2, Figure 6). The average testes number during winter season was 3.25±0.95, and during summer season was 0.75±0.95 while the average total testes during winter season were 1412±397.29 µm, and during summer was 153.5±192.5 µm. The annual average of testes number was 1.75±1.29 and the annual average of total testes was 588.18±567.81 µm at site 2. The maximum average eggs number and total eggs of *A. humilis* at site 2 were recorded during winter season while the minimum values were recorded during autumn season.

The average testes number and total testes during winter season at site 3 (El-Hamraween harbor) were 5.75±0.5 and 1742.375±256.43 µm, respectively while in summer, the recorded values were 2±0.81 and 430.5±148.74 µm, respectively. However, the average egg number at site 3 was 3±0.81 in autumn and 5.5±0.57 in winter while the average total eggs were 287.5±71.2 µm in autumn and 593.125±87.98 µm in winter. Moreover, the annual average egg number was 2.12±2.14 and annual average total eggs were 220.15±258.29 µm at site 3 (Table 1).

In site 4 (Kalawy bay) the average testes number ranged from 2±0.81 during autumn and 2±0 during summer to 4.25±0.5 during winter season, with an average of 2.68±1.07 for the four seasons. The average total testes ranged from 397.25±210.9 µm during autumn to 2053.375±197.18 µm during winter season, with an average of 960.4±691.06 µm for the four seasons. However, the average egg number was 1.25±0.95 during autumn and 4±0.81 during winter, with an average of 1.31±1.77 for the four seasons. The average total eggs were 225.125±174.41 µm during autumn and 852.25±180.58 µm during winter, with an average of 269.34±377.42 µm during the four seasons (Table 3, Figure 8).

In general, the highest average of testes number, testes size and total testes of *A. humilis* were recorded during winter season at all sites (Table 2) (Figures 5, 6, 7, 8). On the contrary, the lowest values were recorded during summer season at sites 1 and 2 and during autumn at sites 3 and 4. Site 3 (the site impacted with phosphate) had the highest average testes number (5.75±0.5, winter). However, site 4 (control site) had the highest average testes size (485.375±46.1 µm, winter) and total testes (2053.375±197.18 µm, winter). In contrast, the minimum average testes number was found at site 2 (0.75±0.95, summer) while the minimum average testes size was recorded at site 1 (80.83±61.029 µm, summer). Also, the

lowest average total testes were recorded at site 1 (113.33±110.5 µm, summer). On the other hand, the highest average eggs number was recorded at sit 3 (5.5±0.57, winter) while the highest average total eggs were recorded at sit 4 (control site) (852.25±180.52 µm, winter) (Table 3). No eggs were detected during spring and summer season.

**Fertility patterns of *S. pistillata***

Data concerning the average seasonal testes number, total testes (µm) (testis length x testis width), egg number and total eggs (µm) (egg length x egg diameter) in *S. pistillata* in the study sites are shown in Tables (4, 5). Testes number of *S. pistillata* at site 1 during autumn season (1.25±1.25) and summer season (1.25±0.5) were less than those recorded during winter season (1.75±1.25) and spring season (1.75±0.95). Site 1 has an annual average testes number of 1.5±0.96 during the four seasons (Table 1). Moreover, the average testes size (310±210.98 µm) and total testes (709.125±481.58 µm) at site 1 during winter were higher than those during autumn (testes size = 193.875±129.28 µm and total testes = 324.625±329.65 µm) (Table 4) (Figure 9). The annual testes size and total testes at site 1 were 254.65±118.64 µm and 450.65±330.24 µm respectively. On the other hand, the lack of eggs in *S. pistillata* occurred only during spring season (breeding season) (Table 5) (Figure 9). The highest average egg number at site 1 was recorded during winter season (1.75±1.25) while the lowest average egg number was recorded during summer (0.75±0.95). Also, the maximum average total eggs at site 1 (376.75±260.29 µm) were recorded in winter while the minimum average total eggs (91.625±116.16 µm) was detected during summer. The average annual egg number, egg size, and total eggs at site 1 were 0.87±1.02, 86.65±93.37 µm and 158.75±208.87 µm, respectively.

At site 2 (Middle reef - NIOF), the maximum seasonal testes number of *S. pistillata* (3±0.81) was recorded in winter while the minimum one (1±0.81) was recorded during summer (Table 4), with an annual average of 2.12±1.2 (Table 1). However, the highest average of each value of testes size (527.625±8.11 µm) and total testes (1584±432.52 µm) was measured in winter (Table 4, Figure 10) while the lowest values (230.375±14.77 µm and 227.375±176.34 µm) were recorded in summer. The annual testes size was 370.06±112.93 µm while the annual total testes were 844.71±594.17 µm. On the other hand, the seasonal egg numbers at site 2 were 3±0.81, 3.25±0.5 and 1±0.81 during autumn, winter and summer, respectively (Table 5), with an annual value of 1.81±1.51 (Table 1). However, the seasonal total eggs at site 2 were 495.25±122.2 µm in autumn, 700.87±81.2 µm in winter and 125.75±100.87 µm in summer, with an annual value 330.46±300.77 µm.

The highest seasonal values of each of testes number (4.75±0.5), testes size (350.875±6.38 µm) and total testes (1667.875±191.23 µm) at site 3 (El-Hamraween harbor) were recorded during winter. (Table 4) (Figure 11). However, the minimum seasonal testes number (2±0.7), testes size (254.375±3.89 µm) and total testes (506±172.19

µm) were recorded during summer season, with annual value of 3.4±1.29, 289.79±38.37 µm and 1021.67±490.83 µm respectively. The seasonal egg numbers at site 3 were 4±0.81, 5±0.81 and 2±1.41 during autumn, winter and summer, respectively. Similarly, the seasonal egg sizes were 117.375±5.76 µm, 123.37±4.71 µm, 74.875±50.18 µm during autumn, winter and summer, respectively. The seasonal total eggs were 466.25±75.31 µm, 619.37±123.29 µm, and 198.25±137.79 µm in autumn, winter and summer respectively. However, the annual egg numbers and total eggs were 2.75±2.14 and 320.96±262.36 µm respectively.

In site 4 (Kalawy bay) the seasonal testes number ranged from 1.25±0.95 during summer to 4±0.81 during winter season, with an annual value of 2.37±1.31. In a similar manner, the average total testes ranged from 382.875±292.62 µm during summer to 2296.37±507.93 µm during winter, with an annual value of 1106.03±813.03 µm. The seasonal total eggs at site 4 were 509.75±257.19 µm, 853.62±160.43 µm, and 104.25±84.19 µm during autumn, winter and summer, respectively while, eggs number were 1.75±0.95, 4±0.81, and 1±0.81 during the same seasons respectively (Table 5, Figures 12 and 13).

Generally, the highest seasonal testes number, testes size and total testes of *S. pistillata* were recorded during winter season at all sites while the lowest values were recorded during summer (Tables 4). The highest seasonal testes number was recorded at site 3 (the site impacted with phosphate) (4.75±0.5, winter) while the highest seasonal testes size (572.375±14.9 µm) and total testes (2296.37± 507.93 µm) were recorded at site 4 (the control site) during winter. In contrast, the minimum average of each of testes number (1±0.81) and total testes (227.375±176.34 µm) was recorded at site 2 during summer while the minimum average testes size (193.875±129.28 µm) was recorded at site 1 during autumn. On the other hand, the highest average eggs number was recorded at sit 3 (5±0.81, winter) while the highest average egg size was recorded at site 4 (295.75±13.14 µm, autumn). Moreover, the maximum total eggs (853.62± 160.43µm) were recorded at site 4 (control site) during winter season, reporting no eggs during spring season.

**Discussion**

In the present study, histological methods were used to assess testes and egg size in *A. humilis* and *S. pistillata*. The dissection method could not be conducted as the polyps were too small to easily dissect without damaging gonads or losing oocytes. Histology has disadvantages including possible inaccuracies in oocyte size-measurements because of tissue shrinkage estimated to be 20 to 30% by Harriott (1983) and underestimating oocyte numbers by failing to section whole gonads or polyps (Harrison and Wallace 1990). Serial sectioning and the study of each section, while laborious will overcome the latter problem but it may still have a possible 20 to 30% of tissue shrinkage. Histological processing tends to cause oocyte shrinkage by dissolving the lipids despite the reasonably accurate mean seasonal values of total eggs and total testes.

Both of *A. humilis* and *S. pistillata* are simultaneous hermaphroditic species has appeared in the sections (Figure 2). This result coincides with that of Rinkevich and Loya (1979a), Richmond and Hunter (1990), Wolstenholme (2004), Nishikawa et al. (2003) and Zakai et al. (2006).

Measures of fecundity in the number of eggs or the number of planulae per polyp can provide a useful index of reproductive effort, in turn, a useful indicator of the health of a coral (Kojis and Quinn 1984; Harrison and Wallace 1990; Albright et al. 2008; Jokiel et al. 2008). Consequently, changes in these measures can be taken as indication of sublethal stress in corals. However, fecundity alone can underestimate the reproductive effort of the corals and is better combined with other reproductive measures such as size of eggs and volume of testes material (Harrison and Wallace 1990; Kolinski and Cox 2003; Glynn and Colley 2009; Harrison 2011). What was mentioned in the present study for the pattern of reproduction of *A. humilis* and *S. pistillata*, is generally consistent with that mentioned by Rinkevich and Loya (1979b), Richmond and Hunter (1990), Nishikawa et al. (2003), Wolstenholme (2004), Zakai et al. (2006) that each of these species is a simultaneous hermaphroditic species. According to Fadlallah (1983), in the hermaphroditic species of the branching coral, the ovaries and spermaries may develop on different mesenteries within the same polyp in the same colony at the same time (most acroporids and pocilloporids). In contrast, Kojis and Quinn (1981, 1982), Ayre and Miller (2006), and Okubo et al. (2007) reported that the same species have different reproductive seasons within one population.

In the present histological investigation, patterns of fertilities (total testes and total eggs) for the hermatypic coral *A. humilis* were lower than those in *S. pistillata* at the four studied sites. This appearance of disparity between the two species could be attributed to the differences in the polyp size of colonies of the two species or perhaps the larger total testes and total eggs of *S. pistillata* will result in the differences in reproductive mode (Rinkevich and Loya, 1979b; Fadlallah and Pearse 1982; Fadlallah 1985; Goffredo and Chadwick-Furman 2003; Zakai et al. 2006). Szmant et al. (1980) provided further evidence for the lack of relationship between egg size, polyp size and mode of development in corals. Carroll et al. (2006) and Rinkevich and Loya (1979b) indicated that *A. humilis* is a spawning species where the fertilization takes place externally while *S. pistillata* is a brooder species releasing planula larvae after the fertilization process.

The present investigation showed that site 3, the site impacted with phosphate, recorded the highest annual mean of testes number and egg number in the two studied species *A. humilis* and *S. pistillata*. This agrees with the laboratory finding of Ward and Harrison (2000) who found that corals exposed to elevated phosphorus resulted in producing more but smaller eggs, and more testes material. Waller and Tyler (2005) reported two main reproductive patterns in marine invertebrates, the production of small numbers of large oocytes, and the production of large numbers of small oocytes. The present data also recorded that, site 3 had the lowest egg size of each of *A. humilis* and *S. pistillata*.

Eutrophication causes significant problems for coral reefs, and can result in degradation of reef ecosystems (Pastorok and Bilyard 1985). Pollution may disrupt reproductive cycles in corals and inhibit larval settlement and post-settlement survival (Tomascik and Sander 1987; Albright et al. 2008; Jokiel et al. 2008), and the coral abundance and diversity of recruits decreased with increasing eutrophication (Hunte and Wittenberg 1992). There was a significant but small decrease in egg size (430 μm in control eggs to 408 μm in eggs from ammonium enrichment treatments), but no differences in total fecundity or fertilization success. This may be related to the presence of zooxanthellae in the eggs of *M. capitata*, in contrast to changes in reproduction in *Acropora species*, whose eggs do not contain zooxanthellae (Cox and Ward 2002).

In shallow reef-building scleractinians, Harrison and Wallace (1990), Harrison (2006), Harrison (2008), and Harrison (2011) demonstrated an inverse relationship between oocyte size and fecundity. In the bathyal scleractinians from the NE Atlantic, sampled *Lophelia pertusa* produces relatively large numbers of small oocytes whereas *Madrepora oculata* produces small numbers of large oocytes. *L. pertusa* pattern is similar to that observed in *Oculina varicosa* which also produces large numbers of small oocytes (Brooke 2002). The present study detected that site 1, the site impacted with oil pollution and fishing activities, recorded the lowest annual mean of testes number, total testes, egg number and total egg in the two studied species *A. humilis* and *S. pistillata*. This agrees with the laboratory finding of Rinkevich and Loya (1979a) who found that chronic oil pollution damages the reproduction ability of *S. pistillata*. However, Guzmán and Holst (1993) evaluated the sublethal effects of oil on coral reproduction using healthy and injured colonies of the reef-building coral *Siderastrea siderea* at heavily oiled and un oiled reefs. Number of reproductive colonies and number of gonads per polyp were not sensitive to the level of oiling, but gonads were significantly larger at unoiled than oiled reefs during spawning periods. Oil pollution adversely affects sexual reproduction in coral (Harrison and Wallace 1990; Lane and Harrison 2002). Rinkevich and Loya (1977) found that the fecundity of colonies of the brooding coral *S. pistillata* was four times greater on an unpolluted reef compared with colonies on a reef subjected to chronic oil pollution near Eilat, Red Sea. Guzman and Holst (1993), and Lane and Harrison (2002) found that corals from the oiled reefs had smaller gonads than those from unaffected areas. Stress could also reduce reproductive output (Brown and Howard 1985; Fabricius et al. 2003; Vermeij et al. 2006, 2010; Torres et al. 2008; Humphrey et al. 2008; Randall and Szemant 2009; Harrison 2011) and even cause death in some cases (Ward 1995; Yakovleva et al. 2009).

In the present histological investigation, testes were observed full of sperms during winter season in the sectioned polyps of *A. humilis,* while eggs were detected during autumn and winter. This coincides with the investigations of Shlesinger and Loya (1985) that the female gonads require about five months (October to

February), while the male gonads require only two months (January and February) for maturity. Different synchronization occurred among hundreds of colonies of 20 *Acropora* species on equatorial reefs in Kenya where spawning occurred over 2-5 months within populations of different species, and gamete release in *Acropora* and some faviid species extended over a 9-month period from August to April (Mangubhai and Harrison 2006, 2009; Mangubhai 2009).

The same authors also reported that *A. humilis* release gametes during late spring and early summer. Kongjandtre et al. (2010) illustrations partially conflict with the investigations mentioned before, as he reported that the male gonads of *A. humilis* start their development at the end of January and February and complete their development in April, while female gonads start their development at the end of October before the male gonads become well developed at April. However, Gylnn et al. (2011) stated that reproduction of corals takes place mainly from March to May when seasonally high sea temperatures and rainfall prevailed in the Galápagos Islands.

In the studied coral species, the ova were developed first before spermeria. Rinkevich and Loya (1979a,b) found that spermeria have never been found alone but always in association with large number of ova. Oogenesis and spermatogenesis started in different periods, with spermaries appearing in approximately the eighth month of ovary development and lasting about 3 months (Pires et al. 1999; Harrison et al. 2011). The lack of eggs in *S. pistillata* in the present study occurred only during spring season at all the studied sites. This could be explained by the fact that the period between December and June was spent in the reproduction process releasing planulae where planulae show distinctive appearance at early spring (Rinkevich and Loya 1979a, b; Shlesinger and Loya 1985; Baird et al. 2010). The gonads development in *S. pistillata* is differing from *A. humilis*. However, female gonads in *S. pistillata* need approximately six months for maturation (July to December) while male gonads require only three months (October to December) (Baird et al. 2010). Richmond and Humter (1990) reported that the reproduction process in *A. humilis* and *S. pistillata* in the Red Sea occurs during spring and summer. However, corals in the inner and eastern Gulf of Thailand spawned following the full moons of February/March, whereas spawning in the southwestern Gulf of Thailand and the Andaman Sea occurred 1 month later following the full moons of March/April (Kongjandtre et al. 2010). In Western Australia, coral spawning occurs predominantly in autumn in contrast to the Great Barrier Reef on Australia's east coast where most spawning occurs in spring (Baird et al. 2010).

The breeding season of coral reefs differs in both different localities and different species (Baird et al. 2002; Wolstenholme 2004; Rosser and Gilmour 2008; Gilmour et al. 2009; Rosser and Baird 2009). It extends from December to July in the northern Red Sea, Gulf of Aqaba (Shlesinger and Loya 1985) and Southern Red Sea (the present study). While in *A. humilis*, the breeding season extends from February to June in the Great Barrier Reef (Bothwell 1981), in the Gulf of Aqaba (Shlesinger and

Loya 1985) and Hurghada (the present study). However, Baird et al. (2010) concluded that the major spawning season of corals on shallow-inshore reefs in the Dampier Archipelago is autumn, although taxa that spawn in spring and summer include *Porites* sp., *Acropora* sp., possibly *T. mesenterina* that are numerically dominant in many of these sites. Consequently, management initiatives to limit the exposure of coral spawn to stressors associated with coastal development may be required in up to five months per year.

## CONCLUSIONS AND RECOMMENDATIONS

Patterns of fertilities (total testes and total eggs) for the hermatypic coral *A. humilis* were lower than those in *S. pistillata* at the four studied sites. Site 3, the site impacted with phosphate, recorded the highest annual mean of testes number and egg number in the two studied species *A. humilis* and *S. pistillata*. However, site 1, the site impacted with oil pollution and fishing activities, recorded the lowest annual mean of testes number, total testes, egg number and total egg for the two studied species. Thus, phosphorus enrichment seems to be considerably less destructive than oil pollution, and thus may represent an 'eco-friendly'. Testes were observed fully of sperms during winter season in the sectioned polyps of *A. humilis,* while eggs were detected during autumn and winter. However, the lack of eggs in *S. pistillata* occurred only during spring season at all the studied sites. In the studied coral species, the ova were developed first before spermeria. The breeding season of coral reefs differs in both different localities and different species extending from December to July in the northern Red Sea, Gulf of Aqaba and Southern Red Sea (the present study). While in *A. humilis*, the breeding season extends from February to June in the Great Barrier Reef, in the Gulf of Aqaba and Hurghada (the present study).

Tough control, public awareness and continuous shore patrolling to the activities of oil pollution and fishing activities at the vicinity of site 1 are urgent. Site 4 is already virgin, and needs more guarding to keep that site always pristine. Precise review on the effect of phosphate on corals is necessary as result of the present field study is different from most other literature in that regard. Although existing corals may continue to grow and survive in an area with elevated nutrients levels, it is essential to maintain water quality on coral reefs within ecologically appropriate limits to ensure successful reproduction of coral and provide recruits for the long-term maintenance and renewal of coral populations. Management strategies to limit the exposure of coral spawn to stressors associated with coastal development are urgent. Scientists should participate in policy debates to improve coral reef legislation and implementation.

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