OBSERVATION ARTICLE

High reproductive synchrony of *Acropora* (Anthozoa: Scleractinia) in the Gulf of Aqaba, Red Sea [version 1; peer review: 2 approved]

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Abstract

Coral spawning in the northern Gulf of Aqaba has been reported to be asynchronous, making it almost unique when compared to other regions in the world. Here, we document the reproductive condition of *Acropora* corals in early June 2014 in Dahab, in the Gulf of Aqaba, 125 km south of previous studies conducted in Eilat, Israel. Seventy-eight percent of *Acropora* colonies from 14 species had mature eggs, indicating that most colonies will spawn on or around the June full moon, with a very high probability of multi-species synchronous spawning. Given the proximity to Eilat, we predict that a comparable sampling protocol would detect similar levels of reproductive synchrony throughout the Gulf of Aqaba consistent with the hypothesis that high levels of spawning synchrony are a feature of all speciose coral assemblages.

Open Peer Review

Reviewer Status ✓ ✓

	Invited Reviewers	
	1	**2**
version 1 published 05 Jan 2015	✓ report	✓ report

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Any reports and responses or comments on the article can be found at the end of the article.

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Observation

Multi-species synchronous spawning of scleractinian corals is a feature reported from almost all speciose coral assemblages (Baird *et al.*, 2009a; Baird *et al.*, 2010; Raj & Edwards, 2010), including the Arabian Sea (Baird *et al.*, 2014), and the Red Sea (Bouwmeester *et al.*, 2011; Bouwmeester *et al.*, 2014; Hanafy *et al.*, 2010). A notable exception is at Eilat, on the Israeli coast, in the Gulf of Aqaba, where spawning is described as asynchronous with different species spawning in different seasons, on different months, and at different stages of the lunar cycle, with no overlap in spawning between species (Shlesinger & Loya, 1985; Shlesinger *et al.*, 1998).

Here, we quantify the reproductive synchrony of *Acropora* corals in Dahab, on the Egyptian coast of the Gulf of Aqaba, 125 km south of Eilat, Israel (Figure 1). Among Red Sea reef habitats, fringing reefs in the Gulf of Aqaba support distinct coral assemblages with high cover and diversity of hard corals (DeVantier *et al.*, 2000).

The reproductive condition of 90 colonies from 15 *Acropora* species was assessed at two dive sites in Dahab, Um Sid (28° 25'14.16"N, 34° 27'27.52"E) and Eel Garden (28° 30'19.21"N, 34° 31'15.58"E), from the 2nd to the 4th of June 2014, a week before the full moon that month (Table 1). *Acropora* colonies at 1–10m depth were examined on snorkel by breaking 1–3 coral branches below the sterile apical zone to expose the developing oocytes. Colonies were recorded as mature when oocytes were visible and pigmented (Figure 2), immature when oocytes were visible and white, and empty when oocytes were too small to see with the naked eye or absent (following Baird *et al.*, 2002). Colonies with mature oocytes are highly likely to spawn close to the night of the next full moon (in this case, the June full moon), whereas colonies with immature eggs are likely to spawn on or around a full

Table 1. Percentage (%) of *Acropora* colonies with mature, immature, and no visible oocytes, on the 2–4 June 2014, in Dahab, Egypt, in the Gulf of Aqaba, Red Sea. n: number of sampled colonies.

Species	% mature	% immature	% empty	n
Acropora aculeus	100	0	0	4
Acropora cytherea	22	11	67	9
Acropora digitifera	100	0	0	6
Acropora eurystoma	86	0	14	7
Acropora gemmifera	100	0	0	7
Acropora horrida	0	0	100	1
Acropora humilis	50	25	25	8
Acropora lutkeni	75	0	25	4
Acropora microclados	100	0	0	4
Acropora monticulosa	100	0	0	7
Acropora nasuta	86	0	14	7
Acropora polystoma	80	0	20	10
Acropora cf *samoensis*	100	0	0	6
Acropora valida	100	0	0	3
Acropora variolosa	57	0	43	7
Total	**78**	**3**	**19**	**90**

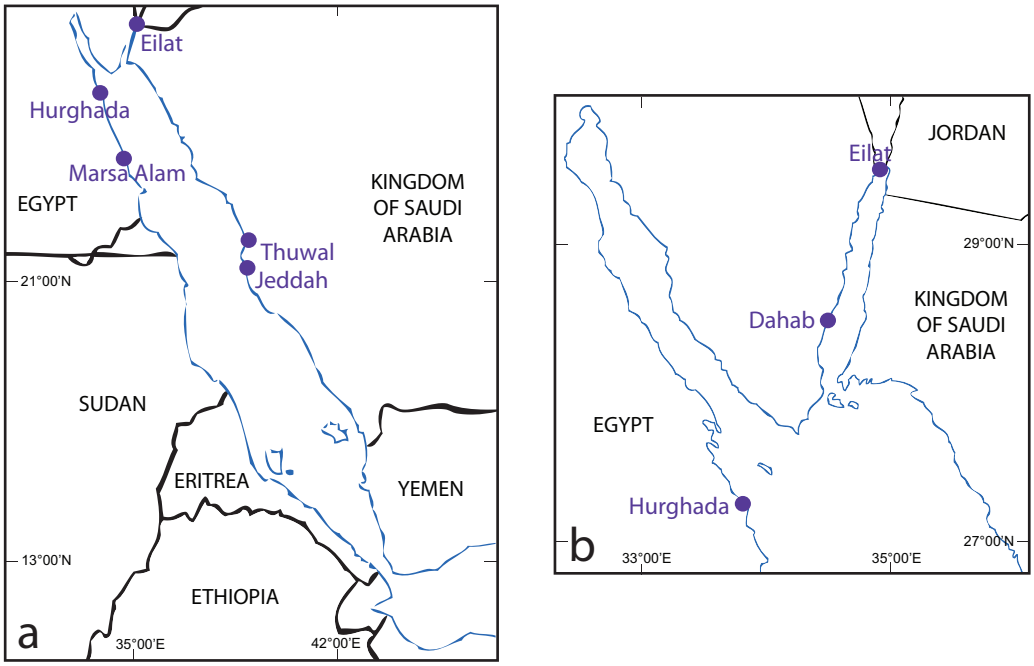

Figure 1. Map of **a** the Red Sea, showing the location of previous work on scleractinian coral spawning in the Red Sea, and **b** the Gulf of Aqaba, showing Dahab, our study site.

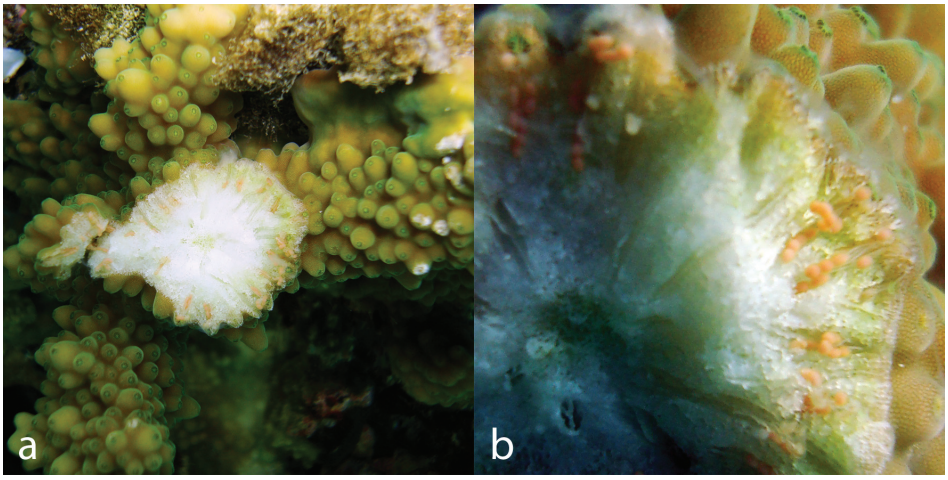

Figure 2. a Exposed oocytes in a mature colony of *Acropora variolosa* **b** close-up of pigmented oocytes.

moon one or two months later (in this case the July or August full moon). Colonies without oocytes have either already spawned or are unlikely to do so for at least three months.

Seventy-one percent of *Acropora* colonies had mature oocytes and an additional three percent had immature oocytes (Table 1). No oocytes were observed in the remaining colonies. Fourteen out of 15 species had at least one colony with mature eggs, and in seven of those species, 100% of the sampled colonies had mature eggs (Table 1).

The reproductive condition in the *Acropora* assemblage at Dahab in June is very similar to that estimated in *Acropora* assemblages on the Egyptian coast of the northern Red Sea, where 85% of colonies from 12 species had mature oocytes in Marsa Alam in April 2008 and 99% of colonies from 17 species had mature oocytes in Hurghada in April 2009 (Hanafy *et al.*, 2010). Subsequent sampling in both years revealed the absence of oocytes in all but one of these species, indicating that spawning had occurred sometime in the previous couple of weeks, most likely around the full moon of April (Hanafy *et al.*, 2010). Nighttime observations in 2012 in Hurghada revealed spawning of 12 *Acropora* species over two consecutive nights around the full moon of May (Kotb, 2012). Similarly, 13 *Acropora* species in Thuwal, central Red Sea (Figure 1a), were observed to spawn together on the same night, both in April 2011 and in April 2012, following initial reproductive surveys which revealed 65% of mature *Acropora* colonies from 9 species in 2011 and 39% of mature *Acropora* colonies from 16 species in 2012 (Bouwmeester *et al.*, 2014). The high percentage of species and colonies with mature oocytes in Dahab one week before the June full moon strongly suggests they will spawn synchronously as observed in Thuwal in the central Red Sea (Bouwmeester *et al.*, 2011; Bouwmeester *et al.*, 2014) and in Hurghada in the northern Red Sea (Hanafy *et al.*, 2010; Kotb, 2012). Broadcast spawning of corals in most locations of the Indo-Pacific occurs as sea surface temperatures are increasing or when temperatures are close to their annual maxima (Baird *et al.*, 2009a). In Dahab, waters start warming in the months of March-April, rising from 21–22°C to a maximum of 26–27°C in the month of August (Cornils *et al.*, 2007; Plähn *et al.*, 2002). Spawning in June most likely occurs when temperatures are ~24–25°C, possibly an optimum temperature for spawning and early larval development in the Gulf of Aqaba.

The month of spawning of *Acropora* species in the Gulf of Aqaba is two months later than in the northern and central Red Sea, where most *Acropora* spawn in April (Bouwmeester *et al.*, 2014; Hanafy *et al.*, 2010). This one or two-month offset is not surprising due to the difference in local temperature regimes and is similar to the latitudinal pattern observed along the east coast of Australia and from the Philippines to Japan (Baird *et al.*, 2009b). Spawning in Dahab does not seem to occur before the waters reach 24–25°C, suggesting that a minimal temperature threshold is required during the warming of surface waters for spawning. In the central Red Sea, those temperatures are reached in March-April, and indeed multi-species spawning of *Acropora* has been recorded in April at 25–27°C (Bouwmeester *et al.*, 2014).

Our data from Dahab match the data from Eilat (Shlesinger & Loya, 1985) for the timing of *Acropora* spawning in the Gulf of Aqaba, however, the larger number of *Acropora* species examined in the present study allows us to understand reproductive synchrony within this genus much more effectively. Indeed, we predict that with a comparable sampling protocol, similar levels of *Acropora* reproductive synchrony would be detected at Eilat, only 125 km north of Dahab, and would support the hypothesis that high levels of spawning synchrony are a feature of all speciose coral assemblages (Guest *et al.*, 2005). The length of the scleractinian reproductive season can be established by sampling distantly related species from the coral assemblage, which in Eilat lasts four months for broadcast spawning species (Guest *et al.*, 2005; Shlesinger & Loya 1985; Shlesinger *et al.*, 1998), but sampling closely related species such as *Acropora* species will determine whether overlap in spawning occurs and will allow estimation of the level of synchrony in the assemblage.

Author contributions

JB conceived the study and collected the data. All authors wrote the manuscript.

Competing interests

No competing interests were disclosed.

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Version 1

Reviewer Report 16 January 2015

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✔ **Andrew G. Bauman**
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This article presents information on the reproductive synchrony of 15 *Acropora* species in the southern Gulf of Aqaba, Red Sea. This is a sound study that used well-established sampling techniques, and provides adequate details for the methods, results and findings. Their results showed a high proportion of *Acropora* colonies (78%) sampled prior to the full moon in June had mature oocytes and suggest that most colonies will spawn in June, with a high probability of multi-species spawning. Most interestingly, their data matched previously spawning records from Eilat, 125km north of their site, providing additional evidence that high levels of spawning synchrony are likely a feature of all speciose coral assemblages.

NOTE: While I agree with the authors that it is likely that the colonies with mature (pigmented) oocytes are generally considered to spawn on, or shortly after, the subsequent full moon, conducting follow up surveys in the subsequent months (i.e., July and August) would confirm whether colonies are in fact releasing all of their gametes. In a similar reproductive study conducted in the neighboring Persian Gulf (Bauman *et al.,* 2011) mature colonies were found over four consecutive months suggesting that some colonies are either not releasing mature gametes or that some colonies are spawning twice.

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 07 January 2015

https://doi.org/10.5256/f1000research.6425.r7207

Jean Kenyon
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The research uses an accepted method of assessing reproductive condition in *Acropora* colonies. The article clearly and concisely reports the location, species, and number of colonies sampled and provides background context on other coral reproductive sampling in the Red Sea, which combine to bring the reader to the same conclusions as the authors regarding multi-species spawning synchrony in this region. One hopes the authors will find the resources to test their hypothesis that similar levels of *Acropora* reproductive synchrony would be detected at Eilat using a comparable sampling protocol. Overall, the writing (including title, abstract, and main body of text) is succinct and provides an appropriate level of detail.

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.