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First record of multi-species synchronous coral spawning from Malaysia

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Abstract

Knowledge about the timing and synchrony of coral spawning has important implications for both the ecology and management of coral reef ecosystems, however, data on spawning timing and extent of synchrony are still lacking for many coral reefs, particularly from equatorial regions and from locations within the coral triangle. Here we present the first documentation of a multi-species coral spawning event from reefs around Pulau Tioman, Peninsular Malaysia, a popular diving and tourist destination located on the edge of the coral triangle. At least 8 coral species from 3 genera and 2 families participated in multi-species spawning over five nights in April 2014, between two nights before and two nights after the full moon. Two *Acropora* species (*A. digitifera* and *A. tenuis*) also spawned one night prior to the full moon in October 2014. While two species of *Acropora* (*A. millepora* and *A. nasuta*) exhibited highly synchronous spawning in April (100% of sampled colonies), two other common species (*A. hyacinthus* and *A. digitifera*) did not contain visible eggs in the majority of colonies sampled (i.e., <15% of colonies) in either April or October, suggesting that these species spawn at other times of the year. To the best of our knowledge, this is the first detailed documented observation of multi-species coral spawning from reefs in Malaysia and these data support the contention that this phenomenon is a feature of all speciose coral assemblages. More research is needed, however, to determine the seasonal cycles and extent of spawning synchrony on these reefs and elsewhere in Malaysia.

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Introduction

Knowledge about the timing and synchrony of coral spawning has important implications for both the ecology and management of coral reef ecosystems (Guest, 2008). Broadcast spawning corals often release gametes synchronously during annual events to increase the chance of fertilization success within populations (Harrison & Wallace, 1990). In addition, within speciose coral assemblages there is often considerable overlap in spawning times among species, leading to multi-species spawning events involving many species and genera (Babcock et al., 1986). For years it was thought that these remarkable reproductive events were restricted to certain geographical regions (Oliver et al., 1988), however recent research from a wide range of locations has revealed that multi-species coral spawning is likely to be a feature of all speciose coral assemblages (Guest et al., 2005a, Baird et al., 2009, Bouwmeester et al., 2015). Nonetheless, data on spawning timing and extent of synchrony are still lacking for many coral reefs, particularly from equatorial regions and from locations within the coral triangle, an area of high species diversity encompassing Malaysia, Indonesia, the Philippines and New Guinea (Hoeksema, 2007). Evidence from reefs within the coral triangle suggest two coral spawning peaks in March/April and October/November, typically with a minor and a major spawning season for each location (Baird et al., 2009). Here we present the first documentation of a multi-species coral spawning event from reefs around Pulau Tioman, Peninsular Malaysia (2° 49' 09.39" N, 104° 09' 34.26" E), a popular diving and tourist destination located on the edge of the coral triangle.

Materials and methods

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Spawning timing for corals at sites around Pulau Tioman was examined using a variety of methods. Corals were sampled at two fringing reef sites on the west coast of Tioman (TDC House Reef: 2° 48' 56.47" N 104° 09' 05.66" E and; Tumuk: 2° 47' 32.80" N 104° 07' 22.02" E) on April 12 2014 (3 days before the full moon) and on October 7 2014 (1 day before full moon) to establish the extent of population synchrony within selected coral populations of *Acropora*. Sampling was done by removing up to three branches from randomly selected, independent (i.e., >5 meters apart), replicate colonies of *Acropora millepora*, *A. nasuta*, *A. hyacinthus* and *A. digitifera* (Table 1) (following Baird et al., 2002). *A. millepora*, and *A. nasuta* were only sampled in April whereas *A. hyacinthus*, *A. digitifera* were sampled in April and October. For each colony, the presence or absence of visible pigmented or white eggs was noted *in situ* by a snorkeler. The presence of pigmented oocytes is indicative of spawning on or close to the date of the next full moon, whereas the presence of visible white eggs indicates that colony will spawn within the next two to three months. Empty colonies have either recently spawned or will not spawn for at least three months (Baird et al., 2002). To establish the night and time of spawning and the extent of spawning synchrony, we placed small egg-sperm bundle traps (the base of an upturned plastic water bottle) over 12 gravid colonies of *A. millepora* and eight of *A. nasuta* on 12 April 2014 at TDC House Reef. Gamete traps were also placed over 2 colonies of *A. digitifera* and, in addition, 2 colonies of *A. tenuis* that were found to contain pigmented eggs on 7 October 2014. Traps were checked each morning for the presence or absence of released gametes until all colonies had spawned. Finally, night time observations were made at TDC House Reef by snorkelers on the nights of 13 to 17 April 2014 and on 8 and 9 October 2014 between the hours of 1900 and 2300 to document the timing of spawning and extent of species participation during multi-species spawning.

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Results and Discussion

100% of sampled colonies of *A. millepora* and *A. nasuta* contained visible pigmented eggs when sampled on 12 April 2014 (Table 1). In contrast 5% of *A. hyacinthus* colonies contained pigmented eggs in April with the remainder of the sampled colonies being empty; and all sampled colonies of *A. digitifera* were found to be empty in April (Table 1). In October, all *A. hyacinthus* colonies were empty whereas 14% of *A. digitifera* colonies contained pigmented eggs (Table 1). Examination of the gamete traps showed that 2 colonies (17%) of *A. millepora* colonies spawned on 13 April, while the remaining tagged colonies of both *A. millepora* and *A. nasuta* spawned on 14 April (one night before the full moon)(Fig. 1, Table 2). Similarly, in October, two tagged colonies each of *A. tenuis* and *A. digitifera* spawned on October 7 (one night before full moon). Coral spawning was observed in situ on four of the five nights of observation in April (13, 14, 16 and 17 April) between the hours of 2030 and 2200. No corals were observed to spawn on 15 April. At least 8 species from 3 genera and 2 families participated in the spawning event (Fig. 1, Table 2). All spawning occurred between 2030 h and 2230 h. Night time observations were carried out on October 8 and 9, but no spawning was witnessed on these nights. The number of species observed to participate in these events is relatively modest compared to spawning events seen elsewhere (e.g., Babcock et al., 1986), however observations were only carried out at one site by two or three observers, therefore we predict that more extensive sampling will reveal many more species participating in multi-species spawning events around Pulau Tioman. While two species of *Acropora* (*A. millepora* and *A. nasuta*) exhibited highly synchronous spawning in April, two other common species (*A. hyacinthus* and *A. digitifera*) did not contain visible eggs in the majority of colonies sampled in either April or October. While evidence from nearby locations suggest that March/April and October/November are the two main spawning

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peaks for this biogeographic region (Baird et al., 2009) extended spawning lasting several months are common on many Indo-Pacific coral reefs (e.g., Bouwmeester et al., 2015). We predict therefore that these and other species are spawning at other times of the year.

The seasonal timing of spawning for *A. millepora* and *A. nasuta* is consistent with observations from elsewhere within the coral triangle (e.g., Singapore, north-western Philippines, Indonesia)(Guest et al., 2002, Vicentuan et al., 2008, Permata et al., 2012). However the differences in timing for *A. hyacinthus* and *A. digitifera* is surprising as these species spawn during the major multi-species spawning period in April in nearby Singapore (Guest et al., 2005a) and Bintan, Indonesia (unpublished data). Furthermore, the lunar timing of spawning is earlier in Pulau Tioman than for conspecifics in Singapore. For example most species in Singapore spawn between 3 and 6 nights after the full moon (Guest et al., 2002, 2005a) whereas in Pulau Tioman corals spawned between 2 nights before and 2 nights after the full moon.

To the best of our knowledge, this is the first detailed documented observation of multi-species coral spawning from reefs in Malaysia and these data support the contention that this phenomenon is a feature of all speciose coral assemblages (Baird & Guest, 2008). More research is needed however to determine the seasonal cycles and extent of spawning synchrony on these reefs and elsewhere in Malaysia. In particular, year round sampling is needed establish reproductive phenologies for a range of species. Furthermore, comparisons of spawning timing among reefs, particularly those on either coast of Peninsular Malaysia would be of great interest as the two coasts experience contrasting monsoon seasons and environmental conditions (Toda et al., 2007).

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References

Babcock RC, Bull GD, Harrison PL, Heyward AJ, Oliver JK, Wallace CC, Willis BL 1986. Synchronous spawnings of 105 scleractinian coral species on the Great Barrier Reef. *Marine Biology* 90: 379-394.

Baird AH, Guest JR 2009. Spawning synchrony in scleractinian corals: comment on Mangubhai & Harrison (2008). *Marine Ecology Progress Series* 374: 301-304.

Baird AH, Marshall PA, Wolstenholme J 2002. Latitudinal variation in the reproduction of *Acropora* in the Coral Sea. In *Proceedings of the 9th International Coral Reef Symposium* 1: 385-389.

Baird AH, Guest JR, Willis BL 2009. Systematic and biogeographical patterns in the reproductive biology of scleractinian corals. *Annual Review of Ecology, Evolution, and Systematics* 40: 551-571.

Bouwmeester J, Baird AH, Chen CJ, Guest JR, Vicentuan KC, Berumen ML (2015). Multi-species spawning synchrony within scleractinian coral assemblages in the Red Sea. *Coral Reefs* 10.1007/s00338-014-1214-6

PeerJ PrePrints

Guest J 2008. Ecology. How reefs respond to mass coral spawning. *Science* 320:(5876) 621-623.

Guest JR, Baird AH, Goh BPL, Chou LM 2002. Multispecific, synchronous coral spawning in Singapore. *Coral Reefs*, 21: 422-423.

Guest JR, Baird AH, Goh BPL, Chou LM 2005a. Seasonal reproduction in equatorial reef corals. *Invertebrate Reproduction & Development* 48: 207-218.

Guest JR, Baird AH, Goh BPL, Chou LM 2005b. Reproductive seasonality in an equatorial assemblage of scleractinian corals. *Coral Reefs* 24: 112-116.

Harrison PL, Wallace CC 1990. Reproduction, dispersal and recruitment of scleractinian corals. In: *Ecosystems of the world*. Elsevier, Amsterdam 25: 133-207.

Hoeksema BW 2007. Delineation of the Indo-Malayan centre of maximum marine biodiversity: the Coral Triangle. In: *Biogeography, time, and place: distributions, barriers, and islands*. Springer, Netherlands 29: 117-178.

Oliver JK, Babcock RC, Harrison PL, Willis BL 1988. Geographic extent of mass coral spawning: clues to ultimate causal factors. In: *Proceedings of the 6th International Coral Reef Symposium* 2: 803-810.

Permata D, Indrayanti E, Haryanti D, Fika L, Arfiyan H, Achmad A 2012. Biannual multispecific spawning in Karimunjawa Archipelago, Indonesia. *Coral Reefs* 31: 907.

PeerJ PrePrints

Toda T, Tomoko O, Takeshi M, Alfian BAAK, Rajuddin MKM, Ryota N, Chen W, Kunio T. T, Othman BHR, Makoto T 2007. Community structures of coral reefs around Peninsular Malaysia. *Journal of Oceanography* 63: 113-123.

Vicentuan KC, Guest JR, Baria MV, Cabaitan PC, Dizon RM, Villanueva RD, Aliño PM, Edwards AJ, Gomez ED, Heyward AJ 2008. Multi-species spawning of corals in north-western Philippines. *Coral Reefs* 27: 83-83.

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Table 1. Proportion of population with pigmented eggs, white eggs and/or empty colonies in April and October 2014.

Species	Date	Pigmented (%)	White (%)	Empty (%)	n
Acropora millepora	12/04/2014	100	0	0	26
Acropora nasuta	12/04/2014	100	0	0	17
Acropora digitifera	12/04/2014	0	0	100	20
	7/10/2014	14	0	0	15
Acropora hyacinthus	12/04/2014	5	0	0	20
	7/10/2014	0	0	100	15

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Table 2. Species participation during a multi-species spawning event in April 2014. Spawning nights are relative to date of full moon in 2014 (April 15). Type of gamete release: B = egg-sperm bundles, S = sperm.

Family	Species	Spawning nights	Spawning time	Gametes released
Acroporidae	*Acropora millepora*	-2 to -1	2115 to 2200	B
	Acropora nasuta	-1	2115 to 2200	B
	Acropora humilis	-1	2115 to 2200	B
	Acropora valida	-1	2115 to 2200	B
	Montipora sp. 1	+1 to +2	2030 to 2225	B
	Montipora sp. 2	+2	2030 to 2225	B
Poritidae	*Porites* sp. 1	+1 to +2	2030 to 2225	S
	Porites sp. 2	+1	2115 to 2225	S

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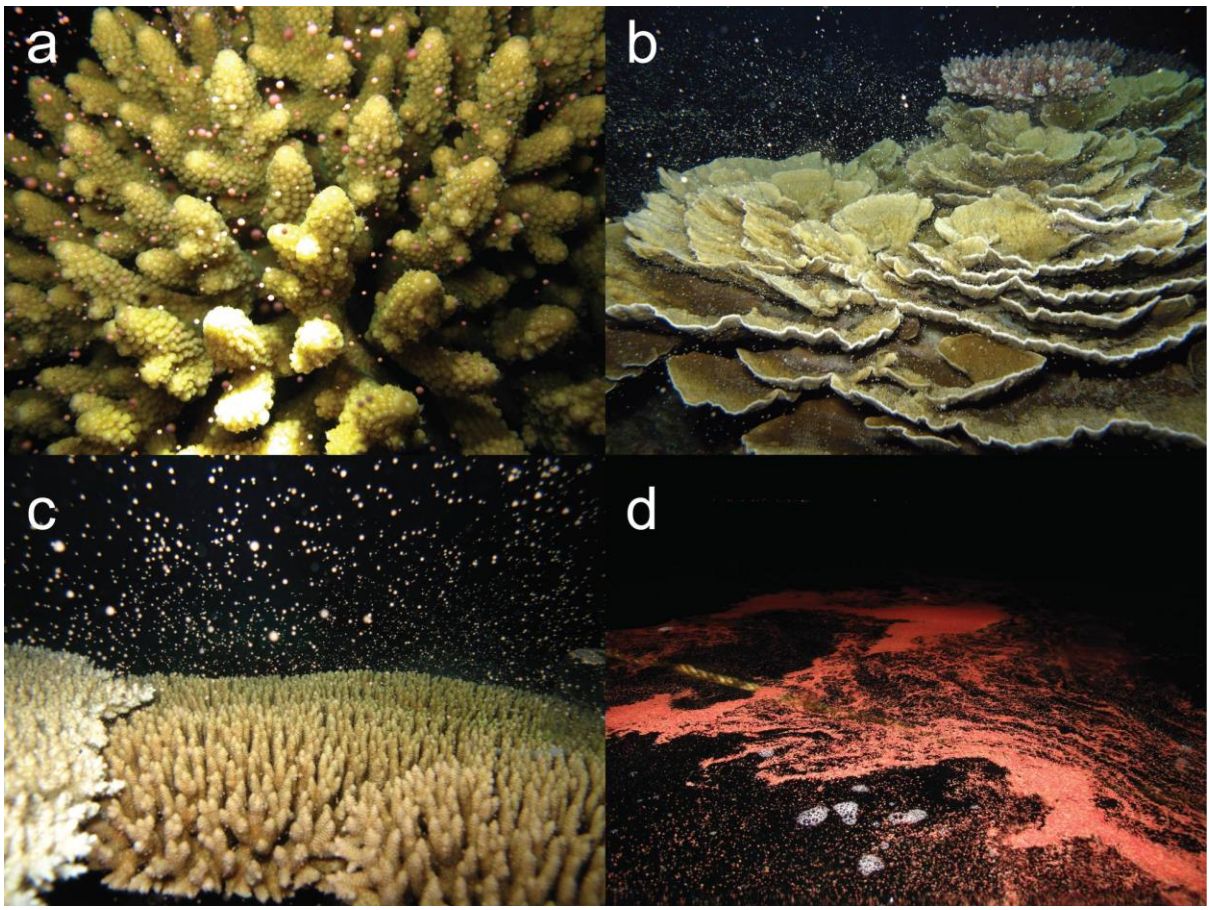
Fig. 1. Coral spawning in Pulau Tioman: a) *Acropora humilis*, b) *Montipora* sp. 1, c) *A. millepora* and d) gamete slick on surface immediately after spawning. Photos: Alvin Chelliah.



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