

First record of multi-species synchronous coral spawning from Malaysia

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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.

1 **First record of multi-species synchronous coral spawning from Malaysia**

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13 **Abstract**

14 Knowledge about the timing and synchrony of coral spawning has important implications for
15 both the ecology and management of coral reef ecosystems, however, data on spawning timing
16 and extent of synchrony are still lacking for many coral reefs, particularly from equatorial regions
17 and from locations within the coral triangle. Here we present the first documentation of a multi-
18 species coral spawning event from reefs around Pulau Tioman, Peninsular Malaysia, a popular
19 diving and tourist destination located on the edge of the coral triangle. At least 8 coral species
20 from 3 genera and 2 families participated in multi-species spawning over five nights in April
21 2014, between two nights before and two nights after the full moon. Two *Acropora* species (*A.*
22 *digitifera* and *A. tenuis*) also spawned one night prior to the full moon in October 2014. While
23 two species of *Acropora* (*A. millepora* and *A. nasuta*) exhibited highly synchronous spawning in
24 April (100% of sampled colonies), two other common species (*A. hyacinthus* and *A. digitifera*)
25 did not contain visible eggs in the majority of colonies sampled (i.e., <15% of colonies) in either
26 April or October, suggesting that these species spawn at other times of the year. To the best of our
27 knowledge, this is the first detailed documented observation of multi-species coral spawning
28 from reefs in Malaysia and these data support the contention that this phenomenon is a feature of
29 all speciose coral assemblages. More research is needed, however, to determine the seasonal
30 cycles and extent of spawning synchrony on these reefs and elsewhere in Malaysia.

31 **Introduction**

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

51 **Materials and methods**

52 Spawning timing for corals at sites around Pulau Tioman was examined using a variety of
 53 methods. Corals were sampled at two fringing reef sites on the west coast of Tioman (TDC House
 54 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
 55 12 2014 (3 days before the full moon) and on October 7 2014 (1 day before full moon) to
 56 establish the extent of population synchrony within selected coral populations of *Acropora*.
 57 Sampling was done by removing up to three branches from randomly selected, independent (i.e.,
 58 >5 meters apart), replicate colonies of *Acropora millepora*, *A. nasuta*, *A. hyacinth*
 59 *digitifera* (Table 1) (following Baird et al., 2002). *A. millepora*, and *A. nasuta* were
 60 in April whereas *A. hyacinthus*, *A. digitifera* were sampled in April and October. I
 61 the presence or absence of visible pigmented or white eggs was noted *in situ* by a
 62 presence of pigmented oocytes is indicative of spawning on or close to the date of the next full
 63 moon, whereas the presence of visible white eggs indicates that colony will spawn within the
 64 next two to three months. Empty colonies have either recently spawned or will not spawn for at
 65 least three months (Baird et al., 2002). To establish the night and time of spawning and the extent
 66 of spawning synchrony, we placed small egg-sperm bundle traps (the base of an upturned plastic
 67 water bottle) over 12 gravid colonies of *A. millepora* and eight of *A. nasuta* on 12 April 2014 at
 68 TDC House Reef. Gamete traps were also placed over 2 colonies of *A. digitifera* and, in addition,
 69 2 colonies of *A. tenuis* that were found to contain pigmented eggs on 7 October 2014. Traps were
 70 checked each morning for the presence or absence of released gametes until all colonies had
 71 spawned. Finally, night time observations were made at TDC House Reef by snorkelers on the
 72 nights of 13 to 17 April 2014 and on 8 and 9 October 2014 between the hours of 1900 and 2300
 73 to document the timing of spawning and extent of species participation during multi-species
 74 spawning.

I suggest including a brief justification for sampling dates here (i.e. days within the spawning season reported for *Acropora* in the Coral Triangle, cf. Baird et al 2009).

Effort in hours?

75 Results and Discussion

76 100% of sampled colonies of *A. millepora* and *A. nasuta* contained visible pigmented eggs when
77 sampled on 12 April 2014 (Table 1). In contrast 5% of *A. hyacinthus* colonies contained
78 pigmented eggs in April with the remainder of the sampled colonies being empty; and all sampled
79 colonies of *A. digitifera* were found to be empty in April (Table 1). In October, all *A. hyacinthus*
80 colonies were empty whereas 14% of *A. digitifera* colonies contained pigmented eggs (Table 1).
81 Examination of the gamete traps showed that 2 colonies (17%) of *A. millepora* colonies spawned
82 on 13 April, while the remaining tagged colonies of both *A. millepora* and *A. nasuta* spawned on
83 14 April (one night before the full moon)(Fig. 1, Table 2). Similarly, in October, two tagged
84 colonies each of *A. tenuis* and *A. digitifera* spawned on October 7 (one night before full moon).
85 Coral spawning was observed in situ on four of the five nights of observation in April (13, 14, 16
86 and 17 April) between the hours of 2030 and 2200. No corals were observed to spawn on 15
87 April. At least 8 species from 3 genera and 2 families participated in the spawning event (Fig. 1,
88 Table 2). All spawning occurred between 2030 h and 2230 h. Night time observations were
89 carried out on October 8 and 9, but no spawning was witnessed on these nights. The number of
90 species observed to participate in these events is relatively modest compared to spawning events
91 seen elsewhere (e.g., Babcock et al., 1986), however observations were only carried out at one
92 site by two or three observers, therefore we predict that more extensive sampling will reveal
93 many more species participating in multi-species spawning events around Pulau Tioman. While
94 two species of *Acropora* (*A. millepora* and *A. nasuta*) exhibited highly synchronous spawning in
95 April, two other common species (*A. hyacinthus* and *A. digitifera*) did not contain visible eggs in
96 the majority of colonies sampled in either April or October. While evidence from nearby
97 locations suggest that March/April and October/November are the two main spawning peaks for
98 this biogeographic region (Baird et al., 2009) extended spawning lasting several months are

99 common on many Indo-Pacific coral reefs (e.g., Bouwmeester et al., 2015). We predict therefore
 100 that these and other species are spawning at other times of the year.

101 The seasonal timing of spawning for *A. millepora* and *A. nasuta* is consistent with
 102 observations from elsewhere within the coral triangle (e.g., Singapore, north-western Philippines,
 103 Indonesia)(Guest et al., 2002, Vicentian et al., 2008, Permata et al., 2012). However the
 104 spawning period in April in nearby Singapore (Guest et al., 2005a)
 105 for *A. millepora* and *A. digitifera* is surprising as these species spawn
 106 between 3 and 6 nights after the full moon (Guest et al., 2002, 2005a) whereas in Pulau Tioman
 107 corals spawned between 2 nights before and 2 nights after the full moon.

I suggest including additional info in the Material & Methods sections, such as size of sampled colonies and habitat (e.g. reef base versus reef top). Thus, authors could rule out other alternative explanations for the lack of observation of spawning in *A. hyacinthus* and *A. digitifera*.

110 To the best of our knowledge, this is the first detailed documented observation of multi-
 111 species coral spawning from reefs in Malaysia and these data support the contention that this
 112 phenomenon is a feature of all speciose coral assemblages (Baird & Guest, 2008). More research
 113 is needed however to determine the seasonal cycles and extent of spawning synchrony on these
 114 reefs and elsewhere in Malaysia. In particular, year round sampling is needed establish

The appropriate reference here, which is cited by Baird & Guest (2008) is as follows:
 Guest, J. R., Baird, A. H., Goh, B. P. L., & Chou, L. M. (2005). Seasonal reproduction in equatorial reef corals. *Invertebrate Reproduction & Development*, 48(1-3), 207-218.

115 Furthermore, comparisons of spawning timing
 116 of Peninsular Malaysia would be of great interest
 117 on seasons and environmental conditions (Toda et
 118 al., 2007).

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122 Department of Marine Parks Malaysia.

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Table 1 (on next page)

Table showing proportion of colonies sampled containing visible eggs.

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
<i>Acropora millepora</i>	12/04/2014	100	0	0	26
<i>Acropora nasuta</i>	12/04/2014	100	0	0	17
<i>Acropora digitifera</i>	12/04/2014	0	0	100	20
	7/10/2014	14	0	0	15
<i>Acropora hyacinthus</i>	12/04/2014	5	0	0	20
	7/10/2014	0	0	100	15

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Photo figure showing multi-species spawning of corals in Pulau Tioman.

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.

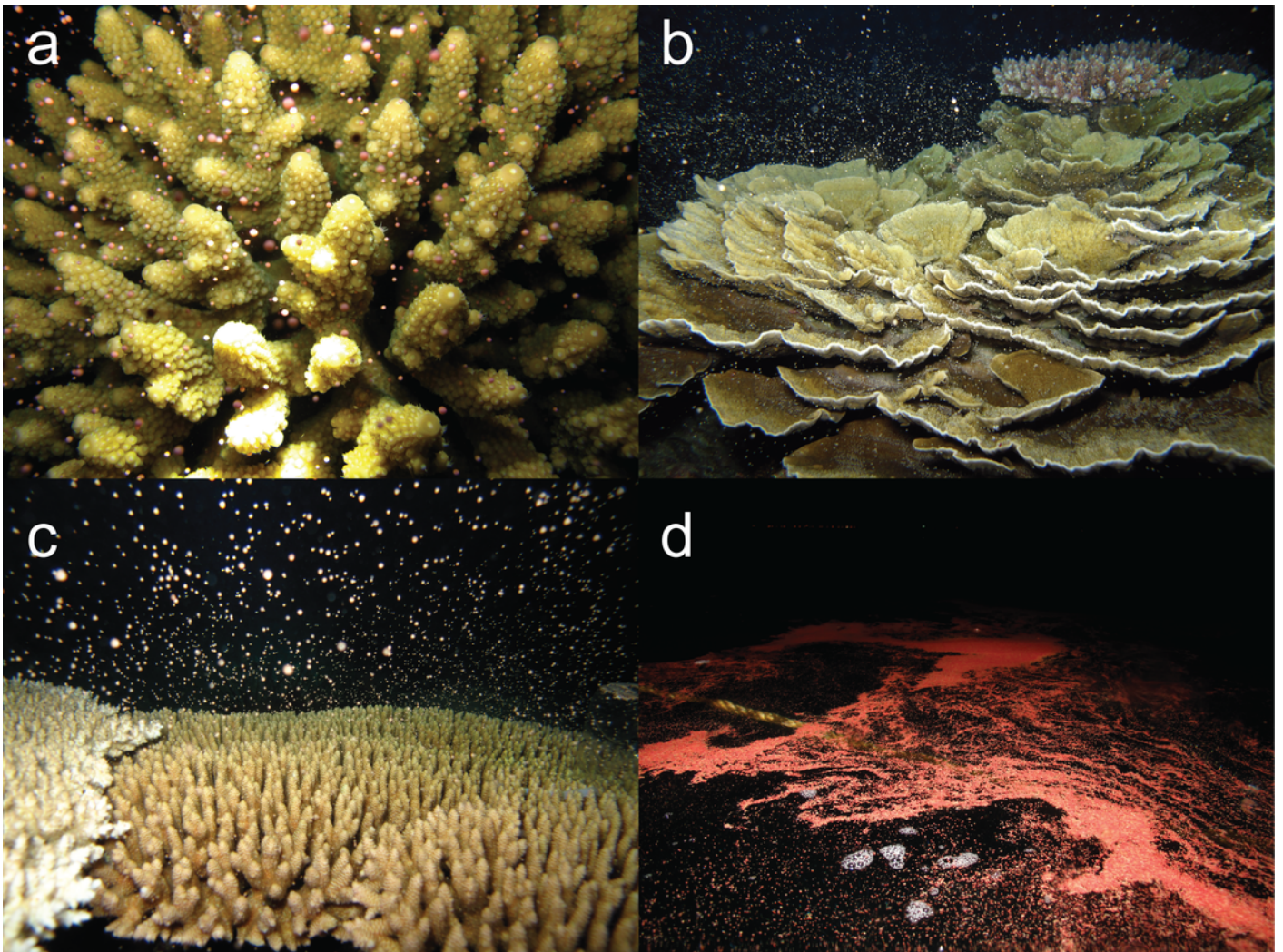


Table 2 (on next page)

Table showing species participation and timing of spawning during multi-species spawning in Pulau Tioman.

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	Spawning time	Gametes
		nights		released
Acroporidae	<i>Acropora millepora</i>	-2 to -1	2115 to 2200	B
	<i>Acropora nasuta</i>	-1	2115 to 2200	B
	<i>Acropora humilis</i>	-1	2115 to 2200	B
	<i>Acropora valida</i>	-1	2115 to 2200	B
	<i>Montipora</i> sp. 1	+1 to +2	2030 to 2225	B
	<i>Montipora</i> sp. 2	+2	2030 to 2225	B
Poritidae	<i>Porites</i> sp. 1	+1 to +2	2030 to 2225	S
	<i>Porites</i> sp. 2	+1	2115 to 2225	S