



ECOSPHERE NATURALIST

Broadcast spawning of *Pocillopora verrucosa* across the eastern and western coast of the central Red Sea

JESSICA BOUWMEESTER ^{1,2,†} DARREN J. COKER,² TANE H. SINCLAIR-TAYLOR,^{2,3} AND MICHAEL L. BERUMEN²

¹Smithsonian Conservation Biology Institute, Front Royal, Virginia 22630 USA

²Red Sea Research Center, Division of Biological and Environmental Science and Engineering, King Abdullah University of Science and Technology, Thuwal 23955 Saudi Arabia

³Australian Institute of Marine Science, Townsville, Queensland 4810 Australia

Citation: Bouwmeester, J., D. J. Coker, T. H. Sinclair-Taylor, and M. L. Berumen. 2021. Broadcast spawning of *Pocillopora verrucosa* across the eastern and western coast of the central Red Sea. *Ecosphere* 12(1):e03340. 10.1002/ecs2.3340

Abstract. Coral spawning is a fundamental process in the preservation of coral reef systems. However, reproductive information is still rare for many coral species and across a number of locations. No reproductive information is yet available from the western coast of the central and southern Red Sea. We document here the daytime spawning of *Pocillopora verrucosa* across the two coasts of the central Red Sea, in Saudi Arabia on the eastern side and in Sudan on the western side. In both sites, *P. verrucosa* released its gametes in the morning, 1–2 d before the new moon, within a 25-day window between mid-May and mid-June, matching other known observations from the east coast of the central Red Sea. Spawning followed a period of rapidly changing sea surface temperature. We here propose that given the reproductive synchrony of *P. verrucosa* across both coasts, the timing of coral spawning from other species is likely to be similar as well.

Key words: cauliflower coral; daytime spawning; Middle East; new moon spawning; Pocilloporidae; reproductive timing; Scleractinia; sexual reproduction.

Received 20 August 2020; accepted 1 September 2020. Corresponding Editor: Dr. Debra Peters.

Copyright: © 2021 The Authors. This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

† **E-mail:** bouwmeesterj@si.edu

Sexual reproduction is vital to the maintenance of coral reefs and to assist in their recovery after mortality events. Most corals are broadcast spawners and release gametes once a year into the water column for external fertilization (Baird et al. 2009). Understanding the timing and spawning cues of key species is fundamental to sustain effective management and conservation of coral reefs, for coral restoration initiatives, and for research related to the reproduction and early-life history of corals. While the timing and synchrony of spawning are known for a large number of locations and species, reproductive data are still scarce on a global scale. For example, the Red Sea, a 2000-km long basin bordered

on both sides by coral reefs, is a relatively understudied region (Berumen et al. 2013). In particular, no reproductive information is currently available for corals along the west coast of the central and southern Red Sea. If coral reproductive patterns in these regions mirror those of corals on the eastern coast of the central Red Sea (Bouwmeester et al. 2015), spawning would be expected to be concentrated in the spring, between April and June.

Pocillopora verrucosa (fam. Pocilloporidae) is an abundant reef-building hard coral commonly observed in the shallow reefs of the central Red Sea (Sheppard and Sheppard 1991). While most coral species spawn in the hours following



Fig. 1. *Pocillopora verrucosa* releasing a large cloud of sperm containing small transparent eggs at Al Jadir reef, Al Lith, Saudi Arabia. Spawning was observed on 17 June 2012, two days before the new moon, at 8:45 a.m.

sunset around the full moon (Babcock et al. 1986), *P. verrucosa* spawns early in the morning around the new moon (Bouwmeester et al. 2011, Schmidt-Roach et al. 2012).

Here, we report the daytime spawning of *P. verrucosa* in the central Red Sea, both in Sudan (western Red Sea) and in Saudi Arabia (eastern Red Sea), from *in situ* observations at comparable latitudes (19°–20° N). We compare the timing of spawning with that of other known locations further north in the Red Sea. Additionally, to investigate the relationship between spawning time and sea surface temperature (SST) changes, we plotted weekly (nighttime) SST data (SST4) from each of the known spawning locations throughout the year of the spawning observation, collected by the Aqua MODIS satellite and extracted from the Giovanni online data system (developed and maintained by the NASA GES

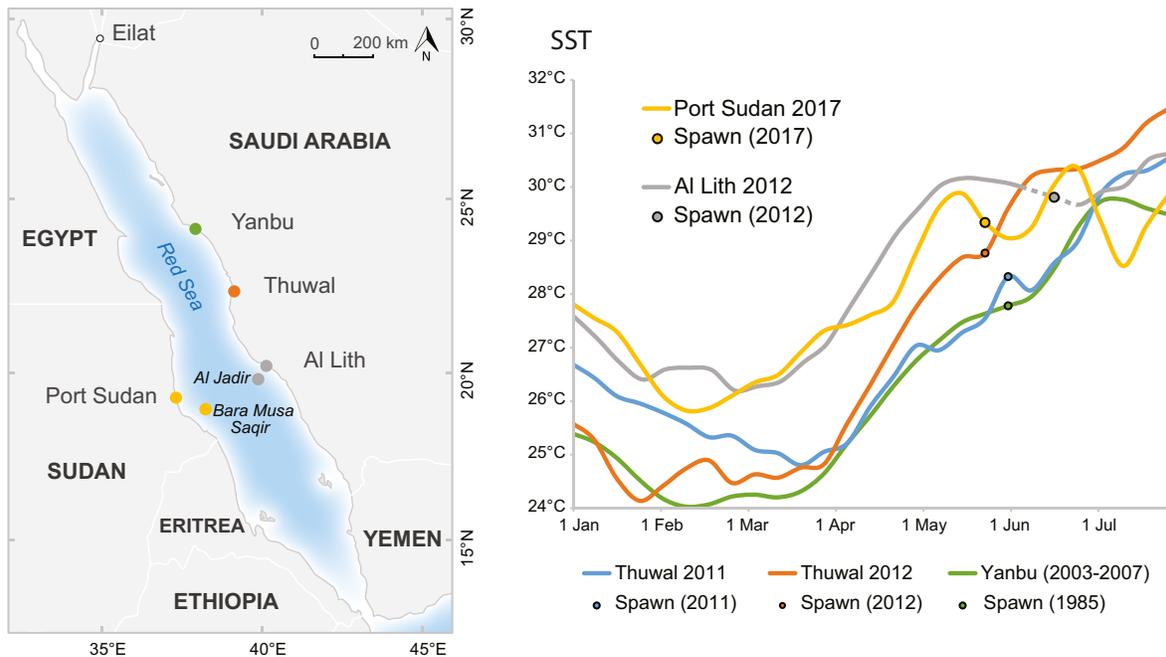


Fig. 2. Left: Location of spawning observations of the coral *Pocillopora verrucosa* in the central Red Sea. Specific locations reported in this study: Bara Musa Saqir, near Port Sudan, and Al Jadir, near Al Lith. Prior reported data are from near Thuwal (Bouwmeester et al. 2011, 2015) and Yanbu (Fadlallah 1985). Right: Sea surface temperature (SST, derived from AQUA MODIS; lines) and timing of spawning (circles) at each location (indicated by color). SST is a three-week moving average, SST data from Yanbu was determined from a five-year range (2003–2007). Dotted line represents missing data.

DISC). SST data from Yanbu were extracted from a 5-yr range (2003–2007) and averaged at the weekly level, as data were unfortunately unavailable from the year of the reproductive observations. All weekly SST data were smoothed using a three-week moving average.

All colonies of *P. verrucosa* visible at the time of spawning ($n = \sim 20$) released gametes in Sudan, at Bara Musa Saqir reef (19°02.898' N, 38°12.115' E) on 24 May 2017 at 8:45 am, one day before the new moon. Across the Red Sea, at Al Jadir reef (19°47.262' N, 39°57.367' E) in Saudi Arabia, *P. verrucosa* released gametes on the morning of the 17 June 2012 (two days before the new moon), at 8:45 a.m. In both locations, spawning did not appear to last more than 10–15 minutes. Spawning consisted of a large cloud of sperm within which small transparent eggs were visible (Fig. 1). Several fishes were observed to feed on the freshly released spawn, including *Pseudanthias squamipinnis*, *Chromis flavaxilla*, *C. dimidiata*, *C. viridis*, *Thalassoma lunare*, *Gomphosus caeruleus*, and *Pomacentrus sulfureus*.

The timing of spawning in Sudan and in Al Lith occurred within a 25-day window that matched other known observations from the region (Fig. 2), notably in Thuwal (Bouwmeester et al. 2011, 2015) and in Yanbu (Fadlallah 1985), and supports spawning occurring following a period of rapidly changing SST (Keith et al. 2016). The later observation in Al Lith (i.e., 17 June 2012) may be due to an early new moon that year in May that fell outside the spawning window and shifted spawning to the following month, or possibly, spawning occurs in both months but only one spawning month was identified due to the absence of targeted spawning surveys outside the observations described here. Indeed, spawning of *P. verrucosa* over several consecutive months has for example been reported in Okinawa (Kinzie 1993). Further north, in Eilat, at the northern end of the Gulf of Aqaba, *P. verrucosa* also spawns around the new moon, but in the later months of July–August (Shlesinger and Loya 1985). The two-month difference in the spawning timing of *P. verrucosa* between the central Red Sea and Eilat is consistent with that of other coral species present in both regions (Ziegler et al. 2019).

The time of spawning in corals is determined by proximate cues, in particular changes in

seawater temperatures (Keith et al. 2016), the monthly lunar cycle, and the daily solar cycle (Brady et al. 2009). Although *P. verrucosa* follows different proximate cues than other species (i.e., new moon period instead of full moon period and daytime spawning instead of nighttime spawning), *P. verrucosa* populations follow the same cues on both sides of the Red Sea and throughout the Indo-Pacific region. Further reproductive work is needed on corals of the western coast of the Red Sea but the similarity in the timing of spawning of the coral *P. verrucosa* suggests that the coral spawning season is likely similar to that of the eastern coast of the Red Sea, with most species spawning every year between April and June.

ACKNOWLEDGMENTS

The authors would like to thank Jesse Cochran for organizing the field work in Al Lith, the crew of the MV Dream 3 in Al Lith, and the captain and crew of the MV Don Questo in Sudan. Funds were provided by KAUST baseline research funding and award CRG-1-BER-002 to MLB. The authors declare no conflict of interest.

LITERATURE CITED

- Babcock, R. C., G. D. Bull, P. L. Harrison, A. J. Heyward, J. K. Oliver, C. C. Wallace, and B. L. Willis. 1986. Synchronous spawnings of 105 scleractinian coral species on the Great Barrier Reef. *Marine Biology* 90:379–394.
- Baird, A. H., J. R. Guest, and B. L. Willis. 2009. Systematic and biogeographical patterns in the reproductive biology of scleractinian corals. *Annual Review of Ecology Evolution and Systematics* 40:551–571.
- Berumen, M. L., et al. 2013. The status of coral reef ecology research in the Red Sea. *Coral Reefs* 32:737–748.
- Bouwmeester, J., A. H. Baird, C. J. Chen, J. R. Guest, K. C. Vicentuan, C. R. Voolstra, and M. L. Berumen. 2015. Multi-species spawning synchrony within scleractinian coral assemblages in the Red Sea. *Coral Reefs* 34:65–77, Erratum 34:79–79.
- Bouwmeester, J., M. L. Berumen, and A. H. Baird. 2011. Daytime broadcast spawning of *Pocillopora verrucosa* on coral reefs of the central Red Sea. *Galaxea* 13:23–24.
- Brady, A., J. Hilton, and P. Vize. 2009. Coral spawn timing is a direct response to solar light cycles and is not an entrained circadian response. *Coral Reefs* 28:677–680.

- Fadlallah, Y. 1985. Reproduction in the coral *Pocillopora verrucosa* on the reefs adjacent to the industrial city of Yanbu (Red Sea, Saudi Arabia). Pages 313–318 in C. Gabrie and B. Salvat, editors. Proceedings of the Fifth International Coral Reef Congress, Volume 4, Tahiti, 27 May - 1 June 1985. Antenne Museum-EPHE, Moorea, French Polynesia.
- Keith, S. A., et al. 2016. Coral mass spawning predicted by rapid seasonal rise in ocean temperature. Proceedings of the Royal Society B: Biological Sciences 283:20160011.
- Kinzie, R. A. III. 1993. Spawning in the reef corals *Pocillopora verrucosa* and *P. eydouxi* at Sesoko Island. Okinawa. Galaxea 11:93–105.
- Schmidt-Roach, S., K. J. Miller, E. Woolsey, G. Gerlach, and A. H. Baird. 2012. Broadcast spawning by *Pocillopora* species on the Great Barrier Reef. PLoS One 7:e50847.
- Sheppard, C. R. C., and A. L. S. Sheppard. 1991. Corals and coral communities of Arabia. Pages 3–170 in W. Buttiker and F. Krupp, editors. Fauna of Saudi Arabia Volume 12. National Commission for Wildlife Conservation and Development, Riyadh, Saudi Arabia, and Natural History Museum Basel, Basel, Switzerland.
- Shlesinger, Y., and Y. Loya. 1985. Coral community reproductive patterns: Red Sea versus the Great Barrier Reef. Science 228:1333–1335.
- Ziegler, M., A. Roik, T. Röthig, C. Wild, N. Rädicker, J. Bouwmeester, and C. R. Voolstra. 2019. Ecophysiology of reef-building corals in the Red Sea. Pages 33–52 in C. R. Voolstra and M. L. Berumen, editors. Coral Reefs of the Red Sea. Coral Reefs of the World. Volume 11. Springer, Berlin, Germany.