

- Hughes, R. N. and H. P. I. Hughes. 1971. A study of the gastropod *Cassid tuberosa* (L.) preying upon sea urchins. *J. Exp. Mar. Biol. Ecol.* 7: 305-314.
- and —. 1981. Morphological and behavioural aspects of feeding in Cassidae (Tonnacea, Mesogastropoda). *Malacologia* 20: 385-402.
- Lessios, H. A. 1989. Mass mortality of *Diadema antillarum* in the Caribbean: what have we learned? *Ann. Rev. Ecol. Syst.* 19: 371-393.
- , D. R. Robertson and J. D. Cubitt. 1984. Spread of *Diadema* mass mortality through the Caribbean. *Science* 226: 335-337.
- Levitan, D. R. and S. J. Genovese. 1989. Substratum-dependent predator-prey dynamics: patch reefs as refuges from gastropod predation. *J. Exp. Mar. Biol. Ecol.* 130: 111-118.
- McClintock, J. B. and J. M. Lawrence. 1984. Size selectivity of prey by *Luidia clathrata* (Say) (Echinodermata: Asteroidea): effect of nutritive condition and age. Pages 533-539 in *Proceedings of the fifth international echinoderm conference, Galway*. Balkema Press, Rotterdam.
- Moore, D. R. 1956. Observations of predation on echinoderms by three species of Cassidae. *Nautilus* 69: 73-76.
- Schroeder, R. E. 1962. Urchin killer. *Sea Frontiers* 8: 156-160.
- Snyder, N. and H. Snyder. 1970. Alarm response of *Diadema antillarum*. *Science* 168: 276-278.
- Warmke, G. L. and R. T. Abbott. 1961. Caribbean seashells: a guide to the marine mollusks of Puerto Rico and other West Indian Islands, Bermuda and the lower Florida Keys. Livingstone Publ. Co., Wynnewood, Pennsylvania. 346 pp.

DATE ACCEPTED: January 12, 1993.

ADDRESS: Department of Biology, University of Alabama at Birmingham, Birmingham, Alabama 35294-1170.

BULLETIN OF MARINE SCIENCE, 52(3): 1017-1021, 1993

MULTIPLE SPECIES SPAWNING ON CURACAO REEFS

Manfred L. J. Van Veghel

In the summer of 1991 I set up a nocturnal reef monitoring program to investigate aspects of spawning behavior such as timing of *Montastrea annularis* morphotypes. The study site was "Slangenbaai," a typical fringing reef on the leeward coast of Curacao (Bak, 1977). Monitoring took place the first 5 days following the full moons of August (26th) and September (23rd) between about 8:30 pm and 10:30 pm. Subsequently days 6, 7 and 8 were monitored between about 6:00 pm and 1:00 am. In October the reef was monitored on days 6, 7 and 8 after the full moon (23rd) between about 9:00 and 11:00 pm. The 75 local divers who participated in this project were asked to swim a 260 m long trail along 284 numbered *M. annularis* colonies at depths between 5 and 15 m. If spawning was observed, the divers recorded colony identification number and spawning time. Sunset on Curacao is close to 7:00 pm.

Besides spawning of *M. annularis*, of which details will be published elsewhere,¹ over a dozen other species were observed spawning in the monitoring periods. Such observations usually remain in scientific notebooks, which are not generally available to those interested. Patterns in species spawning behavior, e.g., spawning of *M. annularis* and the cryptic *Ophiomyxa flaccida* on the same night, are overlooked if such data are not published.

¹ Van Veghel, M. L. J., 1993. Intraspecific variation in reproductive characteristics of a dominant Caribbean reef building coral, *Montastrea annularis*: I. Gametogenesis and spawning behavior (manuscript).

Table 1. Spawning observations at Curacao in 1991. Locations: 1 = Slangenbaai; 2 = Seaquarium Reef; 3 = CARMABI Buoy O; 4 = Porto Marie; 5 = St. Cruz; 6 = Curacao Seaquarium (aquaria observations)

Species	Date	Time (h)	Location	N	or	%
Echinodermata						
<i>Diadema antillarum</i>	13-10	13.30	6	1		
<i>Holothuria mexicana</i>	27-09	17.30	4	1		
	30-09	13.00-13.15	6			> 70%
	09-10	?	6	1		
	15-10	14.00	6			< 10%
	28-10	15.00	6	1		
<i>Ophiocoma echinata</i>	08-10	09.25-12.00	6			> 90%
<i>Ophiomyxa flaccida</i>	29-09	19.35-20.25	1	> 100		
	30-09	19.50-20.30	1	> 100		
Gorgonaria						
<i>Plexaura</i> spp.	29-09	18.55	1	1		
Polychaeta						
<i>Eurythoe complanata</i>	30-09	13.15-13.30	6			> 90%
	30-09	16.00	6			> 90%
<i>Hermodice carunculata</i>	28-11	11.45-12.15	6			> 90%
<i>Spirobranchus giganteus</i>	29-09	18.55	1	1		
Worms unidentified spp.	29-09	20.10-20.40	1	> 100		
	08-10	11.00-11.30	6			> 90%
Mollusca						
<i>Arca imbricata</i>	30-09	15.15	6			> 70%
Scleractinia						
<i>Acropora palmata</i>	26-08	21.20-22.15	2			> 50%
<i>Diploria clivosa</i>	01-10	22.45	1	2		
<i>Montastrea annularis</i>	29-09	22.10-23.10	1 + 2			> 5%
	30-09	20.57-23.00	1			> 30%
	01-10	21.38-22.58	1			> 30%
	29-10	22.00-22.30	1			< 5%
	30-10	22.00-22.30	1			< 2%
<i>Montastrea cavernosa</i>	02-09	20.40-20.55	1	1		
	30-09	23.00	1	3		
	01-10	22.15	1	6		
Spongia						
<i>Ircinia campana</i>	29-09	18.50	1	1		
	29-09	21.15	1	1		
<i>Neofibularia nolitangere</i>	27-09	14.00-16.00	3	?		
	28-09	16.30-16.45	5			30%
	27-10	16.05-16.45	5			> 90%
	28-10	16.00-16.35	3			> 50%

In Table 1, I list all spawning observations made in 1991 on Curacao giving available additional information below. For descriptions of the locations see Van Duyl (1985).

Montastrea cavernosa, a gonochoric broadcasting species, was observed spawning in the Texas Flower Gardens 8 days after the full moon of August 1990 (Szmant, 1991). I observed *M. cavernosa* spawning following the full moons of August and September. Only sperm releasing male individuals were seen. Sperm was released by groups of polyps scattered over the colony surface and such release was synchronized within 1 sec. In a colony it could then take over 1 min before the next synchronized sperm release occurred. One colony was observed releasing sperm over a 15 min period. The *M. cavernosa* sperm release can be categorized



Figure 1. *Montastrea cavernosa* sperm releasing bladder.



Figure 2. *Ophiomyxa flaccida* spawning.

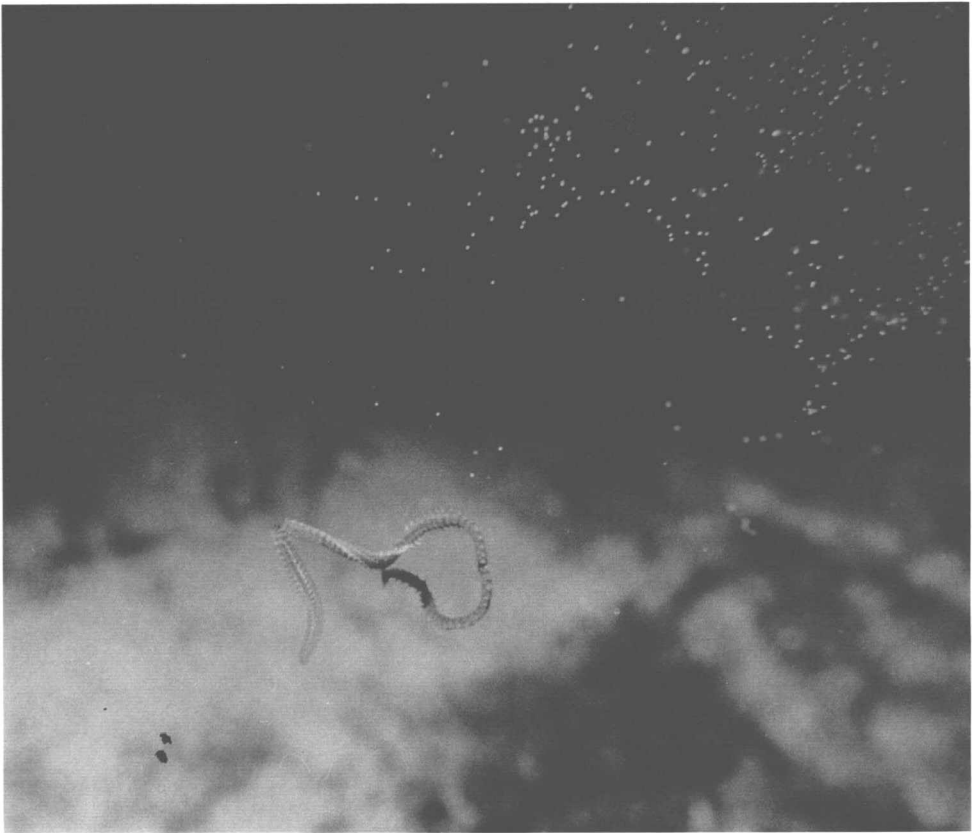


Figure 3. Spawning of unidentified worms.

as type two spawning behavior (Babcock et al., 1986), where the gametes are ejected from the polyp via rapid contractions all over the colony or part of it. Figure 1 shows a transparent bladder coming out of the oral disk shortly after sperm release. I suggest that sperm is concentrated within this pouch in the coelenteron. Consequently, contraction of the muscular tissue, pushing the bladder inside out, results in sperm release.

Acropora palmata, a hermaphroditic broadcast spawner, holds mature gonads in August according to Szmant (1986). This species was observed spawning during full moon in August 1991 at the "Seaquarium" reef. This is rather uncommon because corals usually spawn during the week following full moon (Harrison and Wallace, 1991). One colony was observed spawning on 19 August 1992 (6 days after the full moon) at 21.45 h near CARMABI Buoy 1, while other colonies still possessed eggs (pers. obs.).

There are no previous data available on reproduction in *Diploria clivosa* (Richmond and Hunter, 1990). I suggest that this species is a hermaphroditic protogynous broadcast spawner like its sympatric congener *Diploria strigosa* spawning egg-sperm bundles (Szmant, 1986).

Two specimens of the sponge *Ircinia campana* were observed spawning on one evening when a milky cloud was released from their oscula. One sponge was observed to continue spawning for over 5 min.

Spawning of the sponge *Neofibularia nolitangere* was consistent with former observations at Curacao (Hoppe and Reichert, 1987). They observed this species spawning in the afternoon, 3–5 days after the full moons in September, October, and/or November from 1983–1985. Spawning of this species was always a few days before *M. annularis* spawning. Just prior to the *M. annularis* spawning the cryptic living *Ophiomyxa flaccida* was observed to be exposed on top of living corals, mainly *M. annularis*, in high concentrations of up to more than 50 individuals per m². Ten to 15 individuals on top of each other were releasing gametes (Fig. 2).

At the same time an unidentified worm species (Fig. 3), occurring in two size classes, was observed spawning in the water column approximately 1 m above the sea floor. The length of the worms ranged from 2–15 cm. The largest density was found at the shallow reef (depth ≈ 6 m). There is no information available on the remainder of the species listed in Table 1.

ACKNOWLEDGMENTS

I thank all the participating divers and sponsors of the "1991 Coral Spawning Event," especially my colleagues G. J. Gast, M. Brown, M. Kielman, P. Hoetjes, P. Butler, E. Meesters and H. Bosscher. I thank R. Wolfschoon, S. Sambre and I. van Veghel-Hellmund for their help with logistics. Professor R. P. M. Bak and Dr. A. M. Szmant reviewed the manuscript.

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 spawning of 105 scleractinian coral species on the Great Barrier Reef. *Mar. Biol.* 90: 379–394.
- Bak, R. P. M. 1977. Coral reefs and their zonation in the Netherlands Antilles. *Stud. Geol.* 4, A.A.P.G. Tulsa: 3–16.
- Harrison P. L. and C. C. Wallace. 1991. Reproduction, dispersal and recruitment of Scleractinian corals. Pages 133–207 in Z. Dubinsky, ed. *Ecosystems of the world* 25.
- Hoppe, W. F. and M. J. M. Reichert. 1987. Predictable annual mass release of gametes by the coral reef sponge *Neofibularia nolitangere* (Porifera: Demospongiae). *Mar. Biol.* 94: 277–285.
- Richmond, R. H. and C. L. Hunter. 1990. Reproduction and recruitment of corals: comparisons among the Caribbean, the Tropical Pacific, and the Red Sea. *Mar. Ecol. Prog. Ser.* 60: 185–203.
- Szmant, A. M. 1986. Reproductive ecology of Caribbean reef corals. *Coral Reefs* 5: 43–54.
- . 1991. Sexual reproduction by the Caribbean reef corals *Montastrea annularis* and *Montastrea cavernosa*. *Mar. Ecol. Prog. Ser.* 74: 13–25.
- Van Duyl, F. C. 1985. Atlas of the living reef of Curacao and Bonaire (Netherlands Antilles). Foundation for Scientific Research in Surinam and the Netherlands Antilles 117. p. 37.

DATE ACCEPTED: January 12, 1993.

ADDRESS: University of Amsterdam, CARMABI Institute, P.O. Box 2090, Curacao, Netherlands Antilles.