BULLETIN OF MARINE SCIENCE, 72(3): 871–876, 2003

MASS SPAWNING BY TWO BRITTLE STAR SPECIES, *OPHIODERMA RUBICUNDUM* AND *O. SQUAMOSISSIMUM* (ECHINODERMATA: OPHIUROIDEA), AT THE FLOWER GARDEN BANKS, GULF OF MEXICO

Derek K. Hagman and Peter D. Vize

ABSTRACT

The Flower Garden Banks National Marine Sanctuary in the northwestern Gulf of Mexico hosts a large number of corals that reproduce via mass spawning in the late summer. Other reef invertebrates participate in this annual event, including sponges and christmas tree worms. In this report we describe the participation of hundreds of the brittle stars *Ophioderma rubicundum* Lütken and *O. squamosissimum* Lütken in the year 2000 mass spawning event. *O. rubicundum* spawned mostly on the 7th evening after the August full moon, while *O. squamosissimum* spawned only on the 8th evening. In both instances females were observed to release eggs approximately 30 min after the first males had been sighted releasing sperm. Males of *O. rubicundum* formed large aggregates, while males of *O. squamosissimum* were more solitary. Females were solitary in both species. In a sample of eggs collected immediately upon release from a female *O. squamosissimum,* one was found to be fertilized and cleaving, implying that like gonochoric corals, female brittle stars may use internal fertilization.

One of the most spectacular reproductive processes known are the highly synchronized annual mass spawning events associated with tropical coral reefs. These annual spawning events are closely tied to factors such as annual temperature variation, lunar rhythms and photoperiod (e.g., Giese and Pearse, 1974; Harrison and Wallace, 1990). While some species such as the Palolo worm may spawn alone (Mayer, 1908), other such events involve many dozens of reef species spawning simultaneously (reviewed by Harrison and Wallace, 1990). Invertebrate species other than hermatypic corals have received markedly less attention in spawning studies.

Gittings et al. (1992) included an addendum listing two non-coral invertebrates, christmas tree worms and brittle stars, as participants in the annual spawning events at the Flower Garden Banks. Similarly, van Veghel's (1993) description of mass spawning at Curaçao included participation by several non-coral invertebrates, including brittle stars. These reports provide the first field observations of synchronized spawning among populations of the brittle star species, *Ophioderma rubicundum*.

We report here on our observations of broadcast spawning of two species of brittle stars, *O. rubicundum* and *O. squamosissimum,* on the East Flower Garden Bank in the northwestern Gulf of Mexico. *O. rubicundum* is common and abundant on reefs throughout the tropical western Atlantic (Hendler, 1991), while *O. squamosissimum* has only been reported once previously in the northwestern Gulf of Mexico (Burke, 1974). A review of the existing literature indicates that the genus *Ophioderma* is exclusively gonochoric, with each species exhibiting a single annual reproductive cycle that may result in a single or multiple spawning events (Hendler, 1979, 1991; Mladenov, 1983). Hendler's (1979) study of seasonal gonad maturation status indicated that *O. rubicundum* probably spawned in August or September, but no data on *O. squamosissimum* has been previously reported.

Spawning Observations

Mass spawnings of reef invertebrates have been observed annually, since 1990, at the Flower Garden Banks in the northwestern Gulf of Mexico (Bright, 1991; Gittings et al., 1992; Hagman et al., 1998a). Each summer, eleven invertebrate species complete their annual reproductive cycles during a brief time period around the last quarter moon falling between mid-August to mid-September. Although the majority of the broadcast spawners are hermatypic corals, two ophiuroid species, *Ophioderma rubicundum* and *O. squamosissimum* are also participants.

Ophioderma rubicundum has frequently been observed on the seventh and eighth evenings following the full moon, between 21:00 and 22:30 central daylight time (CDT; Table 1). These sightings have often been attributed to predation on coral gametes, but occasional spawning by brittle stars has also been reported. Approximately 100 individuals of the second species, *O. squamosissimum,* were observed spawning for the first time in August of 2000. Spawning of this species occurred early in the evening, between 20:15–21:15 CDT, on the 8th evening after the full moon (Table 1). All sightings were within a depth range of 20 to 25 m, which represents the reef plateau at the Flower Garden Banks.

Both species exhibited similar spawning behaviors. *O. rubicundum* males tended to aggregate (up to eight individuals) on the apices of coral heads, appearing as a tangled mass of arms and discs (see van Veghel, 1993: fig. 2). *O. squamosissimum* did not form aggregates, but were often observed to be in the vicinity of other males (within 3 m). The lack of physical association with other males may in part be due to the lower numbers of this species. Aggregations of spawning males typically develop up to half an hour before the emergence of female brittle stars. Unlike females, males exhibited little activity during spawning. However, males of the species *O. squamosissimum* did have the tips of their arms curled up off the substrate while spawning. Once they had completed spawning males then slowly retreated into the coral.

Females were always observed alone and exhibited a strikingly different behavior from males. Female brittle stars raised the central disc up off the bottom, perched upon their arms (Fig. 1), and in the case of *O. rubicundum,* exhibited a rocking motion just prior to the release of hundreds of intensely pigmented eggs. Immediately after spawning females quickly dropped back down onto the substrate and returned to their coral crevices.

Four eggs were collected *in situ* immediately post spawning from a single spawning female of *O. squamosissimum* in a small volume of sea water using a 50 ml syringe. The eggs were preserved in 95% ethanol 90–120 min after collection. Subsequent microscopic observation indicated that one of the eggs had developed into a 16 cell embryo (Fig. 2).

We have also observed, as reported by Hendler and Meyer (1982), that both species of ophiuroids respond to illumination by dive lights in a similar fashion under normal con-

Table 1. Spawning in *Ophioderma rubicundum* and *Ophioderma squamosissimum.*

Evening after full moon	*Ophioderma rubicundum*		*Ophioderma squamosissimum*	
	Male	Female	Male	Female
7th	21:15–22:15	22:10–22:30	–	–
8th	21:30–22:10	22:00–22:30	20:15–21:00	21:00–21:20

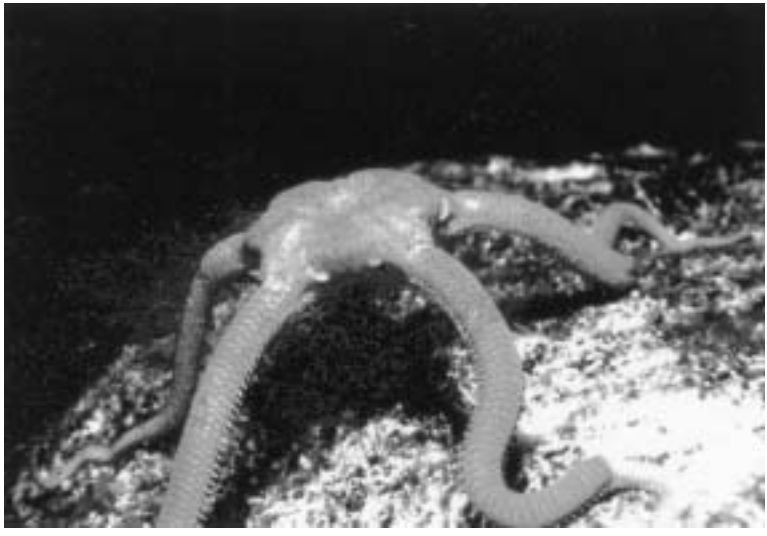

Figure 1. Egg release by *Ophioderma squamosissimum.* The raised disc stance is typical of spawning females. This image is copyright © Gary Merritt, 2000, all rights reserved. Used with permission of the copyright owner.

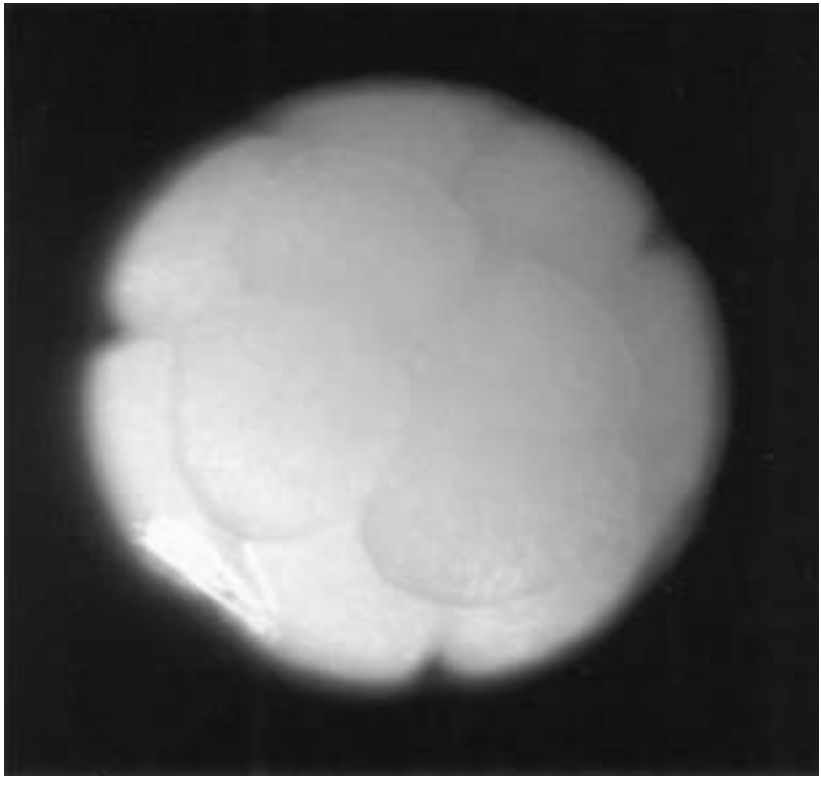

Figure 2. Blastula stage *Ophioderma squamosissimum* embryo that developed from eggs captured immediately upon release.

ditions. Although *O. squamosissimum* was less responsive, both species typically respond to illumination by moving out of the light, even returning to the underside of the reef if illumination persists. However, during gamete release, they are not as responsive and tolerate bright illumination for many minutes.

Discussion

In a previous study along the coast of Panama, Hendler (1979) determined that the breeding season for *O. rubicundum* lasted from July through September. In the absence of observed spawning this conclusion was drawn from measurements of gonadal maturity. No similar study of this or any other ophiuroid species has been conducted at the Flower Gardens. However, over the last 9 yrs *O. rubicundum* has periodically been observed participating in the annual mass spawning events at the Flower Gardens (Gittings et al., 1992). No spawning has been observed by this species either 1 mo prior to, or 1 mo following these events. This is the first such report of synchronized mass spawning by *O. squamosissimum* on any western Atlantic reef. Clearly, both species, as with all other studied members of the genus *Ophioderma*, are gonochoric broadcast spawners (see also Hendler, 1991).

Van Veghel (1993) observed *O. rubicundum*, along with at least 15 other species, spawning during a late summer (September) mass spawning event at Curaçao. Coral spawning at Curaçao typically takes place one month after similar events in the northern Caribbean and Gulf of Mexico, presumably associated with minimal annual variation in seawater temperatures experienced at lower latitudes (e.g., Richmond and Hunter, 1990; Hendler, 1991). A number of studies have demonstrated that the annual breeding seasons of species become less synchronous and more spread out closer to the equator (Giese, 1959; Giese and Pearse, 1974; Kojis, 1986; Oliver et al., 1988). This could explain the potentially longer breeding season of *O. rubicundum* in Panama (9°N) observed by Hendler (1979) relative to the present observations from the Flower Gardens (28°N).

Hendler and Meyer (1982) were the first to report on the natural spawning behavior of an ophiuroid species, *Ophiarthrum pictum*, from Pacific coral reefs. As with our observations at the Flower Gardens, spawning occurred exclusively at night, approximately 1 to 1.5 h after sunset. We observed large numbers (>100) of both brittle star species, *O. rubicundum* and *O. squamosissimum*, which are normally highly cryptic (Hendler and Littman, 1986), gathered upon the pinnacles of large coral colonies prior to spawning in the summer of 2000. While males tended to aggregate in groups (also see van Veghel, 1993), females were always observed as solitary individuals. Spawning by males began by as much as 30 min before females, and in general, males were noticeably absent from the immediate vicinity of females. In addition, spawning was marked by an unusual upright (or 'spider-like'; Hendler and Meyer, 1982) posture in females. This behavior may help minimize entrapment of eggs in the substrate and help disperse the eggs into the water column (Hendler and Meyer, 1982). Males did not exhibit this behavior.

We have previously reported fertilization rates of eggs released from gonochoric scleractinians to approach 100% (Hagman et al., 1998b), raising the possibility that fertilization had occurred internally prior to release. Although preliminary, the observation of fertilization of an ophiuroid egg captured immediately upon release is therefore intriguing and hints that brittle stars, like corals, may utilize internal fertilization. If the spawning of ophiuroids proves to be as temporally consistent as that of corals, the annual

Flower Gardens event may provide an excellent site to further investigate this mode of reproduction.

Acknowledgments

We would like to thank J. DeBose for critical comments on the manuscript, the staff of the Flower Garden Banks National Marine Sanctuary for their help and support, and G. Hendler for references. This research was supported by NOAA, Rinn Boats, Ocean Management Systems and Deep Blue SCUBA. We would like to thank M. Nickell and G. Merritt for field support, and G. Merritt for permission to use the image reproduced in Figure 1. This work was carried out under NOAA permit FGBNMS-2001-015.

Literature Cited

Bright, T. J. 1991. First direct sighting of star coral spawning. Texas Shores, Texas A&M Univ. Sea Grant Prog. 24(1): 2.

Burke, T. E. 1974 Echinoderms. *In* T. J. Bright and L. H. Pequegnat, eds. Biota of the West Flower Garden Bank. Gulf Publishing Co., Houston, Texas. 435 p.

Giese, A. C. 1959. Comparative physiology: annual reproductive cycles of marine invertebrates. Ann. Rev. Physiol. 21: 547–576.

_____ and J. S. Pearse. 1974. Introduction: general principles. Pages 1–49 *in* A. C. Giese and J. S. Pearse, eds. Reproduction of marine invertebrates, vol. I. Acoelomate and Pseudocoelomate Metazoans. Academic Press, New York.

Gittings, S. R., G. S. Boland, K. J. P. Deslarzes, C. L. Combs, B. S. Holland and T. J. Bright. 1992. Mass spawning and reproductive viability of reef corals at the east Flower Garden Bank, northwest Gulf of Mexico. Bull. Mar. Sci. 51: 420–428.

Hagman, D. K., S. R. Gittings and K. J. P. Deslarzes. 1998a. Observations on the timing, species participation and environmental factors influencing annual mass spawning at the Flower Garden Banks (Northwest Gulf of Mexico). Gulf of Mex. Sci. 16(2): 170–179.

_____, _____ and P. D. Vize. 1998b. Fertilization in broadcast spawning corals of the Flower Garden Banks National Marine Sanctuary. Gulf of Mex. Sci. 16(2): 180–187.

Harrison, P. L. and C. C. Wallace. 1990. Reproduction, dispersal and recruitment of scleractinian corals. Pages 133–207 *in* Z. Dubinsky, ed. Ecosystems of the world, vol. 25: Coral Reefs. Elsevier, Amsterdam.

Hendler, G. 1979. Reproductive periodicity of ophiuroids (Echinodermata: Ophiuroidea) on the Atlantic and Pacific coasts of Panama. Pages 145–156 *in* S. E. Stancyk, ed. Reproductive ecology of marine invertebrates. The Belle W. Baruch Library in Marine Science, no. 9. Univ. South Carolina Press, Columbia.

_____. 1991. Echinodermata: Ophiuroidea. Pages 355–511 *in* A. C. Giese, J. S. Pearse and V. B. Pearse, eds. Reproduction of marine invertebrates, vol. VI. The Boxwood Press, California.

_____ and D. L. Meyer. 1982. Ophiuroids *Flagrante delicto* and notes on the spawning behavior of other echinoderms in their natural habitat. Bull. Mar. Sci. 32: 600–607.

_____ and B. S. Littman. 1986. The ploys of sex: relationships among the mode of reproduction, body size and habitats of coral-reef brittlestars. Coral Reefs 5: 31–42.

Kojis, B. L. 1986. Sexual reproduction in *Acropora* (*Isopora*) (Coelenterata: Scleractinia). II. Latitudinal variation in *A. palifera* from the Great Barrier Reef and Papua New Guinea. Mar. Biol. 91: 311–318.

Mayer, A. G. 1908. The annual breeding-swarm of the Atlantic Palolo. Papers Tortugas Lab. Carnegie Inst. Wash. 1: 107–112.

Mladenov, P. V. 1983. Breeding patterns of three species of Caribbean brittle stars (Echinodermata: Ophiuroidea). Bull. Mar. Sci. 33: 363–372.

Oliver, J., R. C. Babcock, P. L. Harrison and B. L. Willis. 1988. Geographic extent of mass coral spawning: clues to ultimate causal factors. Proc. 6th Int'l. Coral Reef Symp. 2: 853–859.

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.

van Veghel, M. L. J. 1993. Multiple species spawning on Curaçao reefs. Bull. Mar. Sci. 52: 1017–1021.

DATE SUBMITTED: June 25, 2001. DATE ACCEPTED: December 21, 2001.

CORRESPONDING AUTHOR: (P.D.V.) *Department of Biological Science, University of Calgary, Calgary , Alberta T2N 1N4, Canada. Tel. 403 220 8502, Fax 403 289 9311, E-mail: <pvize@ucalgary.ca>*.