Simultaneous spawning of *Pocillopora* and *Goniopora* corals in the morning time

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Communicated by Hiroya Yamano (Editor-in-Chief)

Keywords Daytime spawning, Gonochoric coral, Reproductive behavior

In the morning (9:00) of 18 June 2011 (sunrise: 5:55, sunset: 19:34), the simultaneous spawning of two distantly related species of scleractinian corals was observed in Ishigaki Island (24°27'38" N, 124°12'20" E), the southernmost region of Ryukyu Islands, Japan. The observed species were the hermaphroditic spawner *Pocillopora verrucosa* and the gonochoric spawner *Goniopora djiboutiensis* (Fig. 1). Morning-time spawning of *Goniopora* corals is the first record in the world. Both male (ejected sperms) and female (ejected eggs) *Goniopora* colonies were found within a single ridge at the reef slope (Fig. 2). Although a broad survey could not be conducted, at least 5 or 6 colonies ejecting sperms or eggs were found along a few ridges. Small fishes such as damselfish aggregated around spawned colonies, suggesting that they might feed on the eggs and sperms of corals.

Most scleractinian corals spawn during night-time, such as the mass spawning of *Acropora* corals (e.g., Babcock et al. 1986). Recently, there are some reports on corals spawning at daytime. Thus far, it is known that *Porites rus* released sperm in the noon in Chumbe Island in Zanzibar, Western Indian Ocean (Bronstein and Loya 2011), *Diploria labyrinthiformis* spawns just before sunset in the Caribbean (Muller and Vermeij 2011), and *Goniastrea australensis* spawns in the afternoon (16:00–17:00) in the Great Barrier Reef (Kojis and Quinn 1981). Moreover, *P. verrucosa* and *P. eydouxi* spawn (first released sperm and then negatively buoyant eggs) in the early morning (approximately 1 h after sunrise) in Okinawa, mainland of Ryukyu Islands (Kinzie 1993, Hirose et al 2000) and also the central Red Sea (Bouwmeester et al. 2011). In other gonochoric spawners, *Pavona* sp. also spawned (ejecting only sperms) in the noon in the Gulf of Thailand (Plathong et al. 2006), and *Pavona decussata* spawned just 1–2 hours before sunrise in Kochi (Mezaki unpublished data), respectively. Although *P. damicornis* has different reproductive manners

Fig. 1 *Pocillopora verrucosa* (upper) and *Goniopora djiboutiensis* (lower) ejecting sperm in the late morning in Tomino Reef, Ishigaki Island

(e.g. Ward 1992), only spawning in the early morning (3:00–5:00) was observed. Moreover, in *Goniopora*, although the spawning of *G. lobata* just before sunset (18:00–19:00) (Kushimoto, Japan; Woesik 1995) and just after sunset (Lizard Island, Great Barrier Reef; Babcock et al. 1986) have been reported, no spawning in the late morning (>3 h after sunrise) was observed in any regions. In addition, this is the first report in the literature on synchronous daytime spawning of hermaphroditic and gonochoric corals.

These observations suggest that the spawning time of scleractinian corals is likely to be more flexible than previously thought, especially in gonochoric corals (or all corals except bundle spawners). The spawning time is a key factor in the speciation of sessile and simultaneous spawning organisms. This report found that two genetically distant species (see Fukami et al. 2008), which have no probability of crossing each other, spawned simultaneously along a single ridge, suggesting that the daytime spawning of scleractinian corals synchronizes not only between close related species via inter-colony signals but also between distant species probably because of intra-colony cue such as duration after sunrise or sunset that was genetically determined.

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Fig. 2 *Goniopora djiboutiensis* female colony ejecting eggs (arrow head) at the same time with ejecting sperm by a male colony (Fig. 1).