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Diel timing and lunar periodicity of larval release by the caryophyllid coral, *Euphyllia glabrescens* in the Central Philippines

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The larval release or planulation of scleractinian corals (Rinkevich, Loya,1979; Szmant-Froelich *et al.,* 1985; Kojis, 1986; Fan *et al.,* 2006; Villanueva et al., 2008), survivorships of juveniles (Edmunds, 2004; Norström et al., 2007) have been the focus of a number of studies. But in spite of this growing data and information, there are still gaps worth investigating. One economically important species that requires such attention is the highly traded caryophyllid, *Euphyllia glabrescens*. Studying the reproductive behavior of this economically important species is a vital input in the successful mass reproduction in the aquarium industry and for possible restoration efforts in degraded reefs. Planulation by *E. glabrescens* has been shown to follow diel timing and lunar periodicity in Southern Taiwan waters, as reported by Lin (2005) and Fan et al. (2006). Both observed the same diel patterns of larval release with two peaks, one at night and one early morning. The spawning coincided with the light-dark cycle but was independent of tide cycle. However, Lin (2005) with regards to the timing of planulation in relation to lunar cycle reported that the peak of larval release changed with different months and shifted from full moon to new moon during winter and spring, and from new moon to full moon in summer and fall. In the Philippines, Villanueva *et al.* (2008) reported the temporal patterns of planulation of six pocilloporid species in the Bolinao Northwestern Philippines, which is part of the Indo-West Pacific center of diversity for scleractinian corals. They observed a distinct lunar periodicity in all the six species with little temporal overlap, suggesting that timing of larval release is species specific. However, *E. glabrescens* was not included in their study. There have been reports (Harrison, Wallace, 1990; Tanner, 1996) showing that reproductive timing of coral species could vary in different geographical locations.

This study was conducted with the aim to further understand the reproductive timing and recruitment success of *E. glabrescens* (its larval spawning or planulation in relation to season, diel and lunar periodicities, diel periodicity) in the area around Central Philippines (between 10° N latitude and 124° E longitude).

Materials and Methods

The donor site is a fringing reef (Fig. 1.1) with flat low limestone coral reef (10°17′1.33″ N, 124°0′5.21″ E) fronting the USC Marine Research Station in Brgy. Maribago facing Hilutungan Channel located off the eastern part of Mactan Island, Cebu, Philippines. Five mature colonies of *E. glabrescens* with a colony diameter ranging from 7.5–20cm at a depth range of 5-15m were collected with permission from Local Government of Lapu-Lapu City, three days before the commencement of planulation or spawning which usually occurred every full moon. Daily planulation monitoring of mature gravid colonies (Fig. 1.2) were done every eight hours from 8:00 in the morning, 4:00 in the afternoon and 12:00 midnight. Released planulae were immediately collected and filtered using a nylon screen with 215μm mesh size. The filtered planulae were pipetted, placed into a beaker and were counted using a tally counter. After the collection of planulae from the plastic buckets, seawater was replaced with a new filtered seawater and aeration continued.

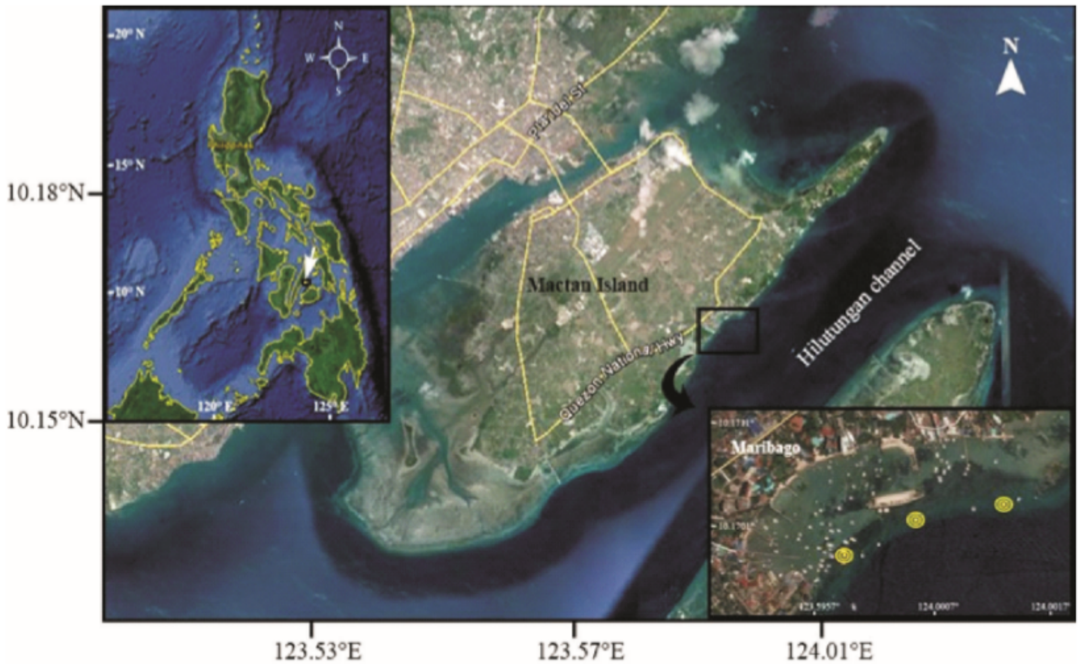

Fig. 1.1. Map showing the donor sites of *Euphyllia glabrescens* in Maribago, Mactan Island, Cebu. The yellow circles represent the reefs where the *E. glabrescens* colonies were tagged and collected.

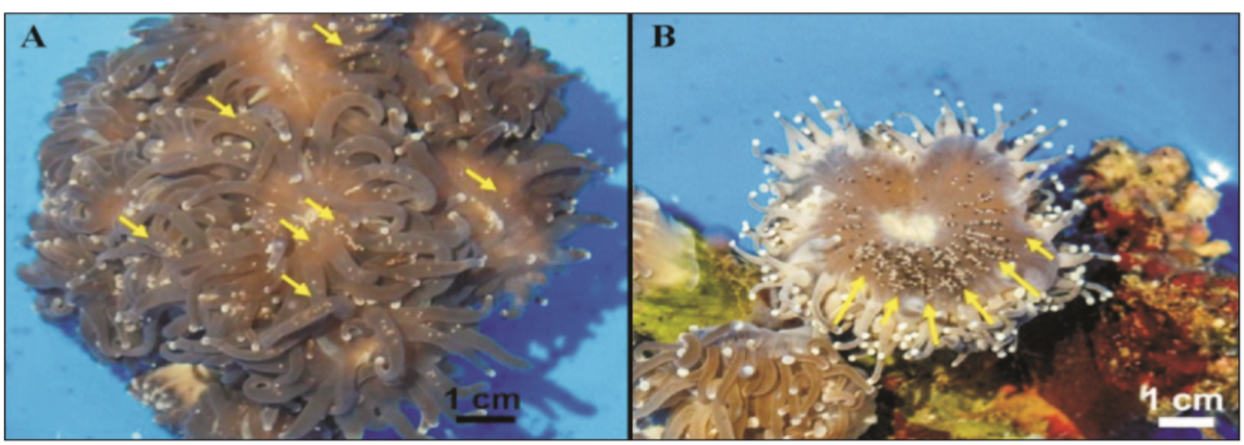

Fig. 1.2. Monitoring a gravid coral, *Euphyllia glabrescens*. **A**) entire colony and **B**) coral polyp in the wet laboratory with planulae inside their tentacles (yellow arrows).

Results

Correlation between release of *E. glabrescens* planulae with time of day

Monthly planulation cycle of *E. glabrescens* (Fig. 1.3) was consistent throughout the month with two peaks, the major peak during evening and minor pick during early morning. Planulation started around 6:00 pm when irradiance is decreasing after sunset, peak occurred between 9:00 pm to 11:00 pm and then decreased at 12:00 am midnight. The spawning resumed at 2:00 in the morning and decreased as irradiance is increasing towards sunrise. Lowest peak occurred during afternoon around 4:00 pm. *E. glabrescens* showed seasonality based on three distinct seasons: warm-dry months (March to May), warm-wet months (June to October) and cool-dry months (November to February) by Villanueva *et al.* (2008). Temperature trends showed that seasonality influenced the number of planulae released. The highest temperatures recorded were during the warm-dry months of March 2015 to May 2015 ranging from 26.22°C to 29.19 °C and the number of planulae released nor high nor low. Highest number of planulae released was during the warm-wet months of June 2015 to October 2015 wherein the optimum temperature ranged from 26.5°C to 28.47°C. The decrease of temperature ranging from 26.29°C to 27.00°C during cool-dry months of November 2015 and December 2015 also decreased the number of planulae released (Fig. 1.4).

Correlation between release of *E. glabrescens* planulae with lunar periodicity

Larval spawning or release of planulae of *E. glabrescens* exhibited lunar periodicity (Fig. 1.3A-I). Most of the months had time-frame for spawning event. The lowest number of planulae released was in July 2015 which could be a recovery

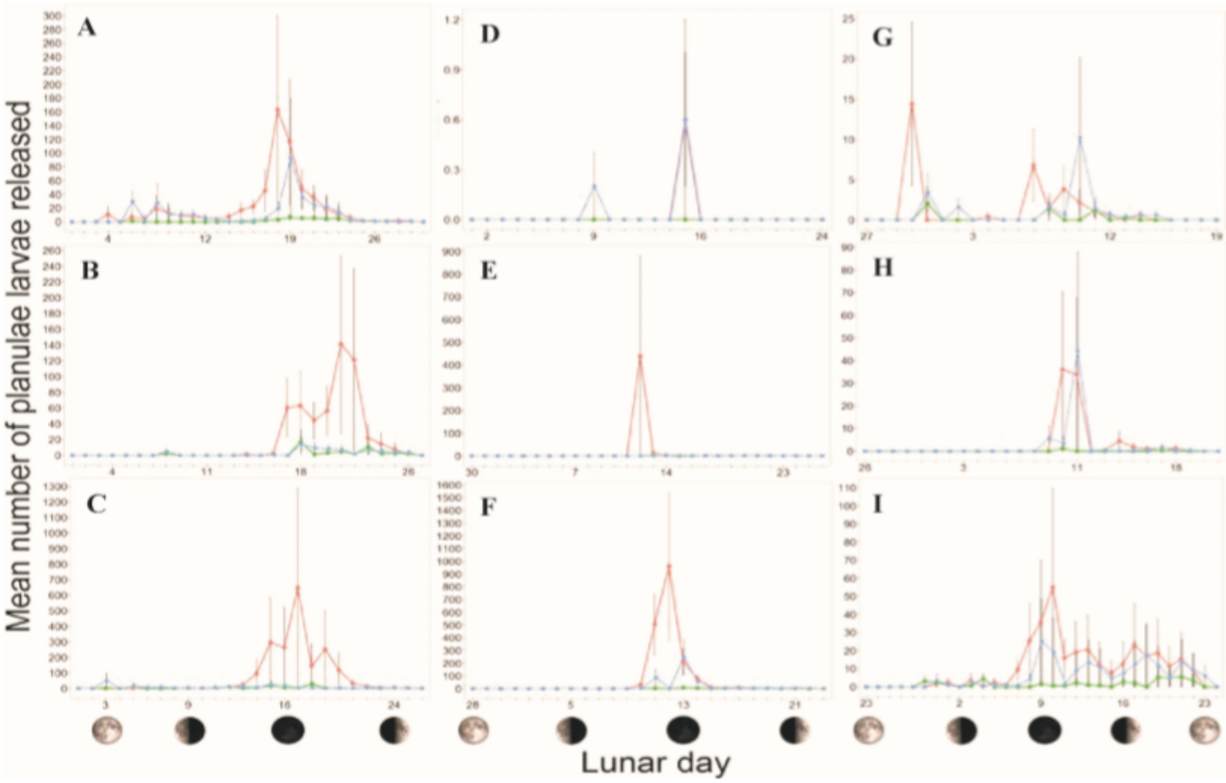

Fig. 1.3 Daily planulation of Euphyllia glabrescens in relation to time of the day and lunar periodicity over 12 months. **A**.) April 2015. **B**.) May 2015. **C**.) June 2015. **D**.) July 2015. **E**.) August. 2015. **F**.) October 2015. **G**.) November 2015. **H**.) December 2015. **I**.) March 2016. Note collection time for planulae released 8:00 am , 4:00 pm , and 12:00 pm . Moon cycle arrangement Full moon , 3rd Quarter , New moon , 1st Quarter .

period since planulation was relatively higher in the previous months. In this study, *E. glabrescens* was able to prolong its larval incubation period inside the polyps as remaining planulae were observed to be still swimming inside the polyp even after spawning ended and was expected to spawn in the next cycle but with a lower numbers of larvae. *E. glabrescens* was capable of polyp incubation due to its spacious corallite and septa with expandable polyps. Releasing of few of numbers of larvae started during full moon or before third quarter. Consequently, planulation starts in a different lunar phase such as full moon (April 2015 and June 2015), few days after full moon (May 2015, November 2015 and March 2016) and during 3rd quarter (July 2015) (Fig. 1.3D) with increasing numbers of larval released. Peak of planulation occurred 2 days before or after new moon and then decreased towards the first quarter. There was only one month that the peak of release shifted to full moon and that was during November 2015 (Fig. 1.3G). In March 2016, a bizarre pattern of larval spawning was observed with a fluctuation of larval release and a sudden increase in the first quarter. This could be attributed as a recovery phase for the recently spawning corals. Data showed that the onset of planulation was during March and ended in December. The

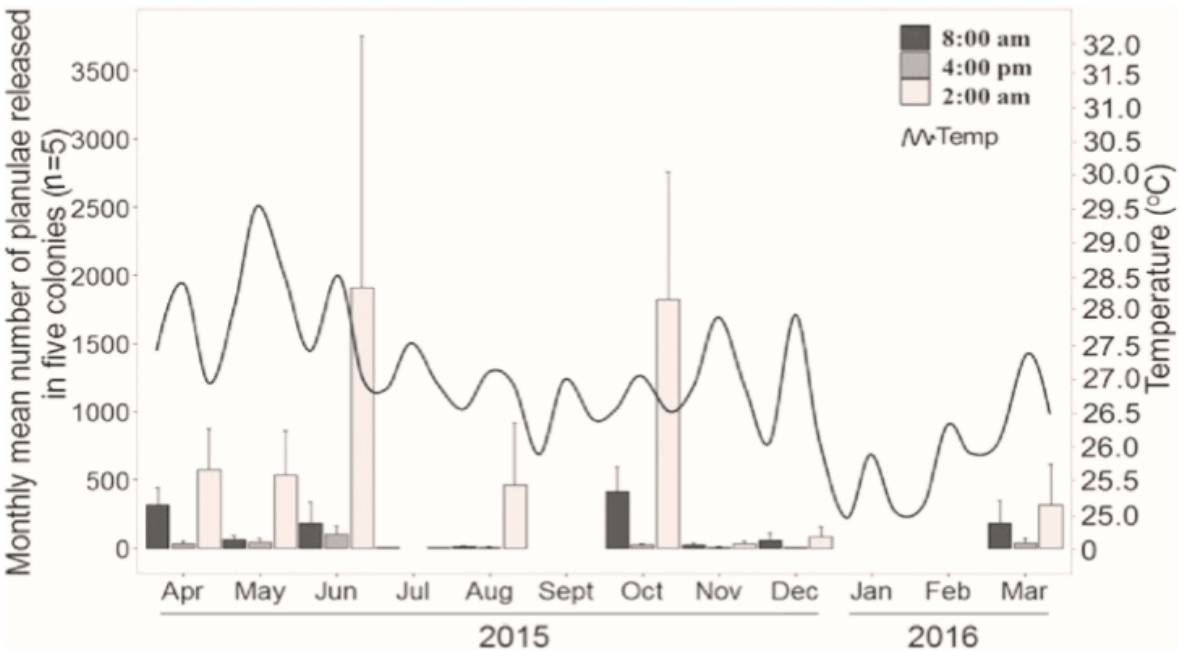

Fig. 1.4 Monthly mean planulation of Euphyllia glabrescens over a one-day cycle in relation to temperature. Note different scales on the y-axes. Planula larvae collected from: 8:00 am – 4:00 pm, 4:00 pm – 12:00 am and 12:00 am – 8:00 am.

month of September was the interval of their recovering state after massive spawning. It is hypothesized that January and February could be periods of recovery and for regaining energy for the next cycle.

Discussion

Diel timing of planulation in *Euphyllia glabrescens*

Timing of spawning in scleractinian corals has been attributed to environmental factors, that include diel timing, seasonality, temperature and lunar periodicity. However, factors are still unclear if there is an interrelationship that acts as a signaler for gamete or larval release (Crowder *et al.,* 2014). Another factor that has been the focus of studies lately is diel timing planulation which led to determining the time of the day when the peak of planulation of brooding corals occurred. Fan *et al.* (2006) recorded two peaks in the timing release of *E. glabrescens* planulae, one occurred in early morning and one in the evening which was also observed in this study. Diel timing shows distinct pattern in brooding scleractinian, the peaks of larvae release close to sunrise (Fan *et al.,* 2006; Villanueva *et al.,* 2008) and after sunset (Villanueva *et al.,* 2011). Different responses to the light-dark cycles may affect the timing of planula release as suggested from broad-casting corals that undergoes different spawning time (Fukami *et al.,* 2003).

With regards to the duration of planulae release, studies (Shlesinger, Loya, 1985; Kojis, 1986a; Oliver et al., 1988) have shown that this could vary greatly among coral

species seasonally and geographically. For example, in the Northwestern Philippines (16°N latitude) the highest planulation rates of *I. cuneata*, *P. damicornis*, *P. verrucosa, S. guttatus, S. caliendrum*, *S. hystrix* and *S. pistillata* were recorded in the warm-dry months of March to May and the lowest in the warm-wet months of June to October except for *P. damicornis* which was recorded November to February during the cool-dry months (Villanueva *et al.,* 2008; Villanueva *et al.,* 2011). In contrast, in the Central Philippines (10°N latitude) where this study was done, the highest planulation of *E. glabrescens* recorded was during warm-wet months of June to October and lowest in the cool-dry months (November to February). Studies on *S. pistillata* highest planulation was recorded in the cool-dry months of November to February and lowest was on the warm-wet months of March to May (Ilano *et al.,* unpublished). According to Schmidt-Nielsen (1997) high temperature affects the developing planulae of the adult coral that cause acceleration of larval release. But in this study no distinct evidence of an accelerated release of larvae within 26.22°C to 29.19°C was found. And according to Edmunds *et al.* (2011) the thermal threshold state and for maximum respiration in planulae is between 26.5°C to 28.47°C.

Lunar periodicity of larval release by *Euphyllia glabrescens*

The planulation in brooding corals in relation to lunar cycle have been recorded to vary even within the same species among allopatric populations (Harrison, Wallace, 1990; Richmond, Hunter, 1990; Tanner, 1996). For instance, the study of Lin (2005) in Nanwan Bay, Southern Taiwan and this study using the same species *E. glabrescens* followed the same lunar pattern on the timing of planulae release. However, this study showed a one month shifting of the peak in planulae release during the full moon. In consonance Fan *et al.* (2006) conducted a light-dark cycle experiment on the same species in November 2015 where the peak shifted to full moon. Releasing larvae in the dark might be advantageous as this can minimize visual predators. The larvae can use light cues (e.g. settling close to sunrise) for settlement hence shortening planktonic phase and prompting for and was able to record two planulation episodes at dawn and major peak after dusk. This suggests that the light-dark cycle could be the cue that induces the release of planulae. The lunar timing was almost consistent throughout the month and the peak of release was before or after new moon except on recruitment in the natal reef (Fan *et al.,* 2006).

Conclusion

Reproductive strategies of the caryophyllid coral *E. glabrescens* are attributed to several factors such as time of the day, lunar period, temperature and season. Released of planulae larvae in response to time of the day usually has two peaks, a major peak that occurs in the evening and minor peak occurs early in the morning. The planulation was synchronized by lunar phases of the moon, planulation starts on full moon or third quarter and peak of

planulation occurs two days before and after new moon. *E. glabrescens* require optimum temperature for major peak released of planulae ranging from 26.5°C to 28.47°C. Geographical differences from 16°N and in this study 10°N latitude highest planulation rate occurred during warm-wet season from June 2015 to October 2015. This study provides vital information on the early life history of a reef building caryophyllid coral *Euphyllia glabrescens* for coral restoration and coral culture purposes. The unique strategy of larval release profound successful recruitment in the natal environment.

Acknowledgements

The first Author is grateful to the Department of Science and Technology (DOST) under the Accelerated Science and Technology Human Resource Development Program (ASTHRDP) and Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) for the financial grant and support.

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