

Original Paper

LIFE HISTORY STUDIES OF *Montipora digitata* IN PIONEER BAY, NORTH QUEENSLAND, AUSTRALIA

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ABSTRACT

Intertidal zone in reef flat is the extreme condition for many species of corals. Periodical tides, wave action and sedimentation become the main challenging factors which usually avoided by most of coral species. However, Montipora digitata is the species that found abundant in these conditions. Having relatively small and short-lived colony, forced this species to find the strategy to survive and maintain the energy efficiently. Understanding biology and life history of M. digitata in the coral reefs is the key to understanding how this species can adapt to the extreme conditions. The biology and life history of this study focused on the population size structure, reproduction, competitive interactions, investment repair and maintain and types of selection. M. digitata led to productivity as a strategy to cope with any extreme condition. This pattern relatively matched with r-and S-R selection.

Key words: Environmental extremes ; life history ; *Montipora digitata* ; tolerance

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INTRODUCTION

Major reef framework builders (hard corals and soft corals) dominated reefs in the Pioneer Bay, North Queensland, Australia. The coral communities come from hard coral genera *Goniastrea*, *Goniopora*, *Lobophyllia*, *Montipora*, *Porites* and *Turbinaria* as well as soft coral genera *Sarcophyton* and *Sinularia* (FRC Environmental, 2005). Generally, corals are known to thrive in clear water and very few nutrients (Bak and Meesters, 2000). However, these genera are recognized have a tolerance of high concentrations of suspended solids and rates of sedimentation (Van Woesik *et al.*, 1999).

Montipora digitata is a species that commonly found abundant on the reef flat in the Pioneer Bay. With the digitate and arborescent growth form, this species tend to have high cover in the extreme tidal condition. This species likely often confronts with severe bleaching, cyclone, freshwater run-off, sedimentation, wave action and competition.

The habitat of this species is often categorized as the marginal reefs. Kleypas *et al.*, 1999 defined this as the reefs that exist near or beyond environmental limits of reefs distribution, which based on physiochemical tolerance boundaries for temperature, salinity, nutrients and light.

Listed as one of the fast growing species of corals, the populations of *M. digitata* have a relatively short period of growth and mass reproduction before die (Heyward and Collins, 1985a). The high physical, chemical and biological disturbances in the tidal conditions strongly force the species to have a strategy and allocate energy to survive and reproduce. Understanding biology and life history of *M. digitata* provides an improved global perspective toward predicting how this species will respond to the conditions of the marginal environment. We predicted that because of its existence, *M. digitata* has mechanism (s) to survive in those extreme conditions. Through

this study we tried to examine whether or not our prediction was proved and if it so, what mechanisms that probably associated to this species. There were some questions that had to be answered related to our prediction. Firstly, what the size structure suggest about recruitment, fragmentation, growth or survival for the species population does. Secondly, whether there is any evidence of sexual/asexual reproduction. The third, what mechanism(s) that be used by this species in competitive interactions does. Whether it tend to win or lose. The fourth, whether the species typically sustained high or low levels of injury. The last, what kinds of selection that this species has to be compromised.

MATERIALS AND METHODS

Field Data Collections of M. digitata

Data were collected in Pioneer Bay on 11-13 April 2009. Population size, which was gained from measuring 2 diameters at right angles of all colonies of *M. digitata* within 0.5 meter squares of belt transect along 10 meters line transect. Examining abundance of *M. digitata* was conducted by calculated number of colonies per 0.5m² then converted into 20m² (as a standard unit). Line intercept transect was used to calculated percent cover this species together with other corals along a 10 m line transect. Growth form(s) was observed directly to examine any variations occurred in its colony morphology at other depths and whether or not attachment each colony into the substrate has occurred. The observations were also carried out to examine the distribution and percent mortality of *M. digitata*. In addition, competitive interactions were examined to know whether or not competition among other species occurred and what mechanisms they used to interact. The effects of attachment, percent mortality and interaction between attachment and percent mortality were analyzed by factorial design ANOVA, correlation between fecundity and diameter of eggs was analyzed by Spearman' test using S-Plus (Jones *et al.*, 2006)

Laboratory Examinations

Fecundity and diameter of eggs were examined through dissecting 10 decalcified fertile polyps followed by counting the number of eggs per polyp within 3 different colonies. Afterward, we measured the diameter of a randomly chosen egg in every polyp as well as the length of the sterile zone in a colony of *M. digitata*. Microscopic anatomy through histological preparations was accomplished as described in detail in the subject manual (Willis, 2009). After the histological slides had been prepared, we identified the tissue types and organelles to gain an understanding of microscopic anatomy of *M. digitata*.

RESULTS AND DISCUSSION

RESULTS

Population size structure and distribution of M. digitata

The diameter colonies of *M. digitata* varied from 5.5 cm to the biggest size, 38 cm. On average diameter colonies of this species was 15.82 cm with median is 13 cm (**Fig. 1**). Furthermore, the population size of *M. digitata* was not distributed randomly in time ($X^2 = 746.6$, $df = 9$, $P < 0.0001$). The variance mean ratio of population size of this species was much greater than 1.

Abundance and percent cover colonies of M. digitata

M. digitata was very abundant in the shallow water. There were 708 colonies per 20 meter squares. Over than 6% *M. digitata* was found along a 10 meter line transect in 55 cm depth (**Fig. 2**). There were other three groups of corals that appeared in the same depth with *M. digitata*, those were *Goniastrea*, *Faviidae* and soft corals. *Faviidae* was recognized most abundant corals within two observed depths with more than 10% transect cover.

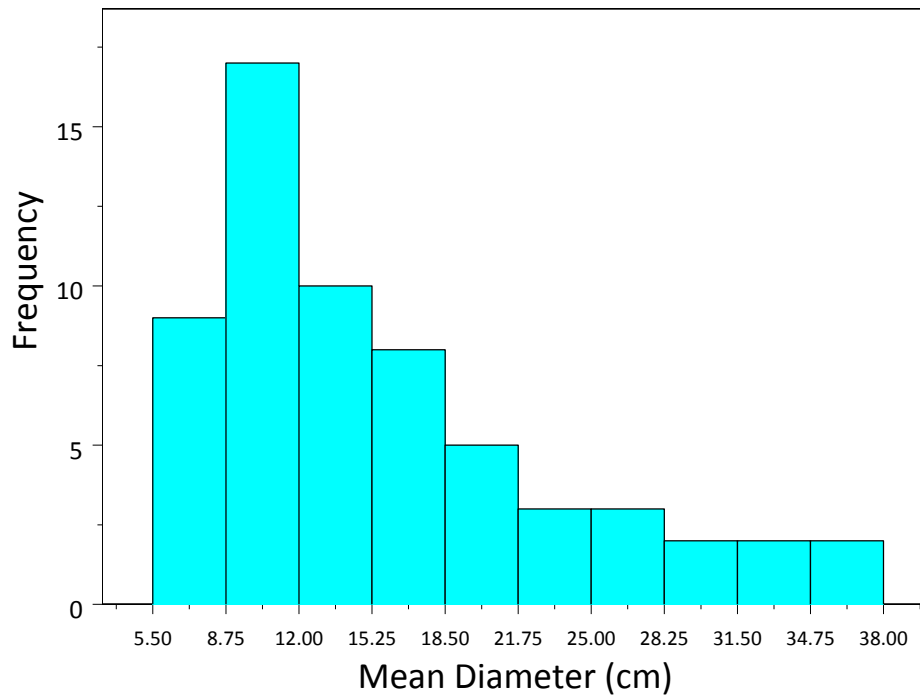


Fig. 1. The distribution of average diameter colonies of *M. digitata* (N = 61, SD = 7.94).

However, in 85 cm, the community of corals tended to be more varied. More corals appeared with the increase of depth. All of the groups of corals that we observed gave their

representatives. Unfortunately, we could not find *M. digitata* in this depth. In this study, we found the uniform of the growth form. It was an arborescent.

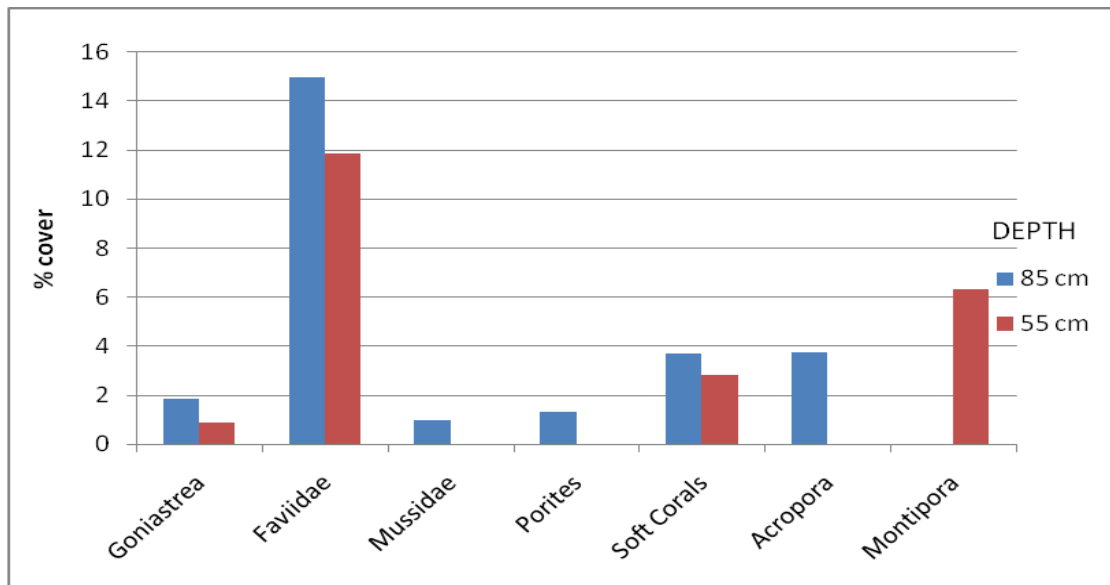


Fig. 2. Percent cover of seven observed group of corals in the two different depths. Percent cover was calculated from total centimeter of each group found per 10 meter line transect.

*Attachment colonies to the substrate and percent mortality of *M. digitata**

There was a significant effect of attachment colonies of *M. digitata* to the substrate (ANOVA $F_{1, 53} = 5.37, P = 0.024$). Overall, mean transformed diameter of attached colonies of *M. digitata* was greater than un-attached colonies among all of percent mortality

categories (**Fig. 3**). In contrast, there was no significant interaction between attachment and percent mortality of *M. digitata* (ANOVA $F_{3, 53} = 0.37, P > 0.05$). There was no significant effect of percent mortality of *M. digitata* (ANOVA $F_{3, 53} = 0.35, P > 0.05$). However, the lowest percent mortality of *M. digitata* (0 – 25%) was occurred in the greatest mean transformed diameter of attached colonies.

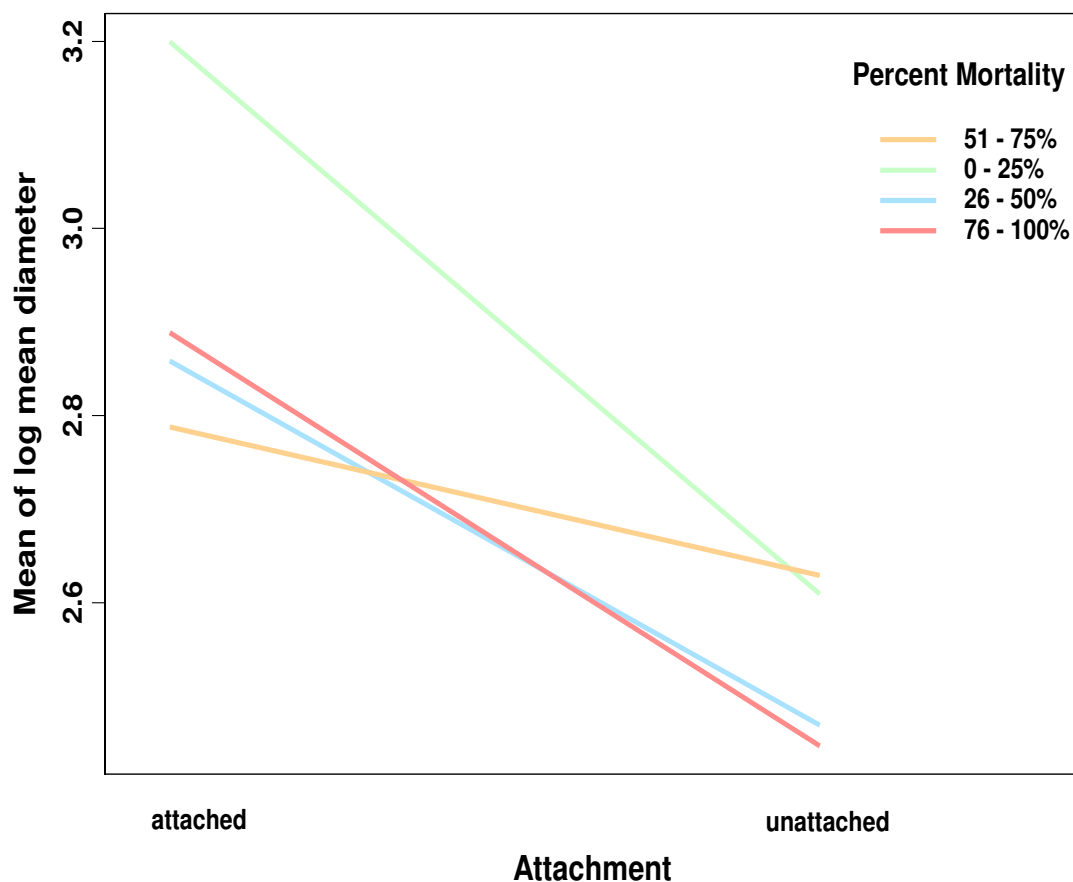


Fig. 3. Interaction between attachment and percent mortality of *M. digitata*.

Reproduction

Oocytes in decalcified polyp tissue were apparent under the stereomicroscope but the identification of spermatogonia and oocytes more clearly in the same tissue required histological staining and higher-power magnification. The oocytes developed on the

mesenteries while the spermatogonia formed slight sacs along the mesenteries (**Fig. 4**). The eggs in the oocytes have irregular in shape, typically more elongate along the oral-aboral axis (**Fig. 5**).

Fig.6. Spearman' rank correlation test indicated there was no correlation between fecundity and diameter of eggs.

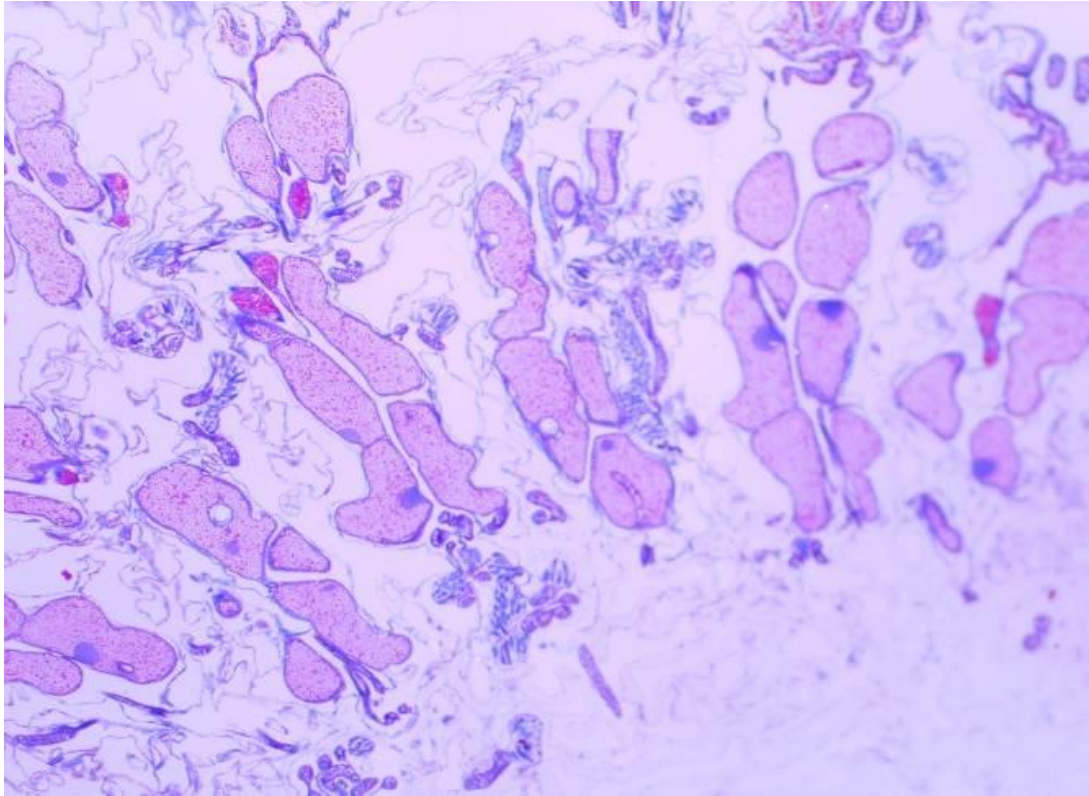


Fig 4. The oocytes (o) and spermatogonia (sp) in histological staining (LS polyp) under stereomicroscope.

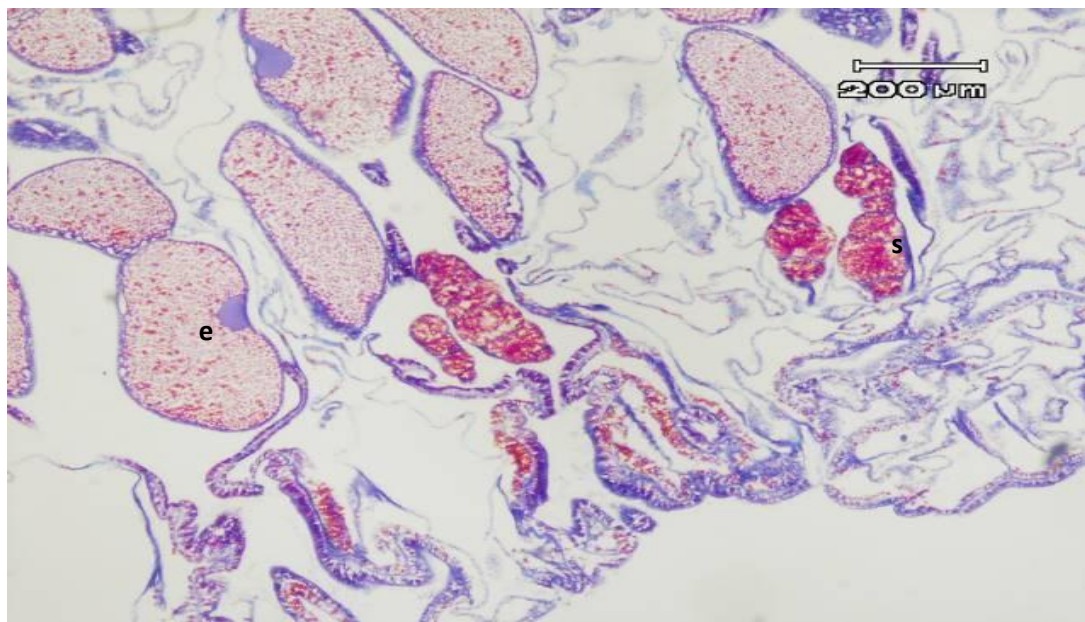


Fig. 5. The egg (e) and sperm(s) under the high-power microscope (LS polyp). The mean number of eggs per polyp was 8.17 ± 1.44 . Among 3 different colonies, the mean number of eggs per polyp looked similar. The mean diameter of eggs among colonies was also similar; (0.45 ± 0.32)

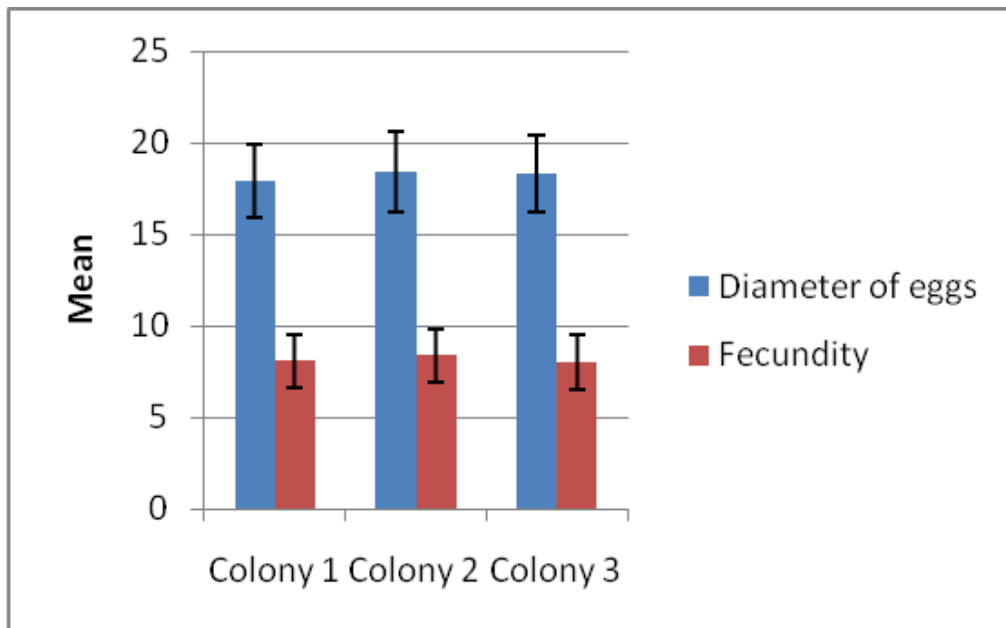


Fig. 6. Mean diameter of eggs and mean number of eggs per polyp (fecundity) within 3 different colonies. Vertical bars represent mean \pm standard error.

Competitive ability

M. digitata was always found lose when competed to other corals, such as *Porites* and

Mussidae. The colonies likely sustained high level of injury or tended to die. However, relatively medium sizes of nematocyst were found along the mesenterial filament (**Fig.7**).

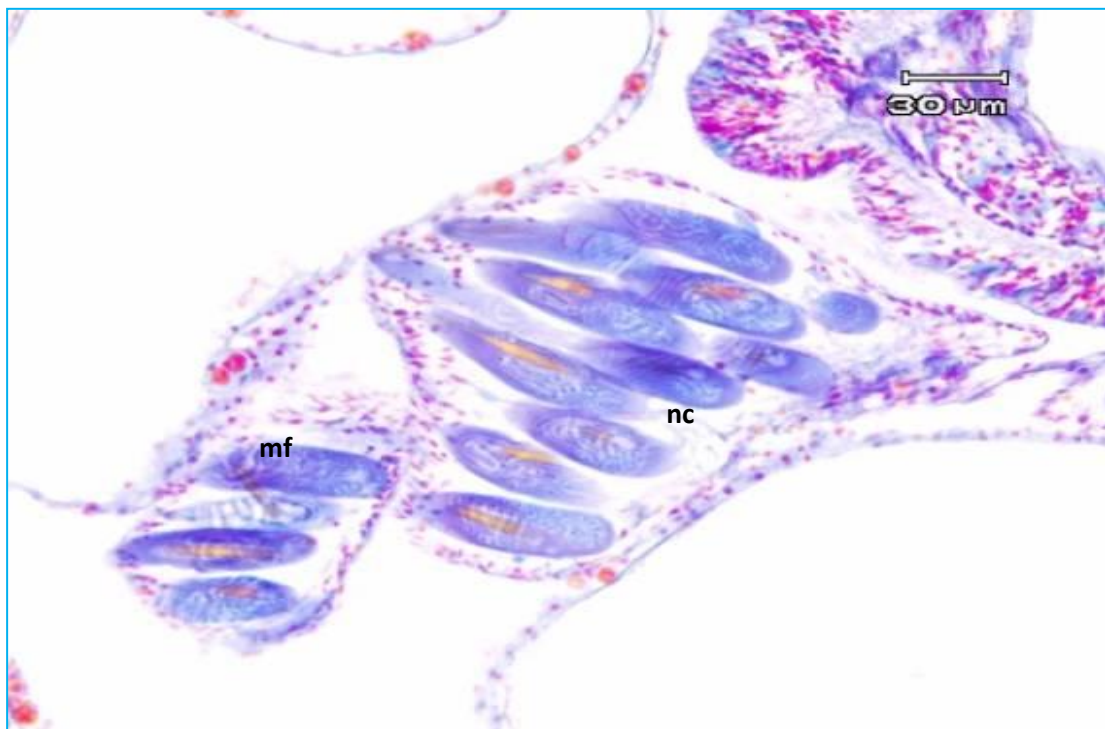


Fig. 7. Nematocyst (nc) in the mesenterial filament (mf).

Zooxanthellae as the algal endosymbionts

The gold-orange colours in gastrodermal layer and inside the oocytes indicated the

existence of zooxanthellae. Zooxanthellae were located evenly within the gastrodermal layer and the oocytes (**Fig. 8**). Almost all of the oocytes that observed in histological slides contained zooxanthellae.

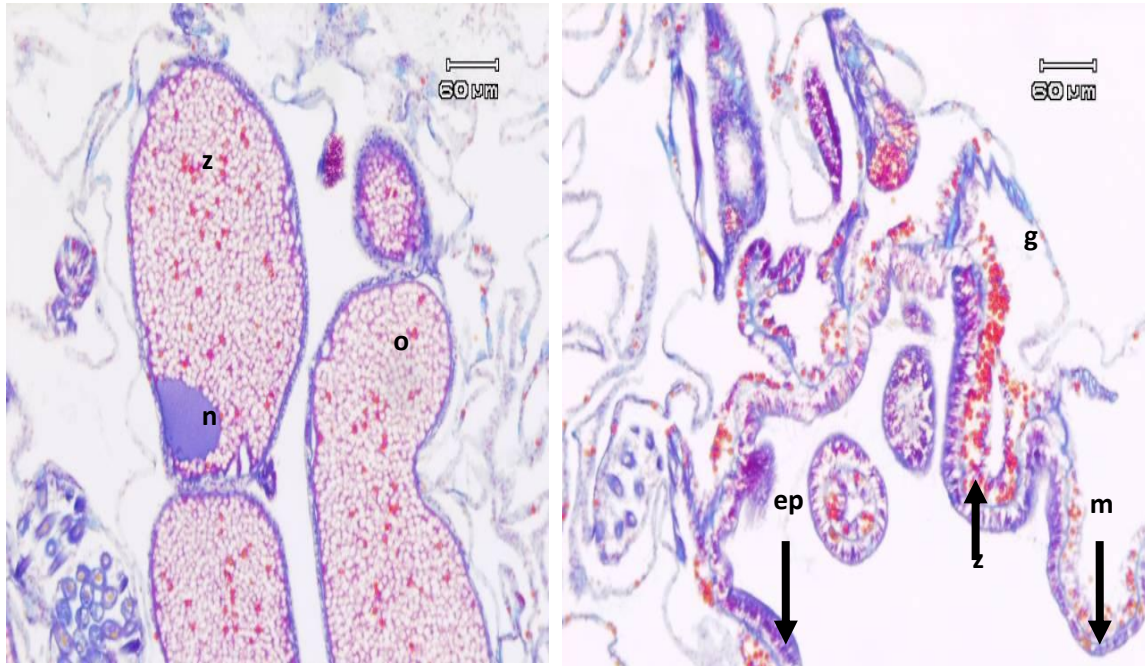


Fig. 8. Zooxanthellae (z) in the oocytes (o) and in the gastrodermis (g). n, nucleus; m, mesoglea; ep, epidermis.

DISCUSSION

*Population size structure and distribution of *M. digitata**

Population size of *M. digitata* was typically small to medium colonies. The previous studies (Heyward and Collins, 1985a) suggested that increases in colony size of *M. digitata* were expressed as percentage increase. Hence, small fragments can imply very rapid growth. Heyward and Collins (1985a), indicated the growth rate of this species is 30.5 mm per year, relatively fast but intermediate compared with Acroporidae. However, *M. digitata* is a short-lived colony that has a larger surface-area to volume ratio at time of death, and is thus more prone to be disintegrated and dispersed by breakage,

waves and currents (Done, 1982). The value of variance mean ratio of *M. digitata* suggested that this species was aggregated in the reef flat. This was simply that communities of corals result from individual species distributing themselves according to their preferences and tolerances to the prevailing environment (Done, 1982). We assumed that the preferences would be followed by the degree of recolonization. Connell (1978) emphasized that composition and diversity of colony at a place was likely also to be a function of the level and frequency characteristics of disturbance at that place, since a significant disturbance reached in the following recolonization.

*Attachment colonies to the substrate and percent mortality of *M. digitata**

The attachment colonies of *M. digitata* to the substrate were likely related to the mode of

reproduction. Un-attached colonies that observed to be dominated by small colonies of this species indicated that this species produced a lot of fragments (Bull, 1982). Since small fragments could grow rapidly, this types of asexual reproduction was likely contributed the big portion of major mode of reproduction. Attached corals which had the greater average diameter indicated more stable colonies. This condition was likely required by colony to maintain the energy to the sexual reproduction purposes through mass spawning.

Reproduction

An anecdotal condition of the arborescent species that can recovery from the strong damage (Shinn, 1972), indicated the presence of particular ability to produce fragments. Ability of small fragments to grow fast makes the fragmentation to be the major strategy of asexual reproduction in *M. digitata*. Bull (1982) also supported that fragmentation was the major means of some populations of this species to maintain themselves.

There was no evidence that fecundity had an association with diameter of eggs. Thus, one polyp could contain different eggs in number and size. However, the appearance of oocytes and spermatogonia inside the observed tissue indicated the evidence of sexual reproduction. Simultaneous hermaphrodite was the type of sexual reproduction of *M. digitata*. This species reproduces bi-annually, releasing egg-sperm bundles during the mass spawning (Coll *et al.*, 1994). In their study, Heyward and Collins (1985a) suggested that *M. digitata* had a period of growth and did mass reproduction before die. The possibility of doing mass reproduction was because of under favourable condition (Connell, 1973).

Competitive ability

M. digitata was indicated as a poor competitor for space in interactions with other common reef flat corals (Heyward and Collins, 1985b). Assuming for the present in the mesenterial filaments, those nematocysts were mastigophore type. Since this species tended to lose in most competitions, the function of

nematocysts was only adhesive and or the particulate feeding. Moreover, the total number of nematocysts per polyp apparently corresponded with the aggressiveness proficiency of coral species as was described by Thomason and Brown (1986).

Investment in repair/maintenance

Previous studies noted that *M. digitata* had the strong power of regeneration (Heyward and Collins, 1985a), however our field observation suggested that the colony sustained significant mortality. The major cause was the tidal disturbances such as wave action and cyclone (Jokiel, 2006). There is a paradox that disturbance of coral reef also represents a positive factor that maintaining vitality of many communities through mobilization of sediment and organic material (Jokiel, 2006). Moreover, strong currents can resuspend sediments and maintain them in suspension (van Woesik *et al.*, 1999). These conditions tend to require the dynamic system to adapt with severe condition such as in tidal environment.

Zooxanthellae as the algal endosymbionts

M. digitata, like other reef-building corals, formed an obligate symbiosis with zooxanthellae. This species transmit their algal endosymbionts directly to the eggs while some other species have to acquire zooxanthellae from the environment every generation (Van Oppen, 2004). Therefore we could find the zooxanthellae distributed evenly in the oocytes. Hirose and Hidaka (2006) implied the early development of zooxanthellae that containing eggs occurred in a few tissue layer that related to the maturity of eggs. Two algal strains (*Symbiodinium* clade C and D) present in *M. digitata*. However, whether or not this species is able to acquire additional symbiont types from the environment is still need to be considered.

M. digitata position on r- and K- selection and CSR selection

Certainly, no organism is completely 'r-selected' or completely 'K-selected'. All of

organisms have to compromise between the two extremes (Pianka, 1970). Relatively, *M. digitata* was represented by 'r-selection'. *M. digitata* has to compromise with the extreme ecological condition and catastrophic that often happened. This species also has to deal with small size and short-lived colonies. Under this situation, the optimal strategy is to put all possible matter and energy into reproduction, produce as many juveniles as possible. Hence, this species leads to productivity. Almost similar with C-S-R selection, *M. digitata* has a high tolerance of stress that comes from the extreme tidal conditions and competitors. This species adapted to highly disturbances as well. In the C-S-R triangle, *M. digitata* is confined to Stress tolerator-Ruderal selection.

The prediction that *M. digitata* has mechanism(s) or strategy to deal with the extreme conditions in the marginal reefs is true. The ability of *M. digitata* to produce many fragments suggested that asexual reproduction is the optimal strategy to cope with any extreme conditions. The energy is allocated mostly for productivity. The abundance of this species could be the indicator of the marine environmental damage, since its high tolerance of extreme conditions. The study of potential bioindicator function of this species is likely useful in the future, while the rapid climate change has already brought a huge effect to the coral reefs.

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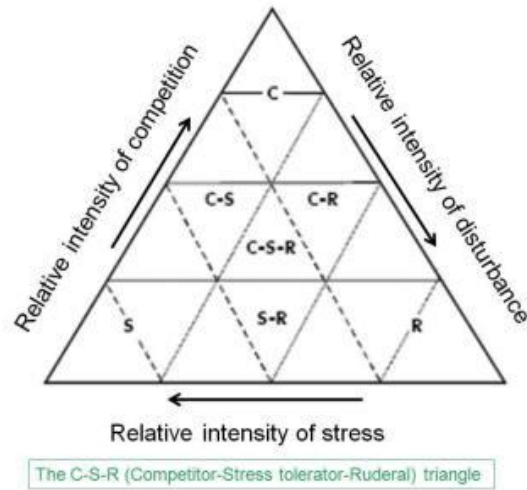


Figure 9. The C-S-R (Competitor-Stress tolerator-Ruderal) triangle (Grime, 1974)

(<http://www.sidthomas.net/Ecology/heisenberg.htm>)

Table 1. Some of the correlates r- and K- selection (Pianka, 1970)

	r-Selection	K-Selection
Mortality	Often catastrophic, nondirected, density- independent	More directed, density- dependent
Population size	Variable in time, recolonization each year	Fairly constant in time, no recolonization necessary
Selection favors	1. Rapid development 2. Early reproduction 3. Small body size	1. Slower development, greater competitive ability 2. Delayed reproduction 3. Larger body size

Length of life	Short, usually less than 1 year	Longer, usually more than 1 year
Leads to	Productivity	Efficiency