Bioerosion in massive porites at reef flat area of the south Java Sea

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Abstract. Scleractinian coral as the main builder of the reef contributes to building a complex reef framework through produce growing aragonite in their skeleton. In shallow water area (reef flat) the reef constructional process will be equal with erosional one, can be caused by mechanical damage such as storm or water motion and biological way (bioerosion). This research focused on the biological agent that influence on bioerosion process on massive Porites. 3 types of bioerosion they were grazing, boring, and etching. We monitored 10 massive Porites coral that was abundant at Pantai Kondang Merak, where each coral colony was segmented into 12 parts and then photographed to record data grazing and boring in massive Porites coral, while for etching was observed using Scanning Electron Microscopy (SEM). The result showed the number of bioerosion from grazing was 581 and boring was 1,155. The etching process was dominated by cyanobacteria Planobola macrogata that live inside of coral skeleton. The grazing process caused by parrotfish and triggerfish, boring caused by polychaetes, bivalves, and sponge. Bioerosion process not only weakening reef structures but also increase habitat complexity of reef-associated biota and expand coral occupy in space with natural propagation.

1. Introduction
The coral reef is a massive structure built by an engineer which have long live age i.e. scleractinian corals. Their skeletal has been provided a complicated framework for thousands of marine organisms [1]. Continuation of coral reef system has been determined by constructive and destructive forces. Growth of coral, calcification process and deposit of crustose coralline algae became the main constructive force. The other forces related to converting massive structure into rubble, sand, and silt through physical, chemical, and biological erosion called a destructive force [2, 3].

Many studies in recent era focusing on coral reef threats such as rising sea surface temperature, overfishing, diseases, storm and bio-erosion [4-7]. Bioerosion is supposed to contribute to coral reef decline on physical force such as direct consumption on live coral by corallivorous fish that can affect coral fitness and accelerate coral decline. But it has an important role in ecological purposes such as recycling material of dissolved Ca\(^{2+}\) and C, produce various sediment in sea bed, creating new habitat to other creatures through carbonate cavities, provide coral larval rough surface for settlement, and provide food resources for grazing fish [2, 8, 9].

Agents of bioerosion or bioeroders are made up of internal and external bioeroders. The internal bioeroders living and excavating of calcareous coral in search of shelter or food, while external bioeroders are present on surface abrading of coral surface [2]. Hutchings [10] have been classified...
bioerosion into three groups, grazing, etching and boring. Grazing activities in coral ecosystem came from sea urchin group (echinoid) and reef fish, their used radula, teeth, and buccal apparatus to abrade of carbonate substrate. Diadema antillarum, D. setosum, pufferfish, and scarus fish reported grazed on live or dead coral producing new sediment [9, 10]. Boring refers to macroborer which actively penetrate on live and dead coral using mechanical or chemical ways. The macroborers organism comes from foraminifera, sponge, bryozoans, polychaetes, mollusks, sipunculans, bivalves, and crustacea [2, 11]. The etching is activity microborers (<100 um) penetrate on live or dead coral by dissolving, such as bacteria, fungi and algae [10] and recent classification by Tribollet and Golubic [2], it compromises into phototrophic (cyanobacteria, chlorophytes, and rhodophytes) and organotrophic (fungi, foraminifera, prokaryotic and eukaryotic microorganisms).

Pantai Kondang Merak located on Malang district about 60 km from downtown Malang. This area has 3 important of tropical ecosystems, mangrove, seagrass, and coral reef. Coral can be found in reef flat area that dominated by massive (Porites, Favites and Goniastrea), laminar – tabulate (Montipora and Acropora) and branching (Acropora and Montipora). Porites are one of coral that susceptible to disease and bioerosion [12]. A previous study on monitoring of grazing activities by reef fish along 14 months in 4 Porites lobata showed the grazing activity was dominated by triggerfish [13]. This research focuses on Pantai Kondang Merak because of the fragility of the condition of coral due to natural environmental factors such as high sedimentation, strong current and high energy of wave, and anthropogenic (tourism activities), also previous extensive data that will support on this research. This study aimed to know the major biological destruction in massive Porites in Pantai Kondang Merak, to estimate the coral health under dynamics stressor conditions.

2. Material and methods

2.1. Study area and research location

This research was conducted April 2017 to May 2017 at Pantai Kondang Merak (112° 30’ 19.80” E - 8° 24’ 14.14” S) (Figure 1). Field observation for monitoring grazing was undertaken in two places, they were stasiun barat and stasiun timur. In the first initial 10 of massive Porites was chosen randomly followed these criteria: colony diameter was 50-60 cm, lifeform massive, depth 1-3 m depth and live coral colony.

![Figure 1](image_url). Research locality in Pantai Kondang Merak, Malang. Red lines are monitoring locations.
2.2. Data collection of bioerosion
Grazing and boring activities on Porites coral were monitored in surface of coral colony. Each coral colony was segmented into 12 parts. Nail and white hemp yarn were used to distinguish segmented colony (Figure 2). Each segment then photographed by an underwater camera (Canon G16, Japan), and through ImageJ software, the number and types of scars and boring were calculated and identified type of bite mark or boring types on each segment. Etching data obtained by took samples 2 x 2 cm from each coral colony used an iron chisel and hammer. The samples obtained randomly from colony surface.

![Figure 2](image)

**Figure 2.** An illustration of coral colony surface where each colony was divided into 12 segments to monitor grazing and boring signs. A, B, C: top view, side view, and segmented coral colony.

2.2.1. Grazing ID. Biological damage caused by grazing is carried out by reef fish, echinoid and gastropods [10]. Parrotfish is herbivorous fish that control algal growth on the coral reef. The foraging activity is group, all together scraping and excavating of life of dead coral leave a visible larger and deeper grazing scars on coral/ reef surface, not only alga removed but also unite reef when feeding. The parrotfish scars are easy to be recognized on coral Porites, usually they have large deep scrapes along colony ridges or hillocky of Porites (Figure 3A, B).

![Figure 3](image)

**Figure 3.** Grazing parrotfish (A, B) and Grazing triggerfish (C).

Grazing triggerfish also categorized as herbivory fish, 55.8% their dietary are from algal [14] but originally triggerfish is omnivorous. Scars bite from triggerfish that leave on Porites surface is paired square mark, small and less damaging than parrotfish scars (Figure 3C).

2.2.2. Macroborer ID. In this research, the boring activity limited only on macrofauna (size >1mm). Macroborer present on dead or live part of coral Porites colony. Some penetrate from dead part or crack of coral Porites, others penetrate coral through their living polyp [15]. Three borer organisms that became attention in this research: sponge, Polychaeta, and bivalve. The sponge is simple animals, fixed on substratum, have many pores to filter their food, and come with various shape also size [16, 17]. The present of sponge on coral Porites is easy to know with common characters as described by [16] (Figure 4).

![Figure 4](image)

**Figure 4.** Shows Polychaeta and bivalve macroborers in the death part of coral colony, then grew within a few weeks [15]. Both of Polychaeta and bivalve do not penetrate deep on coral Porites but some worm such as Spiobranchus sp can growth along with coral increment.
so affected on long hole inside of coral skeleton [18]. Figure 4 (C, D) showed the hole caused by Polychaeta and Figure 4 (E, F) hole because bivalve as well.

![Figure 4](image)

**Figure 4.** Boring due to sponge (A, B); Polychaeta (C, D); bivalve (D, E).

2.2.3. *Etching ID.* Identification of etching or microboring contained in corals is determined based on filament or etching of corals seen through Scanning Electron Microscopy. Microorganisms that produce etching are usually caused by microflora, bacteria or fungi (fungi) [10]. Identification of microorganisms that cause etching or microboring is based on a boring or filamentous trace of the microorganism (Tribollet, pers.comm.) And also, visual identification of microorganisms, referring to [19, 20].

3. **Result and discussion**

3.1. *Grazing and boring incidence*

The total number of bioerosion on 10 massive Porites at Pantai Kondang Merak was 1,736 consist of 581 grazing activities and 1,155 of boring activities. The highest grazing and boring activities were found in Porites massive J (304 grazing and 648 boring activities) (Figure 5). While massive Porites I recorded one-fourth lower of grazing activities than Porites massive J and boring activities on Porites...
massive I was 2.5-fold lower than massive Porites J. The number of grazing and boring incidence on another Porites seemed lower than 50 except Porites massive A.

![Figure 5](image)

**Figure 5.** Grazing and boring activities on 10 massive Porites that were surveyed at Pantai Kondang Merak.

In terms of coral reef ecosystem: stony coral, coralline algae, calcareous green algae, and other biogenic reef produced a complex biogenic reef that massive in size. The reef development has been controlled by various factors: macro-scale process (tectonic event and sea-level change), mesoscale that related physical-oceanography (temperature, salinity, and wave energy), and micro-scale (light, nutrient, and sediment) [21]. The coral grows is part of reef-building, even still living or dead, coral becomes subject of physical and biological breakdown. One positive effect of bioerosion process is habitat modification and effects on biodiversity [22]. Coral can expand their area and become dominant in certain substrates through bioerosion process if a colony of coral was broken the coral fragment will be propagated and developing into a new colony [3]. So, bioerosion takes action as a driver of expanding new structures and function on coral reef ecosystem.

High number of bioerosion in Pantai Kondang Merak suggested high influenced by nutrient input and water discharge. Nutrient came from the forest on upper hill while groundwater from river in west part of Pantai Kondang Merak. Nutrient enrichment in the seawater can stimulate productivity of plankton, raise particulate food and turbidity, encouraging environment for filter feeder bioeroder. Combined of ocean acidification (OA) and nutrient enrichment are 10 times more effective at driving coral macro bioerosion [23]. River water known has high N:P ratio, that had a positive effect on increase of bioerosion [24].

### 3.2. Porites’s colony types effect on number bioerosion

Samples of massive Porites that found in Pantai Kondang Merak form into categories “true” massive Porites and microatoll Porites. The “true” massive Porites typically has helm shaped form with rough hillocky on colony surface. Microatoll (MA) is a ring-shaped of massive Porites that has a dead part on center of colony and surrounded by annular rim living coral. Four types of microatoll were recognized, they were classical, top-hat, up grown and multiple ringed (Table 1). The highest grazing activities were recorded in massive J and A, it was resulted by triggerfish foraging (Figure 6). From the same figure can be shown that the total numbers of scar bites by triggerfish were 402 and by parrotfish were 179.
Table 1. Morphometric of massive Porites.

| No | Code Coral | Diameter (cm) | Height (cm) | Type of Porites |
|----|------------|---------------|-------------|----------------|
| 1  | Massive A  | 80            | 20-40       | MA top head    |
| 2  | Massive B  | 70            | 60          | MA classical   |
| 3  | Massive C  | 80            | 40          | MA top hat     |
| 4  | Massive D  | 50            | 35          | True massive   |
| 5  | Massive E  | 40            | 40          | True massive   |
| 6  | Massive F  | 50            | 45          | True massive   |
| 7  | Massive G  | 100           | 30          | MA upgrown     |
| 8  | Massive H  | 50            | 45          | True massive   |
| 9  | Massive I  | 50            | 45          | True massive   |
| 10 | Massive J  | 120           | 60          | MA upgrown     |

The previous study by Luthfi and Siagian [13] showed micro atoll in Pantai Kondang Merak become microhabitat to others coral and has been colonized by 52 colonies of coral. The dominant species was found were Goniatrea sp, Montipora foliosa, M. capricornis, Pocillopora damicornis, Porites cylindrica dan P. lobata. Type of micro atoll also had a relationship of this case, for example, upgrown Porites microatoll had a more dead part in the center area than classical or multiple ringed. This dead part became a new habitat occupied by another coral.

3.3. Conspicuous bioeroder

Domination of grazer on coral bioerosion was recorded in Figure 6. Triggerfish and parrotfish are main causes of bioerosion. Total scar marks from triggerfish were 402 while parrotfish was 179. Triggerfish prey many types of food: corals, algae, gastropods, sponges and sand dollars [13]. Triggerfish mostly prayed on upper and middle area of coral colony. Triggerfish prefers eating coral polyps on upper and middle part because the possibility of a lot of boring and infauna live in this segment. Foraging Balistiids in coral has been reported in eastern Pacific that 3 triggerfish implicated on coral in the Pacific coast [25]. One species of triggerfish, Pseudobalistes naufragium, excavated massive coral by breaking them for endolithic bivalve without ingestion of live coral tissue [26]. Other species, Melichthys niger, reported as facultative corallivorous that prey on coral up to 1% of coral volume [25]. The parrotfish are herbivorous but have reported grazed on coral [27]. Coral has lower level protein and energy than benthic algae, so that herbivorous fish such as parrotfish foraged algae for keeping quality of nutrition of diet [28]. The scars bite of these fish categorized into two types, spot biting and focused biting. Spot biting is paired scar mark from individual of parrotfish, while focused biting repeating grazing activity in the same coral colony affected on deep scars and removed of tissue [27]. The bites mark on coral massive Porites can be identified of parrotfish species, but the common parrotfish that excavated on massive Porites were Scarus ghobban, Scarus perrico, Scarus rubroviolaceous and Calotomus carolinus [25].

The total number of boring polychaeta, sponge, and bivalves were 1,138, 16 and 1 (Figure 7). The christmas tree worms (Spirobranchus spp) by far become the common infestation biota in massive coral Porites as well. Christmas tree worms (Spirobranchus spp) reported inhabiting in Porites coral at Red Sea and in Okinawa, this tubicolous polychaeta can live under skeleton of Porites lutea up to 40 yrs. [29, 30]. The abundance of this polychaeta as a bioindicator for water quality and increasing nutrient in Bonaire, Dutch Caribbean [31]. The Christmas tree worm is also infested on 3 corals, Montipora, Pavona Porites, at Sulawesi. Contrary to this research, that bivalve (boring Lithophaga) in Sulawesi is very dominant and their density is very high 88 individual/m² [32].
The sponge is one aggressive sessile animal, that both chemically and mechanically to advantage more space and attack another biota competitor such as coral. In Pantai Kondang Merak, the number of boring sponges less is found than polychaeta. Borer sponges found attach in basal of coral up to the middle in Porites I and J. The common borer sponge from Clionaidae, can penetrate their etching cells into coral carbonates and did mechanical boring to expand their colony [33]. Figure 4 (A-B) showed the Niphates sponge, Gelliodes sp (Family Niphatidae), was encrusted and started overtaking on massive Porites. No previous report about competition of coral and Gelliodes sp, but this species was reported as endemic species in Indonesian water [34, 35].

**Figure 6.** Reef fish grazing activities recorded on massive Porites.

**Figure 7.** The number of borers activity in massive Porites.
Figure 8. SEM of Planobola macrogata (A) and diatom (B) found on massive Porites skeletal.

Two types of etching borer ingested on the coral skeleton, such as Planobola macrogata and diatom (Figure 8 A, B). Unicellular cyanobacteria, P. Macrogata, are spherical cavities that have 10-30 µm in diameter. Their surface usually doesn’t have special features [19, 36]. P. macrogata found in surface of coral skeleton, may need light for producing their food through photosynthetic. Diatom is major algae that have to vary in size 2-500 µm and etching diatom in this study was approximately 10 µm in diameter size. Diatom is well known as carbonate borer, frequent report from genus Cocconeis, Achnanthes, and Amphora [37, 38]. An euendoliths organism almost cyanobacteria able to colonize carbonate surface and dissolve 30 mmol CaCO$_3$ m$^{-2}$ day$^{-1}$ and suggested have play role on coral death [38, 39].

4. Conclusion
Massive Porites is a harbor for a high diversity of marine biota. Bioerosion on ten massive Porites as a tiny model shows how the equilibrium process on the coral reef ecosystem. The presence of bioeroders inside it causes weakening and eroding their structure. Three types of bioeroders in Pantai Kondang Merak that effect on coral reef health, they were external bioeroder (triggerfish and parrotfish), internal bioeroder from macroborer (polychaeta, sponges and bivalve) and microborer (etching) from cyanobacteria (Planobola and diatom).

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