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Short Communication

Epipsammic Diatom *Cocconesis* sp. as New Bioeroder in Scleractinian Coral

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Abstract

Laminar coral, Montipora, contributes to the coral reef ecosystem. The laminar life form is usually used by juvenile reef biota to shelter and prey. In an intertidal area, such as Pantai Kondang Merak, these corals are susceptible to erosion caused by mechanical and biological forces. Strong current or other anthropogenic activity may break coral colonies into pieces. Also, some grazers from reef fish and bioeroder potentially weaken coral structures. This study aimed to find the effect of biological agents from Bacillariophyceae, such as *Cocconeis* diatom, on the bioerosion process in laminar coral, e.g., Montipora. Ten montiporid corals from Pantai Kondang Merak were observed to find bio-eroding activities. Each coral colony was divided into 12 parts and photographed to record signs of bio-erosion on coral surface. While observing microborers, a 2x2 cm of the coral surface was observed using Scanning Electron Microscopy (SEM). SEM revealed that a frustule of *Cocconeis* sp. was found inside aragonite laminar coral from Pantai Kondang Merak. *Cocconeis* naturally grows on the coasts of tropical oceans as benthic organisms. They are reported as living attached to many substrates' surfaces and within the substrate as euendolith. This study revealed that *Cocconeis* sp. lived inside the coral skeleton as micro bioeroder by attaching their valve in coral aragonite. Further work needs more observations of another potential euendolith diatom living inside the coral and to build new information on their mechanism of bio-eroding process in more detail.

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1. Introduction

Hard coral or Scleractinian coral are the main builder of coral reef construction. Coral produces three-dimensional shapes of aragonite structure through biomineralization (Allemand *et al.*, 2011). The new space is created inside the coral skeleton attracting other organisms from endoliths to nekton to interact with each other and build an ecosystem (Tribollet, 2008). The new ecosystem will then provide valuable services and basic things for humans in general, both directly and indirectly, such as protecting the shoreline from abrasion, providing food and drugs, increasing economic revenue from coral reef services, and reserve of valuable information about past times (Bellwood *et al.*, 2019). However, some events threaten and potentially degrade the coral reef ecosystem's functions. Increasing sea surface temperature, overfishing, coastal rapid development, pollution, and coral disease all speed up coral mortality followed by a decreasing reef function (Kuffner *et al.*, 2019).

Coral reefs are sustained by constructional forces, such as calcification and biomineralization, equalized by destruction forces (biological- and physical-based erosions). Coral calcification is defined as the coral skeleton built-up of calcium carbonate during a time in which the coral contributes about 5 kg of calcium carbonate per square meter (Chabanet *et al.*, 2005). Increasing carbonate during coral growth is typically used as a measurement and indicator for indications of reef health (DeCarlo *et al.*, 2018), while biomineralization is an organic matrix which mediated mineralization process (Allemand *et al.*, 2011). Ecologists consider erosion of coral to be induced by natural and anthropogenic forces. Natural disturbance can come as eroding biota, storms, and strong currents. While coral mining, destructive fishing, and coral harvesting are human activities that physically erode the coral reef (Chabanet *et al.*, 2005).

Bioerosion is defined as any activities done by reef biota that degrades/erodes coral (Glynn and Manzello, 2015). The agents of bioerosion (bioeroders) are divided into internal and external bioeroders. The bioeroders, living inside the calcareous coral, are called internal bioeroders, while those bioeroders living on the coral surface and abrade them are called external bioeroders (Glynn and Enochs, 2011; Hutchings, 2011). Based on the type of erosion inflicted, Maher *et al.* (2018) divided bioeroders into three kinds: grazing, boring, and etching. Grazing is done mainly by echinoid and reef fish such as *Diadema antillarum*, pufferfish, and scariids fish which commonly grazes on living or dead matter (Hutchings, 1986; Weinstein *et al.*, 2019). Boring erosion is done by foraminifera, sponge, bryozoans, polychaetes, mollusks, sipunculans, bivalves, and crustacea. They make a hole in the coral skeleton through mechanical and chemical ways (Wisshak *et al.*, 2011). The etchings are microorganisms (<100 um) such as bacteria, fungi, and algae that penetrate inside the coral skeleton by dissolving it (Hutchings, 1986). Recently, microborers have been classified as phototrophic (cyanobacteria, chlorophytes, and rhodophytes) and organotrophic (fungi, foraminifera, prokaryotic, and eukaryotic microorganisms) (Tribollet and Golubic, 2011). To the author's knowledge, Bacillariophyta (diatom) has previously never been reported etching on living coral, and few reported in carbonate of dead coral (Bodén, 1988; Wisshak *et al.*, 2014; Nicholson and Clements, 2020).

Diatoms (Bacillariophyta) are unicellular eukaryotes naturally divided into two major groups, centric and pennate diatoms (Manoylov and Ghobara, 2021). Centric diatoms have radially symmetrical frustules, whereas the pennate diatoms have oval shaped bi-symmetrical frustules (Kryk *et al.*, 2020; Risjani *et al.*, 2021). Marine diatoms occupy a wide variety of habitats, from the water column to sediments. Floating diatom is called planktonic and attached diatom is called periphyton. The specific media where the diatom lives have different terms: Epilithic (attaches on rocks), episammic (attaches on sand or carbonate stone), epipelic (attaches on mud), and epipethic (attaches on plants) (Flora *et al.*, 2018).

Pantai Kondang Merak, 60 km from Malang, is an intertidal area covered by Scleractinian coral. The massive and folious coral are dominant in this area (Luthfi and Priyambodo, 2020), but both suffer from diseases and bioerosion (Luthfi *et al.*, 2020). This research focused on Pantai Kondang Merak because the destructive forces caused by natural environmental factors are tremendous. In general, high sedimentation rate, strong current, and high wave energy were the leading natural causes of coral compromised health and erosion (Davidson *et al.*, 2018). A previous study on external bio eroding showed that Porites lobata has experienced eroding activity by reef fishes (triggerfish, butterflyfish, and scariid fish), however, there is no report on internal bio eroding in previous work. This study aims to identify internal coral bioeroders from diatoms (Bacillariophyceae).

2. Materials and Methods

2.1 Study Area and Research Location

This research was conducted from April to May 2017 at Pantai Kondang Merak (112° 30' 19.80" E - 8° 24' 14.14" S) (Figure 1). Two places were decided for Montiporid coral observation: the westside and eastside stations. Ten colonies of laminar coral (Montipora) were chosen randomly following these criteria: colony diameter was 50-60 cm, folious lifeform, at a depth of 1-3 m, and were living coral colony (Luthfi and Priyambodo, 2020).

2.2 Etching Identification

Boring activities on Montipora coral were monitored on each surface of the coral colony. Coral surfaces were photographed with an underwater camera (Canon G16, Japan) and processed through ImageJ software. The numbers and types of boring were calculated and identified. Etching data were obtained by taking 2 x 2 cm samples from each coral colony using an iron chisel and hammer (Luthfi and Priyambodo, 2020).The samples were obtained randomly from the colony surface. Microborers were identified after coral fragments were processed in the laboratory of Exploration of Fisheries and Marine Resources Universitas Brawijaya for bleaching. Then samples were air-dried and pinned on an aluminum stub for Scanning Electron Microscopy at the Central Laboratory of Universitas Negeri Malang. The identification of the biota will follow the established protocol by Witkowski (2001), Hutchings (2008), Wisshak *et al*. (2011), Glynn and Manzello (2015), and Kryk *et al*. (2020). The density of diatom in coral skeleton is calculated by dividing total number of diatoms attached in coral skeleton to the observed SEM area (Blinn *et al*., 1980; Kawamura *et al*., 1988).

3. Results and Discussion

3.1 Results

3.1.1 Boring incidence

A total of ten colonies of laminar coral were monitored in Pantai Kondang Merak. The macro boring was found in colony B (4 bores) and E (2 bores) in which bores were caused by polychaetes (Figure 3). From the sample of 10 colonies, the SEM images showed that the endolithic diatom was present underneath the coral's skeleton (Figure 2A). The density of diatom was 7 cells/ 25 µm^2.

3.1.2 Cocconesis sp. bioeroder

The diatom was small with an average length, and the wide frustule were 5 and 10 µm, respectively. The shape of the diatom was pennate with a bilaterally

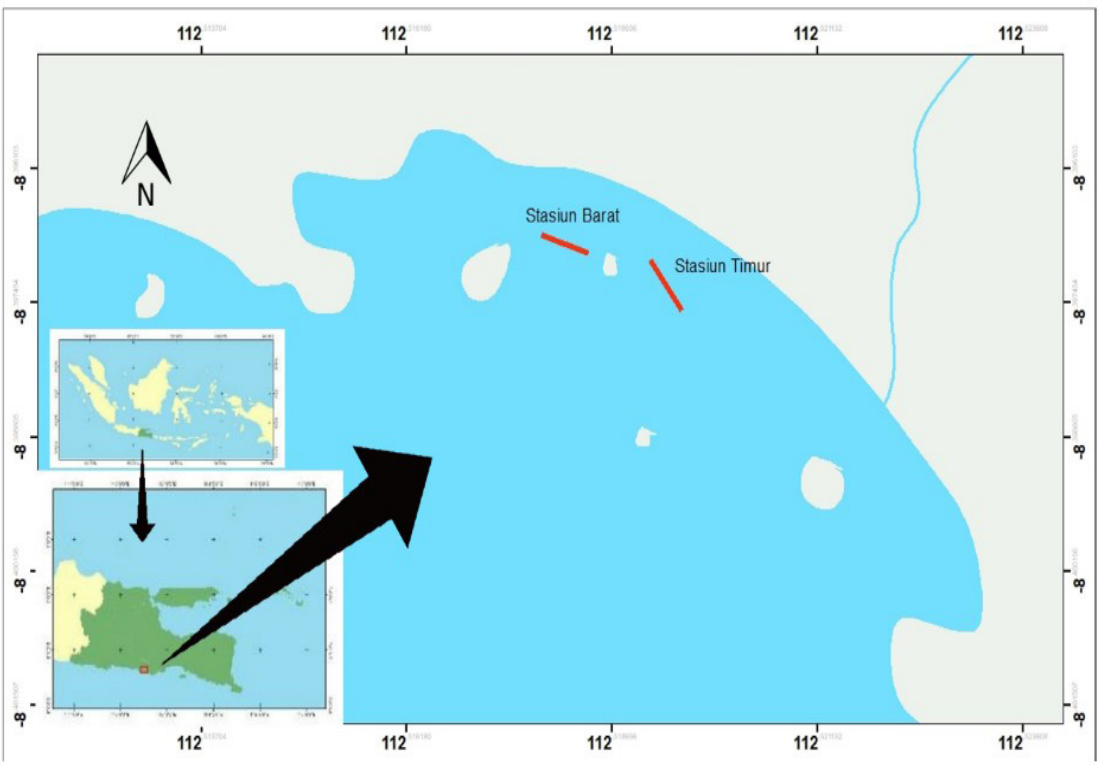

Figure 1. Research locality in Pantai Kondang Merak, Malang. Westside station (8°23'48.33"S; 112°31'4.37"E) and eastside station (8°23'50.22"S; 112°31'9.78"E) were marking by red lines.

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symmetrical shape. The raphe was only present in one of its valves, hence why this diatom was called monoraphiddiatom. Due to the stria structure of the raphe valve (RV) and rapheless valve (RLV) being different from the bioeroder diatom, it was identified as Cocconeis (Riaux-Gobin *et al*., 2021). These diatoms were etching and boring in Montipora coral. Their frustule was attached and penetrated on coral cavities and was seen sinking in coral aragonite (Figure 2A). The diatom only attached to coral cavities may be successful as a microborer since no aragonite attaches to their frustule. The living diatom was obtained from the wild sample by monoculture process and its chloroplast of the diatom (brown color) lies along their valve (Figure 2B-D).

3.2 Discussion

Previous studies showed that coral micro borers were comprised of cyanobacteria, algae, and fungi (Tribulet, 2008), but there were no reports on diatom. One species of cyanobacteria was prevalent on Acroporiid coral (*Isopora palifera*), an anaerobic bacterium from Prosthecochloris, and other filamentous bacteria considerably associated with coral reef such as *Plectonema terebrans*, *Mastigocoleus testarum*, and *Halomicronema excentricum* (Pernice *et al*., 2020). Microalgae are mostly found to live underneath the dead and live coral skeletons, forming a visible green band of coral aragonite. The most dominated species of filamentous green algae was *Ostreobium* spp. This species has been reported to live in Pocilloporid, Acroporid, Stylophorid, Faviid, Montrastreaid, Poritid, and Goniastrid coral (Larkum *et al*., 2003; Gutner-Hoch and Fine, 2011; Massé *et al*., 2018; van Oppen and Blackall, 2019; Yang and Tang, 2019). The endolithic fungi penetrate coral skeleton along with microalgae Ostreobium. The common fungi (Ascomycota and Basidiomycota) intrude on coral Porites, Pocillopora, and Acropora (Bentis *et al*., 2000).

Euendolithic diatom has been reported to attach and etch on the fossil of carbonate (*Ophthalmichnus lyolithon*) and carbonate sand (Bodén, 1988; Wisshak *et al*., 2014), but there are no reports of euendolithic diatoms on coral. The diatom genus Cocconeis Ehrenberg

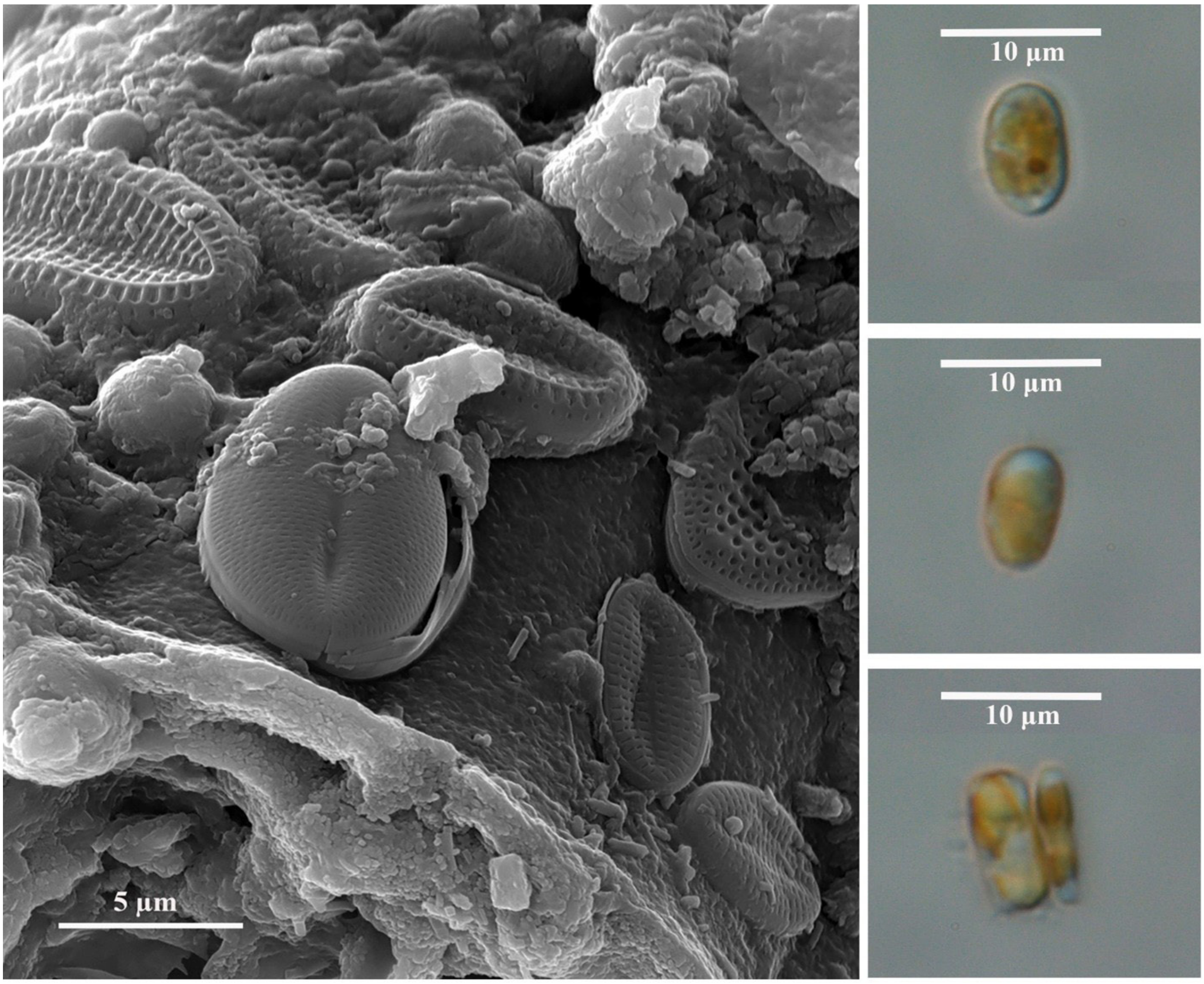

Figure 2. SEM micrographs of *Cocconeis* sp. attached inside Montipora coral skeleton (A). Living photographs of cultured *Cocconeis* sp. with measured bar (B, C, D).

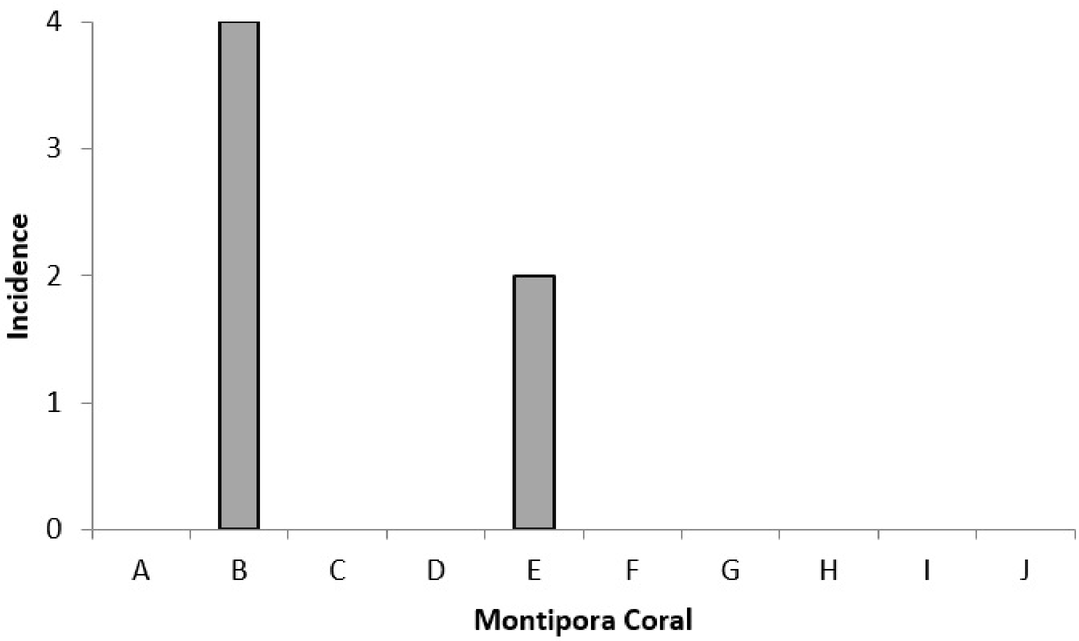

Figure 3. The incidence of boring biota in Montiporid coral

1837 has been known as the fouling diatom community, which can produce an adhesive made from acidic polysaccharides (Daniel *et al*., 1987; Riccio and Lauritano, 2019). However, the mechanism of how the endolithic autotrophs penetrate the coral skeleton and evolve to live inside is unknown. Researchers hypothesize that diatom uses chemical compounds instead of mechanical means (Tribollet, 2008). It has been suggested that substrate dissolution is caused by the production of acid or heterocyclic compound solution from diatom (Golubić and Schneider, 1979; Tribollet, 2008). Diatom probably indirectly penetrates the aragonite of coral since herbivorous fish like parrotfishes (Scarini) scar coral surface by biting, and the borer diatom will live inside of coral along the healing process of coral scars (Nicholson and Clements, 2020). Nicholson and Clements (2020) stated that the number of pennate diatoms is always present on Scarini's bite marks in coral, with a density of >100 cells per cm^2. Bite scars on coral will be recovered within three or four weeks (Mumby, 2009), and during those times, epipsammic diatom is attached to coral by secreting a thin film of adhesive until they are covered by coral skeletons (Chiovitti *et al*., 2006). Since endolithic diatoms are light-dependent, they live beneath live coral tissue and always keep pace with the coral calcification rate (Tribollet, 2008; Tribollet and Golubic, 2011). This technique has been followed by other microalgae, such as Ostreobium quekettii living under the surface of massive coral (Priess *et al*., 2000).

4. Conclusion

The present finding showed summarized evidence that pennate diatom, *Cocconeis* sp., played a significant role as a boring microorganism in living Scleractinian coral. Previously *Cocconeis* sp. is only known as epipsammic diatom, which prefers to live in sediment or sand cavities in an intertidal environment. It needs more research on potentially identifying other euendolith diatoms that live along with living coral. This information will support knowledge of constructive and destructive processes in coral reefs and precisely reveal the impact of a diatom on coral health.

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Authors' Contributions

The contribution of each author is as follow, OML; wrote, conceptualized, and interpreted the original draft. AHP; designed research, analyzed data, and conducted the sampling in the field. YR; conducted technical assistance and managed bibliography. MH;

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conducted the methodology and discussed the result. AW; provided resources, identified diatom, discussed the result, and proofread the manuscript. All authors contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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