The impact of Manta Mae Phinisi ship grounding at Gili Lawa Darat Marine National Park of Komodo, West Manggarai, East Nusa Tenggara

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Abstract. Coral reefs are distributed widely around Indonesia waters which have various functions as fisheries sources and tourism benefits. Coral reefs are very vulnerable to various threats, such as ship grounding in several areas in Indonesia. The measurement of damage width of coral reefs used the irregular polygon method. In contrast, the impact and the level of damage were measured using the underwater photo transect (UPT) method. The grounding of the ship has caused massive damage to coral reefs with a width area of 46.89 m². Types of damage include physical and biological damages that make the coral split, break, and shift. The ship grounding caused the coral colonies to be uprooted and blown from the substrate, destroying coral skeletons, lifting, and sediment displacement. Coral condition at the control area was 35.13% (bad condition), whereas condition on the damaged area as the impact of ship grounding was 14% in trajectory zone. The total width to be claimed was 11.92 m². The degradation of coral reefs can affect and reduce the functions and benefits of ecosystems both ecologically and economically. The shipowner has to do the rehabilitation and compensation of the damaged area.

Keywords: compensation; coral coverage; damage; irregular polygon; trajectory area

1. Introduction

The condition of coral reefs in Indonesia which reported in 2019 was only 6.42% in very good, 22.3% in good, 37.38% in fair, and 33.82% in poor conditions. Some areas have coral cover declined in 2015 and 2016 due to the El Nino, which is indicated as the warm phase of the El Nino Southern Oscillation (ENSO). In addition, the Indian Ocean got warmer and affected the reefs in the western and southern parts of Indonesia, besides the anthropogenic factors [1]. The Indonesian coral reefs have various global problems such as destructive fishing, coral mining, coastal development, ship anchors, tourism activities, and sedimentation sea transportation can cause ship grounding to damage coral reefs [2].

Other issues from natural damage sources such as ocean acidification and global warming caused bleaching events in Seribu Island, Lombok, Padang, and other areas, which happened many times from 1883 till 2016 [3, 4, 5]. Besides the anthropogenic damage source, degradation of coral reefs can occur naturally, such as earthquakes, tsunamis, typhoons, and outbreaks from Acanthaster plancii and Drupella sp [6,7].
Ship grounding often happens on coral reefs, and some of them are unreported in Indonesian waters. The impact of the ship grounding can cause the uprooting and blow of corals from substrat, pulverization of coral colony, uplift, and displacement of send deposits [8,9]. A ship grounding can break the surface of the coral reef, coral skeleton and make the bottom topography changes. The cracked, detached, and unstable coral substrate can cause haphazard injuries to nearby biotas who inhabit coral reefs [10]. This results in a low natural fusion rate of the fragments into the substrate. The almost complete removal of live coral colony fragments can occur due to strong currents or during storms [11]. The damage corals due to ship grounding can cause few coral colonies injuries to large areas undergo changes to abnormal coral reef structures.

According to the report that the Phinisi Manta Mae ship ran aground on June 9, 2018, on the coral reef at Gili Lawa Darat-Komodo National Park. The ship grounding has destroyed the coral reef condition there. This research was needed to be carried out with their aims to analyse the impact of ship grounding to the coral reef condition, including percentage of hard coral cover, identification of coral damage the type and level of damage, and the width of coral reefs damage.

2. Material and method
2.1 Coral reef habitat data
Data collection was carried out on 3-8 August 2018 at Gili Lawa Darat, Marine National Park of Komodo at the coordinates of 8.478° S - 119.556° E (figure 1). It had been 2 months since the incident. The data collection technique was carried out using the SCUBA diving equipment. Observations of the data of live coral cover and biota as well as other types of substrates spread from 1 m to 50 m long transect line with 2 replications. Data collection used the Underwater Photo Transect (UPT) method through underwater photography with a digital camera G16 (Canon, USA) on a quadrant frame with size 58 cm x 44 cm and taking photos horizontal position to the frame every 1 m distance between the frames, and the frames were installed alternately on the left and right sides of the meter line length [12]. Observation of coral species on each transect used belt transect and enumeration methods [13], where observers swim in an area of 2 m x 50 m and recorded each coral species found on each installed transect. Other supporting data such as profile
and type of substrate/damage. Underwater photography and video used a digital camera. Finally, recorded the geographical coordinates (GPS) to mark the observation point for the two locations.

2.2 The damage area width
The first stage was to do a rapid survey by observing the reef profile and identifying the damaged area due to ship grounding on the location. The target area was marked with several buoys surrounding the damaged area as floating markers that follow that unregulated polygon. This area was observed in more detail to get live coral cover and coral species diversity.

The width of coral reef damage has measured the distance between 2 sides of the polygon with 1 cm accuracy on every 2 m addition length until the end of another side of the polygon. Then, the data was moved and re-drew on millimeter paper with scale, and carried out digitization around it by using Image J computer software to get the damage width.

The kind and type of damage on corals and their habitat were observed in polygon areas to get the type of coral damage such as rubble, shards, coral fractures [14, 15]. Documentation used a camera digital Canon G-16 to get an underwater photo and video. Compensation for the affected area that will be claimed to the shipowner was calculated by formula = damage area width (m²) x live coral cover (%) x dead coral cover (%).

2.3 Data analysis
The data were collected analysed from the underwater pictures with total 50 pictures per transect. The Coral Point Count with Excel extensions (CPCe) computer software was used to analyze the underwater photo data on each transect to get the percentage of biota cover and coral species. Each picture put amount of 30 points which was identified what biotas under the point [13, 16]. The percentage of substrate cover categories was obtained from the following formula:

\[
\text{Percentage of cover category} = \frac{\text{Amount category to } - i}{\text{Total random point}} \times 100\%
\]  

The coral condition was assessed referring to the standard criteria for coral condition as stipulated in the regulation of the State Minister of the Environment No. 4 of 2001, namely poor (0 - 24.9%), fair (25 - 49.9%), good (50-74.9%), and excellent (75-100 %). The type and form of the degraded substrate were identified and analyzed based on the affected and unaffected areas. Directly affected areas include general categories, namely: (1) substrate or reefs damage, (2) benthic biota damage or death, (3) coral damage or death due to being buried by pieces of substrate, erosion, and sedimentation from the substrate and dead coral that was hit by a ship grounding. Degradation and types of damage to reefs or corals were carried out descriptively in situ through physical observations of the coral condition in general and the presence of benthos biota. In particular, on scleractinian coral, observations are based on live or dead morphological forms, loose/uprooted corals, broken or crushed corals, changes in the corals’ three-dimensional structure, and changes in corals and reefs’ three-dimensional structure. The coral mortality rate was determined by observing the dead colonies (tends to be 100 percent bleaching, a part bleaching or starting to be covered by algae) following the distribution of the damaged area [17, 9, 18].

3. Result and discussion
3.1 Live cover and diversity of scleractinian corals in the control site
Observation of the benthic and the substrate condition is becoming very important for determining the coral condition outside of the damaged areas. Observation of the bottom substrate condition was carried out approximately 5 m from the location of the ship grounding, which was a
representation of the initial corals condition. The results of observations show that dead coral dominated the bottom substrate condition with algae (DCA) of 49.43%, the hard coral cover of 35.13%, and other living biotas of 11.43%. The live coral cover is categorized as fair damaged, in which the initial condition of live coral reef cover around the ship grounding site is 35.13%, as depicted in the control location (figure 2a).

A DCA of 72% dominated by benthic in the trajectory area. The percentage of hard coral at locations that were directly hit by ships ranged from 14%, which was categorized as poor condition (figure 2a).

The growth form of hard coral in the control site is dominantly composed of a CB of 13.30%, ACB of 10.97%, and ACT of 4.83%. The form of coral growth varies greatly and is used as one of the criteria for determining coral species—other than CB such as *Stylopora, Pocillopora* and *Porites* [19]. Complete data on hard coral growth forms that have been found presenting in figure 3. Hard coral found in ship grounding area was dominated by the branching coral growth (CB) of 7.89%, followed by *Acropora* coral branching growth (ACB) of 2.33%, and massive coral (CM) of 2.78%. More complete data on hard coral growth forms can be seen in figure 4. The dominant coral growth forms are coral branching (CB), *Acropora* branching (ACB), and coral massive (CM). Coral

**Figure 2.** Diagram of the benthic cover at the control site (a), cover condition at trajectory area (b). (HC: Hard Corals, DCA: Dead Coral, DCA: Dead Coral with Algae, SC: Soft Coral, SP: Sponge, FS: Flashy Seaweed, OT: Others, R: Rubble, S: Sand).

**Figure 3.** Diagram of the growth of hard coral at the control area. (ACB: Acropora Branching, ACD: Acropora Digitate, ACT: Acropora Tabulate, CB: Coral Branching, CE: Coral Encrusting, CF: Coral Foliose, CM: Coral Massive, CMR: Coral Mushroom, CS: Coral Sub-massive).
growth rates varied between 1.5 – 20 cm/year depending on the species. The corals such as *Porites* spp, *Favites* spp, *Favia* spp have a growth rate of 1.5 – 2 cm/year [19]. Most of these coral species have massive and sub-massive growth forms, so they are categorized as very slow-growing corals. The fast-growing coral such as *Acropora* can reach 20 cm/year with an average rate of 6.24-15.24 cm/year. Other branched coral species such as *Pocillopora* and *Seriatopora* have an average growth rate of 4.22-8.88 cm/year [33, 34, 35, 19, 36].

### 3.2 Conservation status

Conservation criteria for protecting species and communities, namely uniqueness, threat, and utility (UU No. 5/1990) through the approach to the importance of species, community and ecosystem values, are the main considerations in this coral reef ecosystem. The ecological importance is as a buffer for the world’s coral species diversity [20, 21, 19, 22]. The results of the identification show 30 genera of coral that are included in the red list of IUCN (International Union for Conservation of Nature). There are 17 species in near threatened status, meaning that this species is in the criteria of approaching vulnerable because of the population and distribution on conservation efforts. There are 8 categories of least concern, meaning that they must be the focus of attention in monitoring related to population and their distribution in nature. There are 6 species vulnerable, meaning that these species are close to endangered status, where most of the causes are damage or loss of habitat for these species In addition, there is one type of data deficient, meaning the availability of population data is very minimal.

### 3.3 The impact and width area of coral damage

The type of coral damage and indications of a ship grounding can be seen in several conditions of the corals affected: a) the impact of being crushed, b) the colony was split into chunks and cut branches, and c) the formation of a new substrate condition where the bottom part was lifted to the surface and partly seemed to be compacted to the left and right sides of the former keel of the ship with irregular conditions compared to the normal conditions.

The colony was split into large and small chunks indicating a strong collision, resulting in coral colonies being broken and scattered on the bottom of the water at the scene. Branched coral fractures have been covered with algae, indicating the coral has died. Newly dead corals will be...
easily covered by algae quickly after about 1-2 weeks and will become an obstacle for new coral larvae to attach to the existing algae substrate as shown in figure 5 [23, 24, 25].

New substrate conditions formed, the ship’s stern ran aground, making a deep basin so that the substrate conditions changed where the bottom layer turned into a surface. This condition causes several live coral colonies to enter the mound of coral fractures, such as corals from the Fungiidae family, *Halomitra pileus* species buried between coral fractures since the ship ran aground. Conditions when buried (b) and conditions after being removed showed coral bleaching/stress (c).

**Table 1.** The total area of damage and total area of damage claimed

| Damage type | Area (m²) | Live cover (%) | Dead coral (%) | Damage claim width (m²) |
|-------------|-----------|----------------|----------------|------------------------|
| Trajectory  | 46.89     | 36.33          | 70             | 11.92                  |

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The directly affected area can be seen from the grounding of the Manta Mae ship in the trajectory area, which signed a huge basin and some corals were damaged due to being hit by the ship. After being analyzed by direct measurements in the field and analyzed using Image G software, the total area obtained from the damaged area is 46.89 m² (figure 6).

Observation of coral reef damage did not find any dispersal damage. Furthermore, the measurement results of the total area of damage will then be multiplied by the initial conditions of
coral reef cover and coral mortality to obtain the extent of damage claimed to the ship. The full results are shown in the table 1.

3.4 Impact on coral biology and Ecology

Coral mortality affected by ship grounding was found at a depth of 3-5 m, where corals had already died. These corals came from the group of growth forms Acropora Branching (ACB), Coral Branching (CB), Coral Folious (CF), Coral Mushroom (CMR), Coral Massive (CM), and Coral Sub-massive (CS). The affected corals came from 14 coral genera, including Acropora, Euphyllia, Diploastrea, Favia, Fungia, Heliofungia, Halomitra, Hydnophora, Montipora, Mycedium, Pavona, Pocillopora, Porites, Leptoseris, and Heliopora.

Other types of animals or biota found were clams (*Tridacna* sp), sea cucumbers, soft corals (*Dendronephthya*), crinoids, ascidians, gorgonians, and anemones which are in symbiosis with Nemo fish (*Amphiprion* sp).

Among the affected coral species, two types of coral require a long time to recover, namely *Porites lutea, Favites* sp from a massive life form. These corals have a slow growth rate compared to other types of coral from the branching group. Based on the results of research on Cemara Kecil Island, Karimunjawa Islands on the Eastside and West Side with 2 different depths of 3m and 10m, it is known that the growth rate of *Porites lutea* ranges from 5.38 to 17.00 mm/year [27].

Dead coral chunks from the life form massif, small visible cracks that are almost separated prove that the collision against the coral reef was strong enough to damage the coral reef. Besides, small coral fragments measuring 10 cm have been separated and are side by side with chunks of dead coral around them.

There was a change in color to the pink of the coral species of *Porites lutea* as a result of the stress response that was trying to adapt and survive after the disturbance from the ship aground (figure 8). Tissue discoloration is only caused by animals that live in association in coral colonies (borers), competitors, algae, fish bite marks, and lastly, damage marks that can be associated with a ship grounding in the larger coral colony of this massive growth. Furthermore, it is said that tissue discoloration is not a characteristic of coral disease [28].

Some of the massif coral colonies that have died have traces of ship paint attached, which will make it difficult for parts of the colony to recover as before. The ship’s paint contains anti-biofouling to prevent attached animals from sticking to the hull. Sticking animals will slow down the ship and can damage the ship’s hull faster. Boat paint containing this antifouling compound is known as Trybutyl Tin (TBT). In this case, the contamination of this compound is very effective in killing larvae and adult attachment animals [29]. This will reduce the recruitment of new corals [30], and it can inhibit fertilization and larval metamorphosis [31]. The use of TBT harms marine ecosystems [32, 37] as the TBT compounds are classified as highly toxic compounds and naturally difficult to decompose. Thus, the presence of ship paint attached to coral colonies will be able to
disrupt coral growth and inhibit the attachment of other biotas, including coral larvae, to dead coral chunks that have ship paint on them. Indications of contamination of TBT compounds can also be detected from the sediment at the site of the ship aground [9]. However, using the coral bacterium Pelagiobacter variabilis is currently considered safer as an antifouling [33].

4. Conclusion

Ship grounding of Manta Mae Phinisi damaged coral reefs with a total area of 46.89 m$^2$ and the claim for compensation was 11.92 m$^2$ after calculating coral condition in the outside and inside coral damaged area. The condition of live coral in the control area was an average of 35.13%. There were 30 genera of coral included in the IUCN (International Union for Conservation of Nature) red list with near threatened, least concern, vulnerable, and data deficient. The impact of damage to coral reefs being crushed, split into chunks and cut branches, and new substrate conditions are formed. The ship ran aground, causing the corals to experience stress marked by the bleaching of some colonies, the color changed to pink, and there were buried coral colonies.

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