Assessment of coral reefs damaged due to MV Pazifik ran aground in the Sape Strait using an aerial photography approach and species distribution modeling

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Abstract. Indonesia as an archipelagic country has a high biodiversity of coral reefs but is very vulnerable to various threats, one of the causes of damage to coral reefs is by ship aground. The damage causes minor injuries to the degradation of the reef structure. The location of the grounding sometimes on the small islands with calm currents, but sometimes in straits with strong currents. However, the assessment must be carried out, so it is necessary to develop an approach to assessing that. The purpose of this study is to assess the damage of coral reefs, to quantify the extent of damage, and identify species of corals affected. The observation used ground truth (underwater photo transect), aerial photography, machine learning, and species distribution modeling. The results obtained from aerial photography show that the MV Pazifik has damage to coral reefs reaching 613.63 m². Based on the coral genera distribution model, it was found 35–55 genera (control location), while at the ship aground, were found 3–5 genera. Therefore, the control location is a coral reef ecosystem that is dominated by corals, while at the ship aground it can be the habitat for several hard coral genera.

Keywords: aerial photography; coral reef damage; coral reef ecosystem; genera distribution model; MV Pazifik; ship aground

1. Introduction
Various global problems threaten the world’s marine ecosystems, including in Indonesia, which could ultimately lead to the destruction of coral reef ecosystems. In addition to the actual degradation that occurs, there are very serious concerns that threaten the existence of coral reefs and marine life from 'the evil twin': ocean acidification due to increased carbon dioxide and ocean warming due to global warming [1-4]. Damage and degradation of coral reefs can occur naturally and anthropogenically, directly or indirectly accumulated from various sources. Physical damage is naturally occurring earthquakes, tsunamis and typhoons, and massive outbreaks from Achantaster plancii and Drupella sp. [5-7]. Damage caused by the utilities of coastal areas such as agriculture, industry, coastal dredging, poison fishing and fish bombs (destructive fishing techniques), reef damage due to vessel anchorage,
tourism activities, sea reclamation/stockpiling/hoarding, sedimentation, coral mining, and other. Human activities in the field of transportation (marine transportation) can disrupt and damage coral reef ecosystems such as pollution and massive damage due to ship grounded [7-11].

Since ancient time, ship groundings on coral reefs are frequent, which create biophysical damages, such as coral and sediment deposit displacements, skeletal damage, and loss of structural rugosity [10, 12-16]. Some off-ship grounding cracks the surface of the coral reef, the framework generally becomes stabilized and prone to subsequent mobilization and destruction. Reef hard can be destroyed and topography altered. Detached coral rubble can injure plants and animals within their vicinity [17]. Salvage operations usually only focus on damages to reefs, not concerning damages due to fuel and cargo slick from hull breakage, which create long term effect to the coral regeneration process [18]. Resulting from low natural fusion levels of fragments to substrates, virtually complete removal of living coral colonies fragments may occur during subsequent storms [19]. Damages from ship groundings can vary from minor and harmless to loss of reefs rugosity. For example, damage of coral reefs due to ship grounding by MV Lyric Poet in Bangka-Belitung waters has damaged hundreds of square meters of coral reefs and degradation of the structural complexity of the reefs to form like a canal [20].

Indonesia is an archipelagic country that is very vulnerable to various threats of coral reef damage. Various cases of damage to coral reefs damaged by the ship grounded were overlooked by scientists, coral reef managers, divers, and sailors themselves. Indonesia has the potential of marine wealth and high biodiversity that is utilized for the prosperity of society. Coral reef ecosystems with various habitat types and characteristics not only envelop almost all of the islands but also spread in remote seas far from the mainland. The sea utilization as well as the media of transportation sometimes collides with this ecosystem.

Coral reef damage caused by aground of the MV Pazifik ship (08.29.213 S, 119.2030 E) in Sape Strait. The ship that ran aground was a tanker that weighs 35,853 GT (gross tonnage), 205 m long, and 32.23 m with a draft or the keel of the ship from the surface air to the bottom of the hull of approximately 11.6 m. As well as the top speed recorded at 10.3 knots with an average of 8 knots. Ship aground rarely catches researchers’ attention, causing the damage to be overlooked. Therefore, it is crucial to study the impact of these sunken on damages to reefs habitat in Indonesia. The purposes of this study are identifying and mapping damage levels of the coral reefs and identifying the affected coral reefs species and last, to quantify the damaged area of the coral reef.

2. Materials and methods

2.1. Location and time of research
The research was done at Sape Strait from 3–8 August 2018. The area of damage to coral reefs by the aground of the LPK MV Pazifik ship was measured using aerial photography at the GPS point (08.29213° S; 119.2030° E) (figure 1). Ground check data were collected at two points, where the GPS was respectively 08.455360° S; 119.296690° E and 08.452280° S; 119.278460° E (figure 1). These two locations can represent to estimate habitat conditions, live coral cover, coral species at depths that are between 8 m and 10 m.

2.2. Data collection technique for coral reef habitat
The data collection technique for the underwater substrate was done with Underwater Photo Transect (UPT) [21, 22]. Coral species data collection was carried out using belt transects and enumeration [23]. 1 x 50 m each transect. Observation points were set on non-affected areas (four transects) (see figure 1).

2.3. Aerial photography
Taking aerial photographs using the DJI Phantom 4 drone were carried out on August 4, 2018, which began with planning a flight path using the Drone Deploy an application with a flying height of 100 meters at the coordinate point 08.0291278° S–1190.201830° E and surroundings to obtain representative visual data. Take-off and landing were controlled manually from a small boat. It is worth highlighting
that atmospheric and marine weather. The results of the aerial photographs that have been taken have a coordinate point just above the location of the grounding. From the results of the drone mapping, 90 images were produced which were then processed using the Photoscan application.

The results of the shooting are processed by combining all drone photos with a spatial resolution of 4.3 (four points three) centimeters per pixel using the Agisoft Photoscan software by merging/aligning photos with each other and creating a mosaic. Aerial photography with drones is used as the basic for mapping damage at a standard scale using the length of the ship as a reference. Digitization is carried out around the white color of the wrecked ship so that the area of damage is obtained. The area of habitat damage (m²) caused by shipwrecks was calculated using Image J Ver. 1.51j8 software. The use of this method has often been used in coral reef research, such as calculating the extent of the impact of coral disease [24-27].

2.4. Species distribution modeling
Coral occurrence and environmental data were used as the input for Maxent version 3.4.1 (https://biodiversityinformatics.amnh.org/open_source/maxent/) to model coral distributions [28]. Default model parameters were used as they have performed well in other studies and validated on a wide range of datasets (a convergent threshold of 10–5, maximum iteration value of 500, and a regularization multiplier of 1) [29]. The threshold feature used was a 10 percentile training presence. Models were run with three-fold cross-validation, where presence locations were split into training data for model fitting and test data for model evaluation, and then averaged [30]. Then analyzed by modeling approach and cloud-based Landsat 8 satellite imagery. Based on modeling, it will obtain estimated data on the genera of hard corals that can grow in that location (ship grounding).

Map of Ship Grounding MV Pazifik and Survey Location
Sape Strait – West Nusa Tenggara

Legend
- Ship Grounding
- Area MV Pazifik
- Survey Location

Figure 1. Ship grounding area of MV PASIFIK in Sape Strait, West Nusa Tenggara (Coordinate 08.4881430° S; 119.3377760° E) and Controlled survey area in the southern part of Gili Banta Island (Coordinate of Sampling station 1: 08.455360° S; 119.296690° E and Sampling station 2: 08.452280° S; 119.278460° E).
2.5. Data analysis

2.5.1. Live coral cover. Underwater photographic data on each transect were analyzed using CPCe software, Coral Point Count with Excel extensions [31]. Analysis of the percentage underwater substrate covered by calculating the percentage category of substrate cover obtained from the formula [23]:

\[
\text{Percentage of category cover} = \frac{\text{number of i - categories}}{\text{number of random dots}} \times 100\% \quad (1)
\]

In general, the assessment of coral reef conditions refers to the standard criteria for coral reef damage based on the Decree of the State Minister for the Environment No. 4 [32], namely damaged (0–24.9%), moderate (25–49.9%), good (50–74.9%) and very good (75–100%).

2.5.2. Number of hard coral genera. The number of coral reefs damaged can be seen from the number of coral genera around the aground ship, it was analyzed using image data. Two points of observation location for coral condition (figure 2), used as comparison data by utilizing the appearance of the same color at the two locations to determine the number of coral genera at the site of the ship aground. Analysis of the distribution of coral genera in certain waters has been carried out on several genera and even the level of coral species in several locations in Indonesia [33]. Besides, the Landsat 8 image data analysis method has often been used to determine the condition of corals [34].

3. Results and discussion

3.1. Hard coral cover and diversity at the ground check point

The results of observations at locations that represent the condition of the coral reefs around the ship aground were found the average percentage of hard coral cover was 13.36% (damaged category) based on the Decree of the State Minister of Environment No. 4 [32]. While the dominant substrate cover is soft coral (SC) by 62% and dead coral with algae (DCA) by 23%. Furthermore, other substrate categories are at values below 5% such as rubble, sponge, sands, and recent dead coral (figure 2). The condition of coral cover in the waters of Gili Banta has decreased significantly from the previous condition about 3 years ago (2015). According to [35] the average of hard coral covered in Gili Banta was 45% with the highest value in West Gili Banta (50% = Good Category), while the soft coral cover is quite high by the strong current energy and sea waves of the Sape Strait which marks the characteristics of the surrounding coral reef habitat in Gili Banta and its surroundings [35].

![Figure 2. Graph of the percentage of the bottom substrate coverage at unaffected locations (GCRMN category).](image)

The hard coral cover in Gili Banta (control location) was dominated by coral growth forms (coral foliose = CF), then massive forms (coral massive = CM) and branched corals (Coral branching = CB). There were 38 hard coral species were found at the site, 26 genera belonging to the Anthozoan class and
1 genus belonging to the Hydrozoan class. According to Tarigan et al. [35], in the waters of Gili Banta were found around 75 genera based on a survey in several locations in Gili Banta and Kelapa Island.

3.2. Modeling and cloud based satellite imagery approach

The location of the ship aground in the middle of the Sape Strait was a challenge for the team to collect data on damages and condition of coral reef ecosystems. Water conditions are quite extreme, so it is necessary to wait for the time during the highest or lowest tide because at this time the waters will be calm. This time is used to get closer to the location, but still unable to dive due to the meeting of a fairly strong current. Based on direct observation at the site and modeling studies with the Hycom satellite imagery, it was found that the current site velocity reached an average of 4 m/s, and sometimes the maximum could reach 18 m/s.

In the waters of Gili Banta in the east, there is an encounter between 3 currents that cause vortex currents, which originate from the Sape Strait, Sumba Strait, and the Flores Sea. Meanwhile, the average wave height in the Gili Banta region ranges from 20–70 cm and is dominant in the northwest direction. In the northern monsoon wave height can reach an average of 0.7 m [36]. The extreme conditions at the location make it impossible for SCUBA or snorkeling surveys. So Species distribution modeling approach can be used to collect data on coral genera around the ship grounding. The nearest location is used as an approximation to the reference point. The closest location to the ship aground is Gili Banta Island.

Based on the results of the coral genera distribution model (figure 3), it was found 35 and 55 genera at the control location (transect 1 and 2), while at the ship aground only 3–5 genera were found that were possible to live. Therefore, the sampling station represents the rich coral reefs ecosystem, while the ship grounded area has poor coral richness. Based on our result, the use of species distribution modeling can be one of the alternatives in predicting genera affected with ship grounding where SCUBA surveys were not feasible due to environmental and safety constraints. This method has been widely used by several other researchers to predicting the distribution of coral species or coral genera [28], live corals, seagrass, sand and coral debris in Morotai Island, North Maluku Province [37]; distribution and condition of coral reefs around Panjang Island, Sumenep Regency [29]; and to obtain changes in the area of coral reefs on Langkai Island, Spermonde Islands [38].

3.3. The extent of damage area with drone

The use of drones for different types of vegetation classification has increased many folds over the last decade [39]. This is due to the technological development of affordable and lightweight drones. With drones, a very high and flexible spatial resolution can be achieved, which is not possible with satellite imagery due to their fixed orbits.

However, another method to get detailed monitoring of small areas is to use unmanned aerial vehicles (UAVs), more commonly known as drones. Drones have been explicitly used for species detection. A study states many advantages of using a drone over satellite imagery for the identification of land cover communities such as water and mangrove. Drone imagery has also been applied for specific applications such as analyzing vegetation under shallow water, tracking waterbirds, and their habitats [39, 40].

Based on drone data we get the area directly affected (figure 4) is visible from the ground of the MV Pazifik (trajectory/hull footprint), which is the main area where the hull ran aground, hit, and ran over. The total area of damage due to aground vessels is 613.63 m². Meanwhile, the indirectly affected areas (dispersal) could not be observed because there was no SCUBA survey due to the current conditions that were not possible for the safety of the survey team. Our results show that consumer-grade drones can be effective for applied in the monitoring of coral reefs at scales that lie between the typical scales of SCUBA, it is in line with the results of research by Hedley et al. [41] which states that drone surveys are more effective than scuba diving or snorkeling surveys, or typical of airborne or satellite mapping. Several other researchers also stated that monitoring the characteristics of coral reefs is essential to understand their trajectories under scenarios of climatic or anthropogenic stress or their recovery from these impacts [41] or other airborne imagery such as aerial photographs, which are currently extensively used to monitor the trajectory of bleaching events and wildlife [42-45].
**Figure 3.** Coral genera distribution model on the ship grounding and two sampling stations in Gili Banta.

**Figure 4.** The extent of coral reefs habitat in Sape Strait, Gili Banta Island, West Nusa Tenggara.
4. Conclusions
Based on our results the grounding of MV Pazifik has affected at least 3–5 coral genera with the extent of 613.63 m² of the total area. However, the control site showed a higher genera count (26 genera) with a coral cover of 13.36%, since they are more habitable to corals. The use of species distribution models and drone imagery can become alternatives in the impact of ship grounding to coral reefs where SCUBA or snorkeling surveys cannot be done.

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