The impact of Motor Tanker (MT) Alex grounding on a patch reef 'Gosong Panjang' in the Manggar waters, Bangka-Belitung Province

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Abstract. The ship's ran aground on coral reefs often result in severe physical and biological damage. It is including the removal and crushing of corals reefs (dislodging), the destruction of coral skeletons (pulverization), the erosion and removal of sedimentary calcium carbonate. It is almost cause the loss of three-dimensional complexity. Moreover, this event occurred in the patch reef was far away from the nearest land, located in the waters of Manggar–Bangka-Belitung Province with a distance of ± 65 nautical miles from the city of Manggar. The ship ground has caused damage to the marine environment especially the patch reef ‘Gosong Panjang’ at the location. The Fishbone method with the transect gauge is used to measure the extent of the affected area in each zone and underwater photo transect to measure the level of coral reef damage. Total extent of the affected area of each zone taking into account the survival of corals i.e., 10.177 square meter. Hard coral cover condition in the affected area of 7.7% goes to serious damage or poor. Hard coral species was affected in location where 43 species and 21 species are listed as red IUCN (International Union for Conservation of Nature) with vulnerable status and near threatened.

Keywords: coral diversity; coral reefs; damage area; impact and noimpact zone; type of damage

1. Introduction
The Indonesian Institute of Sciences on 2019 issued the status of Indonesia's coral reef which is only left 6.42 percent in excellent condition. Coral cover for the western region is about 8.97 percent with very good condition; the center is about 4.91 percent and the eastern section 4.05 percent [1].The causes of coral reef damage are due to pollution, ship grounding, coral diseases, climate change phenomena and other natural factors.

Various global problems threaten the world's marine ecosystems which could ultimately lead to the destruction of coral reef ecosystems, including in Indonesia. 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 [2-6]. Physical damage is naturally coming from earthquakes, tsunamis and typhoons and massive outbreaks such as Achantaster plancii and Drupella sp [7, 8]. 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 [9, 13].

Ship groundings on coral reefs often result biological and physical damage in severe location, such as dislodgement, pulverization skeletons, displacement of sediment deposits, and loss of 3-dimensional complexity [14-16]. Some of the ship groundings crack the surface of coral reef, the framework
generally becomes unstabilized and prone to subsequent mobilization and destruction. After that, hard coral will be vulnerable and altered the topography. Hard coral that mobile can cause incidental injury to nearby animals and plants [17]. Salvage operations usually add to reef damages, without counting damages by fuel and cargo slicking from the ruptured hull. This causes acute and long-lasting effects on the regenerative processes of coral communities [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]. Injury to coral reefs by groundings can range from relatively minor injuries to the degradation of the structural complexity of the reefs.

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. The sea utilization, as well as the media of transportation sometimes collides with this ecosystem.

This research was conducted to assess the condition of coral reef ‘Gosong Panjang’ and the impact due to MT Alex ran aground. More specific goals are to investigated coral reef condition recently and to investigated spatial trends in impact zone.

2. Materials and methods
2.1. Location and time of research
This data collecting is done between 7-12 July 2017 (3 months after the grounding). Data retrieval technique is done ‘insitu’ (ground truth) using SCUBA for underwater survey and line transect/survey measure tape. Rapid Reef Assessment (RRA) surveys are conducted to observe the reef profile of the target site and to identify affected area and unaffected area on MT Alex grounding area (figure 1). Once the constraints of the two regions are clearly identified from the water level, this point is marked underwater with a specific buoy of markers on the boundary of the trench/mound (pile of coral rubble) or the flat area of the ship footprint. Floating buoy signing and recoding of coordinates point with GPS are performed on every corner on the rear end and in front of the ship footprint is used as benchmark for underwater mapping. The markers between these impacted areas and unimpacted areas also serve as a benchmark for determine data of coral cover and coral species between areas in detail.

2.2 Data collection
Data collection of coral condition was assessed using underwater photo transect (UPT) method through underwater photography using underwater digital camera [20-22]. Observation area made at 5 points i.e., 3 in the unaffected area and 2 in the affected area. The determination of the 5 representation transects based on consideration results in the first stage of the survey. Observation of coral species of each transect using belt transect and enumeration methods [23], where the observer swam at a radius of 2 x 50 m and recorded each type of coral found in each transect installed.

The Fishbone method (figure 2) with the transect gauge is used to measure the extent of the affected area in each zone [24, 25]. Observations and marking in the early stages are sufficient to provide a topographic map of the damage reef where the meter line is located. By following the stretch of the transect line (roll 100 and 50 meters, 1 cm accuracy) on the left-right of the line, observations and measurements are performed on each of the damage zones.

2.3. Data analysis
The underwater photo data of each transect is analyzed using CPCe software [26]. The percentage analysis of biota cover refers to English et al. [23] with the calculation of the percentage of substrate cover categories obtained from the formula:

\[
\text{Percent Cover} = \frac{\text{Number of Categories} - i}{\text{Number of random point}} \times 100\%
\]
The assessment of coral reef condition generally refers to the standard criteria of coral reef damage based on the Decree of the State Minister of Environment No. 4 of 2001, i.e., damaged (0-24.9%), medium (25-49.9%), good (50-74.9%) and very good (75-100%). Specific damage criteria at the coral

**Figure 1.** Survey area MT Alex Grounding on Belitung waters (± 65 nautical miles of Manggar city).

**Figure 2.** Fishbone method [24, 25].

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colony status level were categorized by estimating the percentage of old and recent dead partial mortality [27-29].

The types and forms of degraded substrate are identified and analyzed based on the affected and unaffected areas, then the areas directly affected by the general category (1) substrate/reef damage, (2) damage / death of benthic biota, (3) coral damage, and indirectly, the death of live corals from buried piles of debris or substrate pieces, erosion and sedimentation of the substrate and dead coral affected by ship collisions. Degradation and types of coral and reef damage are done 'in situ' descriptively by observing the physical condition of coral reefs in general and the presence of benthic biota. Particularly in hard coral biota (Scleractinia) observations are based on the form of live or dead morphology, dislodging and fracturing corals, pulverizing coral skeletons, displacing sediments from ground, and destroying the 3-D structural complexity of the reef. The coral mortality rate was determined by observation of dead colonies (tend to be 100 percent white, or algae-covered, white skeleton) and wide spread of the area [16, 15, 11].

Total affected area is based on measuring the meter width on each zone of the type and extent of coral damage by calculating the longest and widest widths of the width. In the zone of the ship body and the coral pile on both sides, the calculation is based on the longest length and widest width to obtain the area with the formula of length x width (rectangle). In the front and rear zone of the ship (propeller) the calculation is based on the longest and widest width, perpendicular and symmetrical length adjusted to the shape of the stretch of the affected area (ellipse) with the formula: \( \phi \times \text{axis}_1 \times \text{axis}_2 \).

3. Results and discussion

3.1. Hard coral cover and its diversity in affected and unaffected areas

The profile of the reef 'Gosong Panjang' is shaped like a hill poking from the seabed (patch reef) which at its peak has a depth of ± 10 meter depth. Coral reef ecosystem 'Gosong Panjang' is situated far isolated from the mainland, but full inhabited by various biota, benthic life such as coelenterate, molluscs, crustaceans, echinoderms, polychaeta, sponges and tunicates and other biota that live freely in the surrounding waters (pelagic, plankton or nekton) (cover ranges from 70-80 percent). The main component of reef building at this location was a Scleractinia corals Lobophyllia, Porites, Euphyllia and Acropora. Although it is beyond the scope of the coral triangle region, ecoregion Bangka-Belitung (Karimata-Malacca Strait) was important as a buffer the existence of world coral diversity [4, 30].

Observations at the study sites found various components of living benthic biota in the coral reef ecosystem. The main components of coral reefs, i.e., hard corals in unaffected or natural areas (figure 3a) around the location of ship grounding were found to be average 36 % (27.1, 33.2 and 47.7%) entered the criteria ‘medium’ based on the Decree of the State Minister of Environment No.4 (2001). The hard coral cover was dominated by foliose coral growth 8.42 percent, massive coral 7.91 percent, coral branching 6.60 %, sub-massive coral 4.44 % (figure 3b). Other’s biota such as sea lilies has 21.6 %.

In the representation of affected areas (figure 4a), the percentage of hard coral cover that survived was 7.7 percent. This percentage value is in criteria ‘seriously damage’ (poor) based on the Decree of the Minister of State for Environment no. 4 (2001). The hard coral cover was dominated by dead coral with algae 31.92 percent, then coral branching 2.87 percent, coral massive 1.31 percent, and foliose coral 1.27 percent respectively (figure 4b).

Dead coral with in the affected area is larger (49%) than the unaffected (natural) control area (19%). Similarly, rubble and dead corals are higher in affected areas than control areas (natural). This at least shows the effect of distance impact due to ship collisions that ran aground on the coral reef 'Gosong Panjang'. Fragments or coral fractional particles are dispersed following the dynamics of oceanography and shuttle down surviving of benthic biota around the primary grounding area.

Observation of hard coral species at both sampling sites (affected and not affected), found 43 species of hard corals belonging to the Anthozoa of 23 genera. Lobophyllia and Porites genus is the most numerous species found in the location (5 species), following Euphyllia (4 species) and Acropora, Fungia, Galaxea, Hydnopora, Merullina, Pectinia, Platygryra (2 species). The least-identified genera
Caulastrea, Chypastrea, Diploastrea, Goniopora, Herpolitha, Pavona, Physogyra, Sandhalolita and Symphillia respectively (1 species) (Table 1 and Table 2).

The conservation criteria for the protection of species and communities, namely uniqueness, vulnerability and usefulness (UU No.5/1990) through the important value approach of species, communities and ecosystems are the main considerations in this 'gosong panjang' reef ecosystem. Ecological significance is as a buffer for the existence of the diversity of coral species [4, 31, 32]. Based on the results of identification, there are 13 species of corals record at IUCN red list (near threatened) that means the species is entering criteria that are close to vulnerable because the population and its distribution depends on conservation efforts. There are 14 species classified as 'least concern' category means that it should be the focus of attention in population-related monitoring and distribution in nature. There are 11 species classified at vulnerable category, its means these species are nearing endangered status where most of the cause is the destruction or loss of habitat.

3.2. Areas of impact and level of damage
Based on the observation, it is clear that the ship footprint ran aground on the coral reefs, makes it easier to quick determine the position of 'buoy' marking for assessment (14-15 m). Determination of the underwater survey by installing 'buoy' based on the geographical position of GPS coordinates as a sign for benchmark measurement, mapping and assessment.

More detailed observations underwater are clearly visible the reefs peak (reef flat) at a depth of ± 10 meter of natural (undamaged) and damaged area. The abandoned ship hull leaves a clear-cut trace on the reef and gives a mound/pile effect and coral fragments extending on the left and right sides. Similarly, clear holes due to rotation propeller on the reef slopes from depth 18 to at most 30 meter (Rear-Back), colonies of corals were uprooted dislodging due to propeller blowing. The wide and varied trace marks, types and extent of coral injury / reef damage due to the impact of the MT Alex grounding were categorized into 5 zones (Figure 5):
Table 1. Conservation status of hard coral (Scleractinia) in the observation sites.

| Genera | Coral Species | IUCN Red List |
|--------|---------------|---------------|
| Acropora | Acropora divaricata (Dana, 1846) | Near Threatened |
| Acropora | Acropora tenuis (Dana, 1846) | Near Threatened |
| Caulastrea | Caulastrea tumida (Matthai,1928) | Near Threatened |
| Chypastrea | Cyphastrea serailia (Forskal, 1775) | Least Concern |
| Diploastrea | Diploastrea heliopora (lammarck, 1816) | Near Threatened |
| Euphyllia | Euphyllia ancora (Veron &Pichon, 1980) | Vulnerable |
| Euphyllia | Euphyllia cristata (Chevalier, 1971) | Vulnerable |
| Euphyllia | Euphyllia divisa (Veron and Pichon, 1980) | Near Threatened |
| Fungia | Fungia concina (Verrill, 1864) | Near Threatened |
| Fungia | Fungia paumotensis (Stuchbury, 1833) | Least Concern |
| Galaxea | Galaxea astreata (LAMARCK, 1816) | Vulnerable |
| Galaxea | Galaxea fascicularis (Linnaeus, 1767) | Near Threatened |
| Goniopora | Goniopora lobata (Edwards & Haime, 1860) (2) | Near Threatened |
| Herpolitha | Herpolitha limax (Houttuyn, 1772) | Least Concern |
| Hydnopora | Hydnophora microconos (Lammarck, 1816) | Near Threatened |
| Hydnopora | Hydnopora rigida (Dana, 1946) | Least Concern |
| Lobophyllia | Lobophyllia corymbosa (Forskal, 1775) | Vulnerable |
| Lobophyllia | Lobophyllia flabelliformis (Veron, 1981) | Vulnerable |
| Lobophyllia | Lobophyllia hawaii (Yabe & Sugiyama, 1936) | Least Concern |
| Lobophyllia | Lobophyllia hemprichii (Ehrenberg, 1834) | Near Threatened |
| Lobophyllia | Lobophyllia pachysepta (Chevalier, 1975) | Vulnerable |
| Merullina | Merullina ampliata (Ellis & Solander, 1786) | Least Concern |
| Merullina | Merullina scabriacula (Dana, 1846) | Least Concern |
| Pachyseris | Pachyseris rugosa (Lammarck, 1901) | Least Concern |
| Pachyseris | Pachyseris speciosa (Dana, 1846) | Vulnerable |
| Pavona | Pavona cactus (Forskal, 1775) | Vulnerable |
| Pectinia | Pectinia alcicornis (Saville & Kent, 1871) | Vulnerable |
| Pectinia | Pectinia lactuca (Pallas, 1766) | Vulnerable |
| Physogyra | Physogyra lichtensteini (Edwards & Haime 1851) | Vulnerable |
| Platygyra | Platygyra sinensis (M. Edwards & Haime, 1849) | Least Concern |
| Platygyra | Platygyra daedalea (Ellis & Solander, 1786) | Least Concern |
| Pocillopora | Pocillopora damicornis (Linnaeus, 1758) | Least Concern |
| Polyphyllia | Polyphyllia talpina (Lammarck 1801) | Least Concern |
| Porites | Porites (synarea) rus (Forskal, 1775) | Near Threatened |
| Porites | Porites cylindrica (Dana, 1846) | Near Threatened |
| Porites | Porites lobata (Dana, 1846) | Near Threatened |
| Porites | Porites mayeri (Vaughn, 1918) | Least Concern |
| Porites | Porites nigrescens (Dana, 1848) (1) | Vulnerable |
The Trajectory Zone, Hull Footprint is the primary area where the ship body ran aground, crashing, passing and running over long coral reef with reef characteristic cuts like (white limestone) from 20 meter up to the reef flat at an average depth of 12 meter. The reefs on this area are hit by a large and wide trench with an average thickness of 4 meter (min.2 m and max.8 m). There is a dead massive coral colony of *Porites* that shifts to the left and right side indicating the strength of the collision. 100 percent mortality of benthic biota, especially hard corals in this zone and unseen the initial recruitment / recovery of algae especially corals.

The Bow area (i.e., the northern part of the ship's grounded zone) does not appear as living or damaged coral colonies. The zone at the bottom depth of 12-16 meters is clearly visible dominated by substrate of fine particle white sediment (± 1-meter depth). Occasionally sediment particles of white limestone crushed corals are lifted by the current and block the underwater view. This white sand sediment from chalk marks a strong 'bulbous bow' hit on coral reefs due to the reef's 'hang'. The coral at this location is certainly 100 percent dead due to a 'bulbous bow' strike moving along the ship's body.

Berm/Mound are zone with various fracturing corals, rubble piles and lime white sediments due to ship body collisions stacked to the left and right side (tunnel effect) from the Trajectory Zone with an average height of berm 2.5 meters (max. 5 m) and 0-12 meters wide. 100 percent mortality of benthic biota, especially hard coral, is found in this zone.

Sterm/Wash Propeller Zone is a reef slope area (18-30 meters depth) where the reefs are loss 3-dimensional complexity due to broken corals and colonies slammed by rotating vanes. The main character of coral damage to this zone is the removal and dislodgment of coral colonies to a depth 30 meters. Nearly 100 percent of mortality in this area (98%).

### Table 2. Conservation status of hard coral (Scleractinian) in the observation sites.

| Genera           | Coral Species                          | IUCN Red List       |
|------------------|---------------------------------------|---------------------|
| Psammocora       | *Psammocora contigua* (Esper, 1797)   | Near Threatened     |
|                  | *Psammocora nierstraszi* (Van Der Horst, 1921) | Least Concern       |
| Sandhalolitha    | *Sandhalolitha dentata* (Quelch, 1884) |                      |
| Symphyllia       | *Symphyllia radians* (Milne Edwards & Haime, 1849) | Least Concern       |

Figure 5. Reef zone affected by type and level of damaged. (a) trajectory zone (Hull Footprint), (b) bow area, (e, g, c) mound zone (Rubble Pile/berm), (d) wash–propeller, and (f, h) stern/wash propeller zone.
Dead corals mortality can increase and expand over time due to oceanographic dynamics lifting the remnants of limestone. Thus, can affected area on the left and right sides of the mound zone (The Dispersal Zone).

### 3.3. Area of damaged

Based on the observations, it was found that the ship ran aground in the ‘Gosong panjang’ reefs crashing with the bow position facing the north and the propeller to the south (figure 6). The draft ship which has a height of 20.9 meters crashed up into the coral reef from a depth of 20 to 12 meters.

In the trajectory zone (hull footprint), the measured track width is 70 meters. Approximately there is a space gap of 5 meter on the left and right of the ship (actual ship width 60.04 meters). This indicates the rotation and movement of the ship when it is foundered. On average there are 4.4 meters of coral mound on the left side and 5.6 meters bumps on the right side. The length of the trajectory measured along the mark between the coral mound and the flat reef plane is 315 meters on the left side. It is estimated that the longer the northward decreases at the end of the reef to a depth of 16 meters (not measurable due to the limited time of diving). On the right side the total measured along the 300 meters with an unmeasured bias at the northern end due to visibility limitations (vis. <5 meters) about 30 meters.

Colonies of corals were found dead (broken/crushed) along area 21,525 m² area.

At the northern end of the hull footprint, the bow area (bulbous bow) found no benthic biota living in an elliptical area 100 meters from the left and right side of the mound with the widest 10 meters wide radius, obtained a total area of 1,570 m² area.

Mound rubble zone averages 4.4 meters width on the left side and 5.6 meter on the right side of the trajectory zone with an average height of 2.5 meter and a length of 615 meter with an estimated total area of 1,533 m². The height of the mound of rubble/fracturing corals and the thickness of coral reef in the trajectory zone can estimate biomass and age of ‘Gosong Panjang’ reef. In the dispersal zone obtained an average width of 14 meters (8.610 m²) on the left and right. The total area of these 5 zones with the type/extent of damage obtained at 36,417 square meters (table 4).

However, with the gap of the width of the former ship's hull (5 meters left and right) in the footprint zone (70 m) compared to the actual width of the vessel (60.04 m) indicates the rotation of ship movement when it ran aground or while refloating from aground. For additional information, 2 tug boats that assist MT Alex in refloating efforts will certainly move maneuvering (rotation back and forth, left and right) above the reef with a mean depth of 10 meters has a significant impact on coral reefs. This is the main

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**Table 3. Level and the extent of coral reefs damaged.**

| Damage Zone           | Depth (meter) | Reef Benthic          | Hard Coral                  | Mortality (%) |
|-----------------------|---------------|-----------------------|-----------------------------|---------------|
| Bow Zone (Bulbous Bow)| 12-14-16      | sedimentation         | destroyed (fragmentation)   | 100           |
| Hull Footprint        | 20-12-14      | crushed, cut off,     | destroyed, (rubble)         | 100           |
| Berm/Mound            | 9-8-12        | Stacked up, buried,   | crushed, burried,           | 100           |
|                       |               | pile                   | rubble pile                 |               |
| Wash/Propeller        | 16-20-30      | Loss of 3-D complexity | removal coral, dislodgement | 98            |
| Dispersal zone (indirect damaged) | 9-16 (±10)  | Buried coral suspension material | Sedimentation, coral of opportunity | 50-50 |

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- Dead corals mortality can increase and expand over time due to oceanographic dynamics lifting the remnants of limestone. Thus, can affected area on the left and right sides of the mound zone (The Dispersal Zone).
consideration why the area estimate in this study is greater than the result of sonar sensors. Furthermore, sonar maps can be interpreted differently, especially if they do not cover the whole area.

4. Conclusion
The main components of reef forming in this location are hard coral (scleractinian) Lobophyllia, Porites, Euphyllia and Acropora. The uniqueness of hard coral species (scleractinian) found in the research sites are 43 species and 21 species are listed as red IUCN (International Union for Conservation of Nature) with vulnerable status and near threatened. There is a change in the complexity of the three dimensions.

**Table 4.** The extent of coral reef affected.

| Damage zone                  | Extents | Live Coral Coverage (%) | Mortality (%) | Total Damage Area (m²) |
|------------------------------|---------|-------------------------|---------------|------------------------|
| Bow Zone (Bulbous Bow)       | 1,570   | 36                      | 100           | 565                    |
| Hull Footprint               | 21,525  | 36                      | 100           | 7,749                  |
| Berm/Mound                   | 1,533   | 36                      | 100           | 552                    |
| Wash/Propeller              | 3,179   | 36                      | 98            | 1,122                  |
| Dispersal zone (indirect damaged) | 8,610 | 7,7                      | 28,3          | 189                    |
| **Total (m²)**              | 36,417  |                         |               | 10,177                 |
of the reef structure with almost 100 percent of coral mortality in the vicinity area leaving a white coral skeleton trace, cut-off, broken/fracturing, shifted, crushed/dislodging, uprooted. In concern, if not immediately handle the impact of ship grounded will be more widespread and threat the reef as a whole. Further research is needed on the effects of tribultyltin (TBT) pollutants on this ecosystem.

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