Impact of Ship Grounding on Coral Reefs in Indonesian Waters

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Abstract. Indonesia as an archipelagic country is prone to damage to coral reefs. The grounding of ships on coral reefs has resulted in severe physical and biological damage. The grounding of ships on coral reefs has resulted in severe physical and biological damage, including the uprooting and crashing of coral skeletons, dislodgment and displacement of sediment, and loss of three-dimensional complexity. Most of the damage was devastating. The purpose of this study is to identify levels of damage and impact of shipgrounding to coral reefs in Indonesian waters. The research method in this study uses the Line Intercept Transect (LIT) and underwater photo transect (UPT) to measurement of the level of damage and its impact. The result of this study is profile of coral reefs that were predominantly hit by ships was a patch reef (67%) and and mostly occurred due to human error (78%). This research found some types of damage in the form of a trajectory, mounds, propeller, partials, and dispersals. There has been a very significant change in the bottom substrate of the waters both by large, medium, and small vessels. The average live hard coral cover in affected area from 42.70 ± 5.26%, changing to no live coral, it is mean the mortality of live coral cover reached 100%. And rubble coverage increased from 11.19±6.10% to 61±18.41%. Increasing of rubble is an important concern because it causes acute damage to coral reefs, the same as coral damage caused by fishing bombs and destructive fishing.

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1 Introduction

The current condition of Indonesia's coral reefs is only 6.56% in excellent condition, the rest are in good, moderate, and poor condition. The distribution of conditions for the western region is around 8.97%; the central part is 4.91% and the eastern part is 4.05% [1]. Coral reefs have an important role for other marine biota, such as providing habitat for more than one million species and providing ecosystem services (such as providing food and protecting beaches) for humans in tropical and subtropical regions. However, these conditions do not make coral reefs free from the threat of damage and decline in their condition.

The decline in the condition of coral reefs is caused by natural and anthropogenic factors. Human activities in the shipping sector (sea transportation) disrupt and damage coral reef ecosystems such as pollution and massive damage due to ship groundings [2][3][4][5]. Since humans first started building ships, ship strandings on coral reefs have often been inevitable and resulted in severe biological and physical damage. The occurrence of ships running aground on coral reefs is very rarely a concern so very few can be recorded. For example, reported shipwreck incidents in Florida reach 600 incidents each year and if we count those that are not reported, the number will be even higher [6]. Indonesia as an archipelagic country has a strategic position in national and international maritime shipping lanes. Data from marine traffic in 2017 shows that Indonesian waters are passed by ships of various types and sizes reaching 327 thousand routes/23 km2/year (www.marinetraffic.com). The high number of sea shipping routes in Indonesian waters causes the potential for ships to run aground and damage coral reefs to be high.

The damage caused by the collision will vary, depending on the weight, speed, type, and size of the ship. The damage can range from relatively minor injuries to complete degradation of the structural complexity of coral reefs as an ecosystem. Many previous studies in Indonesia related to coral reef damage only focused on the impact of fish bombing, overfishing, and climate change, but studies related to the impact of ships running aground were only found in 3-4 journals. Currently, there is very little assessment of the impact of damage to coral reefs due to ships running aground in Indonesia, this has resulted in the government's lack of attention to incidents of ships running aground that damage the coral reef ecosystem. For this reason, there is a need for scientific studies that are expected to help the government assess the impact of this damage on Indonesia's coral reefs. So this study needs to be carried out to identify the type of coral reef profile affected, identify the condition of the bottom substrate in the affected area, identify the type of coral affected, identify and map areas of coral reef damage, and quantify the extent of the area and level of coral reef damage.

2 Material And Methode

2.1 Location and time research

This research was conducted in Indonesian waters representing the western, central, and eastern parts (Figure 1). Ships aground are grouped into 3 types, namely: phinisi, landing craft tank (LCT) or Barge, and bulk carrier type. The research was carried out from 2017 to 2019. Each observation at each location was carried out for ± 3-5 days.

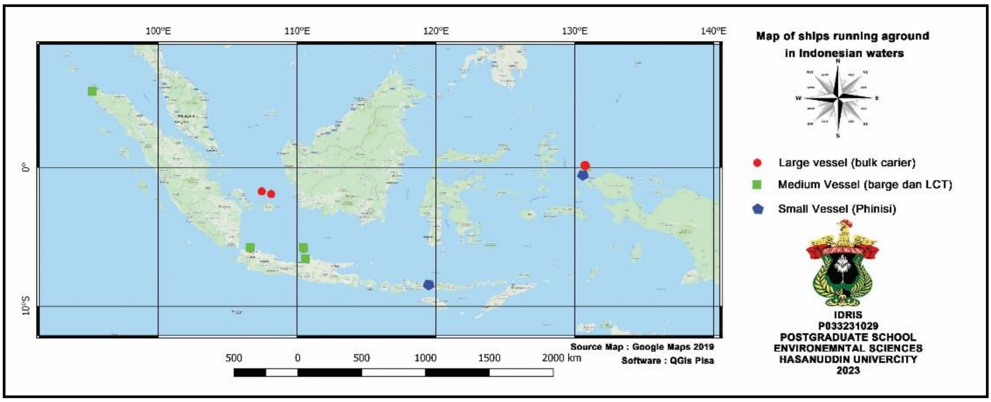

Figure 1. Location of ships that ran aground in Indonesian waters as a research location with 3 sizes and types (Large Vessel (Bulk Carrier Type), Medium Vessel (Barge and LCT Type), Small Vessel (Phinisi Type))

Ships ran aground in this study were grouped into 3 categories ships based on their weight and 3 types of ships based on their shape. The groups and types of ships that have been identified are small ships (weighing < 100 tons) with the phinisi type, medium ships (weighing between 100-3000 tons) with the Landing Craft Tank (LCT) and Barge types; and large ships. (weight > 3000 tons) with Bulk Carrier type (Table 1).

Table 1. Grouping of ships that ran aground based on Gross Tonnage (GT), type of ship, and location of the ship aground

No	Type	Gross Tonase (GT)	Ctegory	Latitude	Longitude
1	Phinisi	98	Small Vessel (< 100 GT)	5°51’11”	106°38'16"
2	Phinisi	98		5°47'12.38"	110°27'29. 40"
3	Landing Craft Tank (LCT)	102	Medium Vessel (100-3,000 GT)	1°44'19.90"	107°27'2.7 0"
4	Landing Craft Tank (LCT)	719		1°58'088"	108°06'419 "
5	Barge	2.500		5°51’18”	110°29'17"
6	Barge	2.500		5°28’56”	95°13'36"
7	Bulk carrier	154,379	Large Vessel (> 3,000 GT)	8,4780	119,5560
8	Bulk carrier	4,200		00°32’19,49 ”	130°33,19' 91"
9	Bulk carrier	44,203		00°30’992”	130°40’28 3”

Source: processed and modified from www.marinetrafic.com; www.indoyachts.

2.2 Survey Method

2.2.1 Data Collection Techniques

The data collection technique was carried out using ground truth using SCUBA diving equipment and using transect lines as a guide. Swim surveys for fast underwater observations are accompanied by determining marker points and geographic coordinates (GPS) (Rapid Reef Assessment [7].

1. Collecting data on the condition of the underwater substrate using the Underwater Photo Transect (UPT) method
2. Collect data on coral species using the belt transect and enumeration method [8], where observers swim in a radius of 2 x 50 m and record each type of coral found on each transect installed.
3. Collect data on the extent of coral reef damage using the Fishbone Method (Figure 2) with a roll meter used as a measuring tool [9] [10].
4. For partial coral damage, specifically the size of the area of direct damage (affected) is obtained using a 1 x 1-meter grid quadrant technique with a 10 cm grid (Modification of English et al, 1997) (Figure 3).

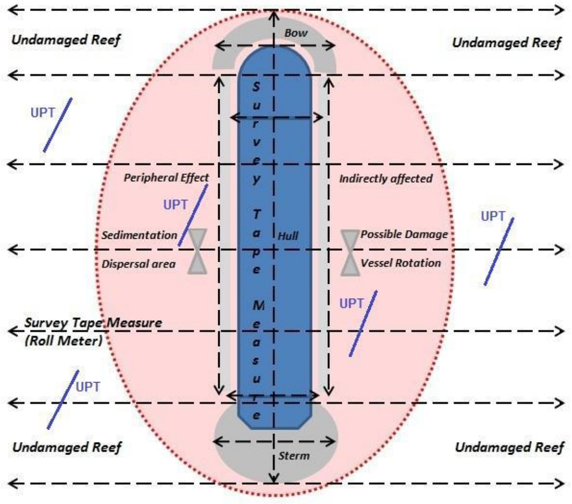

Figure 2. Illustration of the fishbone method [9] [10].

Figure 3. Square grid method (modification from English et al, 1997)

2.2.2 Data Analysis

UPT data on each transect is analyzed using Coral Point Counter software for Excel extension (CPCe) [11], whereas if using LIT the data will be processed using Microsoft Excel 2007 software. Analysis of the percentage of bottom substrate cover refers to the categories specified. used English et al. (1997) to calculate the percentage of substrate cover categories obtained from the formula :

$$\text{Persentage of category coverage} = \frac{\text{Sum of Category i}}{\text{Sum of Random Point}} x\ 100\%$$

atau

$$\text{Persentage of category coverage} = \frac{Long\ of\ category\ i}{Long\ of\ transect} x\ 100\%$$

Coral reef condition assessment generally refers to standard criteria for coral reef damage based on criteria for assessing coral reef condition referring to the criteria developed by Giyanto et al., 2017 (Table 2).

Table 2. Coral reef condition criteria and recovery potential

No	Hard Coral Coverage		Potential Recovery	
	Category	Criteria	Kategori	Criteria
1	Low	<19%	Low	Fleshy seaweed => 3% atau Rubble > 60%; HC <= 5%
2	Moderate	19 -35%		
3	High	>35%	High	Fleshy seaweed < 3% atau Rubble <= 60%; HC > 5%

The total area of affected of coral damage was obtained by measuring the distance between points directly underwater. Based on the formula for calculating the area of an irregular polygon :

$$A_P = \frac{(X_1 \cdot Y_2 - X_2 \cdot Y_1) + (X_2 \cdot Y_3 - X_3 \cdot Y_2) + (X_3 \cdot Y_4 - X_4 \cdot Y_3) + \ldots + (X_n \cdot Y_1 - X_1 \cdot Y_n)}{2}$$

(AP = area of the polygon, while X and Y are the coordinates of a point when viewed from the X or Y axis), These two measurement techniques are analyzed with the help of a computer program. The distance between points underwater is plotted and analyzed using a combination of the CPCe software program.

Non-parametric statistical analysis uses the Kruskall Wallis Test with SPSS Statistics 23 software. This test is used because the data taken is natural condition data that cannot be controlled. This statistical analysis was carried out to see differences in changes in the condition of the bottom water substrate in the control area and the affected area.

3 Result And Discussion

3.1 Profile of affected coral reefs and causes of ships running aground

The incidence of ships running aground on coral reefs mostly occurs on patch reefs as much as 67 percent and on fringing reefs as much as 33 percent (Figure 5). The ship ran aground in Indonesian waters at 9 locations caused by human error, bad weather, and signal failure. Most of the causes are human error (78 percent), bad weather 11 percent and signaling failure 11 percent (Figure 4).

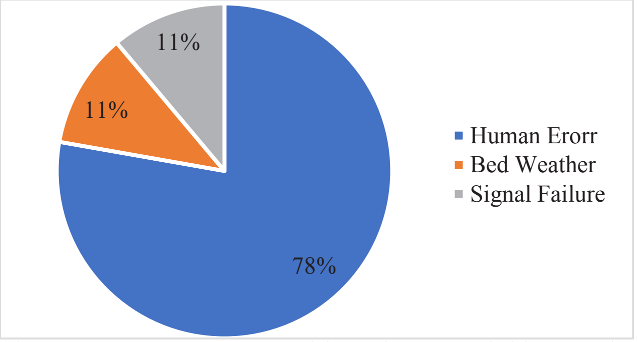

Figure 4. Percentage composition of causes of ships running aground on coral reefs

The incidents of ships running aground on coral reefs in this study were identified as mostly caused by human error, bad weather and signal failures.

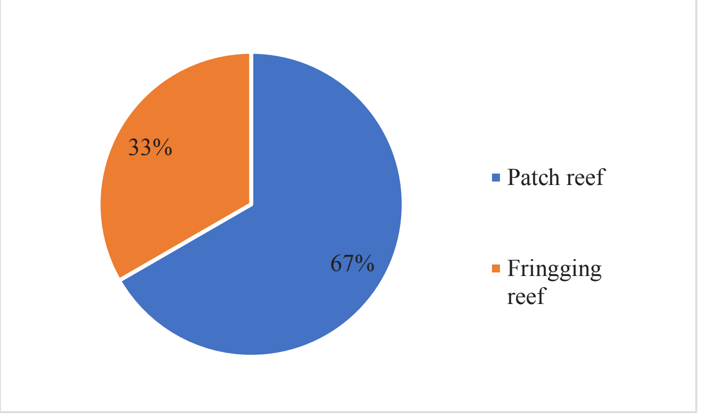

Figure 5. Percentage composition of coral reef profiles hit by ships

Ships running aground on coral reefs have occurred since the development of the world of shipping. According to Hayasaka-Ramírez and Ortiz-Lozano (2014), ship strandings occurred during the period 1902-1945 and 1970-2010, which were caused by human error, engine failure, bad weather, and signal failure. This is in line with the results of this study that ships ran aground in 9 locations due to human error, bad weather, and signaling failures during shipping. The locations where ships ran aground on coral reefs mostly occurred on patch reef and a few on fringing coral reefs. Incidents like this were also reported to occur in Florida, most of which affected on patch reef that were not visible from the surface [9].

3.2 Impact on the condition of the underwater substrate

Observation of the condition of the bottom substrate was divided into 3 areas, the natural area (control area) which is 5-10 m from the grounded location, the indirectly affected area, and the directly affected area. The control area is an area of coral reef that is not affected by the ship running aground. Determining this control area is very important to see changes in the bottom substrate before the disturbance occurs, so that changes in the condition of the bottom substrate at that location can be seen. Observation of bottom substrate conditions in this study is based on 5 main groups, namely live coral (LC), dead coral (DC), dead coral with algae (DCA), Rubble (R), biotic = non-coral benthic animals and abiotic = sand, mud, and rock.

The results of observations at the location where the ship ran aground showed that there had been a change in the condition of the bottom substrate of the waters. On large ship (bulk carrier ships), there has been a significant reduction in live hard coral (LC) cover from an average of 49.54 ± 17.23% (control area) to only 1.09 ± 0.61% (directly affected area) and 8, 99±4.53% (indirectly affected area). Based on changes in LC cover, it can be said that 98.92% of live hard corals was died in directly affected areas. In addition, rubble cover increased significantly from only 11.19 ± 6.10% (control area) to 61 ± 18.41% (directly affected area) and 29.01 ± 16.91% (indirectly affected area), while other substrate categories (DCA, DC, Biotic, and Abiotic) tend to be stable (Figure 6A).

Impacts by medium vessels also cause very significant changes in the bottom substrate of the waters. This can be seen in the average live hard coral cover of 42.70 ± 5.26% (control area), changing to no live coral at all in areas directly affected. This means that the death of live hard coral reaches 100% in directly affected areas. Apart from that, very significant changes also occurred in rubble cover, from only 0.83 ± 0.69% in the control area and increasing drastically in the directly affected area to 73.00 ± 20.29% and indirectly affected areas to 18.74 ± 9.14%. Dead coral cover (DC) also increased from only 2.21% in the control area to 25% in the directly affected area and 19.32% indirectly affected area (Figure 6B).

On the small boat (Phinisi type), changes in the bottom substrate of the waters also occurred in live coral from 35.45 ± 0.31% (control area) decreasing to 11.40 ± 0.0% (indirectly affected area), and no live coral was found in the directly affected area. Based on the very significant change in live hard coral cover, it shows that there has been 100% death of live hard coral in the directly affected area. This was also followed by an increase in rubble cover from only 6.51 ± 6.51% (control area) to 60 ± 5% (directly affected area) and 31.39 ± 0% (indirectly affected area) (Figure 6C).

In general, it can be said that all sizes and types of ships that have run aground have caused very significant changes in the condition of the bottom water substrate, where the initial conditions were dominated by live coral cover, changing to the dominance of rubble, DCA, and DC. This change was considered very significant based on the results of the Kruskall-Wallis test showing that the change in the condition of live coral cover to dead coral was significantly different, in crushed areas and dispersal areas for all sizes and types of ships that ran aground. This can be seen from the P-Value (Asymp. Sig) of 0.047 < 0.05 which is the critical limit value.

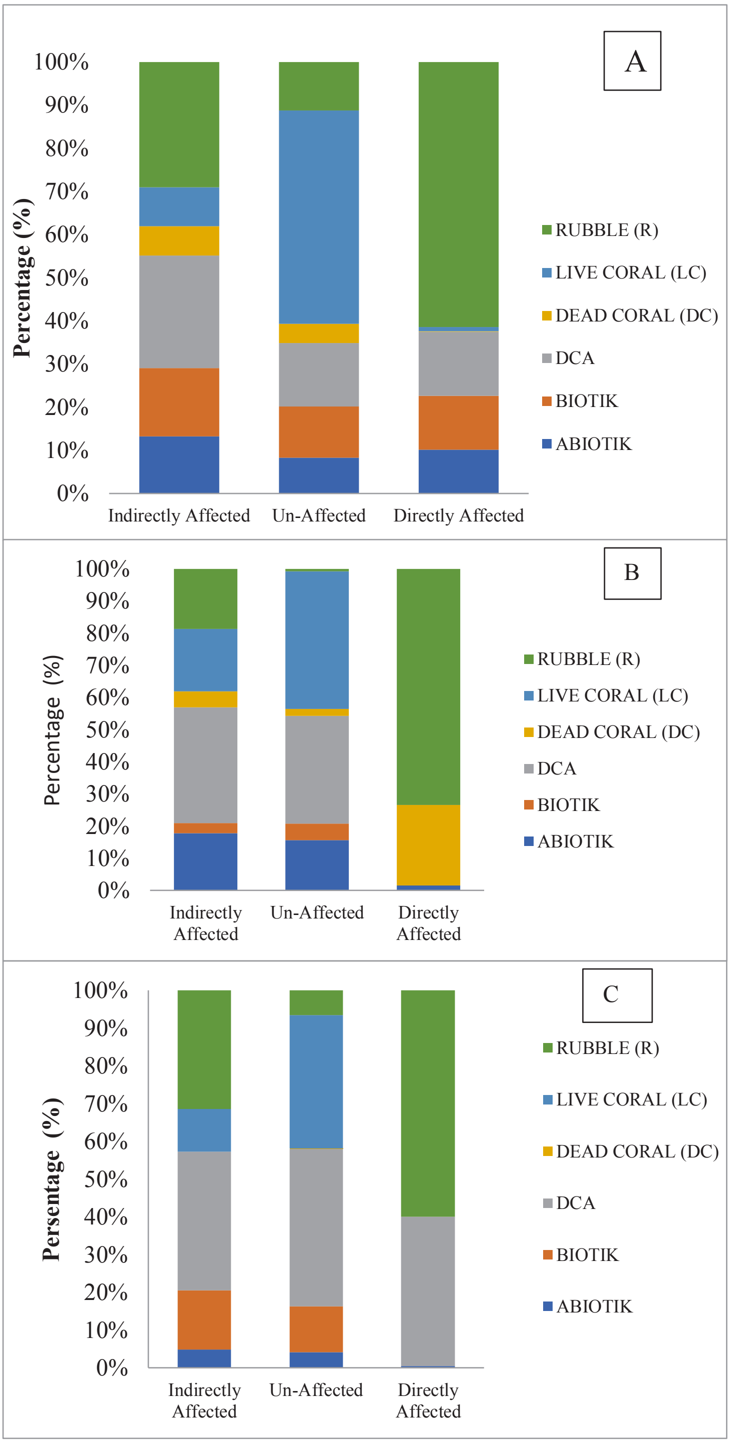

Figure 6. Condition of the waterbed substrate in the control area, directly affected and indirectly affected by all types and sizes of ships (A: Large Ship (bulk carrier type), B: Medium ships (Barge and LCT type), C: Small Ships (Phinisi type))

The impact caused by a ship running aground on coral reefs is assessed based on changes in the condition of the bottom substrate between the control area and the affected area (directly and indirectly). Based on the results of this study, there is a change in the condition of the bottom substrate, which was dominated by live coral cover, changing to become dominant with rubble, dead coral, and dead coral with algae. The results of research by several experts state that the impact of a ship running aground causes a decrease in live coral cover in the form of uprooting, crashing, destruction of coral skeletons, and displacement of sediment deposits, as well as loss of the three-dimensional complex structure of coral reefs [14][15][16][17][4][18]. Apart from that, according to Schroeder et al., (2008), when a ship hits a coral reef, it will open up the colonization of the previously existing substrate, thereby creating an open space that is difficult for young corals to attach to. Furthermore, according to Alison et al., (2012) stated that the percentage of live coral that survives at the site of a ship running aground after more than one year is generally very low..

Rubble beds are difficult to grow or attach to coral juveniles because their movement is very dynamic, so it will hinder the recovery of coral reefs. This is in line with the statement of Giyanto, et al. (2017) and Idris, et al. (2022) that dominant rubble cover will reduce the ability of coral reefs to recover. The low recovery of coral reefs is due to the very low recruitment of coral juveniles in the rubble and it is also possible that there will be no recruitment, but will be overgrown or covered by algae [20] [21] [22] [23]. Another impact is the loss of living coral colonies around it, because rubble is very easily carried by currents, waves, and storms [24][25]. Such physical damage is acute and is a significant source of disturbance and mortality for coral reefs and hinders recovery [26][21][27].

3.3 Affected Area, Level and Extent of Damage to Coral Reefs

In this study, the types of damage to coral reefs due to ships running aground are grouped into 3 groups based on ship size (small, medium and large) and ship type (phinisi ships, barges and LCT ships, and bulk carrier ships) namely:

3.3.1. Large Vessels (bulk carrier ships)

The results of observations this study was found 4 areas of damage to coral reefs caused by ships, based on the traces, type, and level of damage, that is :

a. The trajectory Area (Figure 7) is the main area where the ship's body collides, passes, and runs over coral reefs. The main characteristic of damage in this area is that coral reef formations are cut or eroded flat, eliminating the 3-dimensional structure of the coral reef. In this area, sometimes reef flats that have been hit will form like a "canal" with rubble dominant. Often it will also form long mounds of coral reef pieces on the left and right sides like "canal walls" with varying heights ranging from ~0.5 m to more than ~3 m.

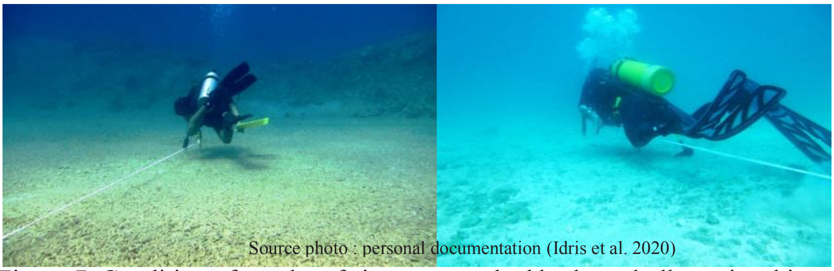

Figure 7. Condition of coral reefs in areas crushed by large bulk carrier ships.

b. The mound area (Figure 8) is a pile of various coral fragments and limestone skeleton fragments piled up on the left and right sides like a "canal wall" with different mound heights depending on the size of the ship. As in the runoff area, the damage to coral reefs and other benthic biota was very severe, no surviving benthic biota was found in this area. The bottom substrate of the waters found was dominated by rubble, sand, and fragments of coral limestone skeletons lifted by the ship's hull. The results of measuring the height of the "wall" reached an average of 2.5 m.

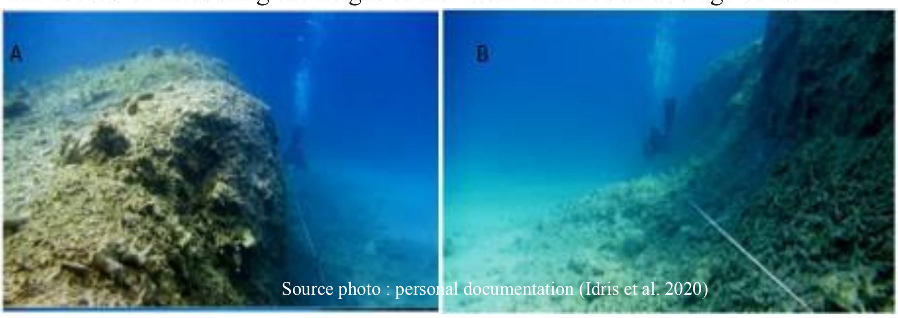

Figure 8. Condition of the coral reef in the mound area (A=left mound and B=right mound) on a large bulk carrier-type ship.

c. The propeller zone area, (Figure 9) is a reef flat with a certain depth that forms a "bowl/puddle". The number of “bowls” will depend on the movement of the ship when trying to get out of the grounded area. The damage to this area was also very severe, but the form of damage was in the form of coral fragments being lifted and thrown into the surrounding area. The damage can be in the form of split and cut pieces of coral that are larger than rubble.

Figure 9. Condition of coral reefs in the propeller area on large bulk carrier ships

d. The dispersion zone area (Figure 10) is the area on the left and right sides of the mound area which indirectly follows the dynamics of currents, waves, and storms. This dynamic lifts the remaining sediment and unstable coral fragments and covers the surrounding living coral. The damage in this area was quite severe but did not kill all the coral and benthic biota. The main characteristic of the damage is that live coral colonies are buried or crushed or partially crushed by coral fragments, but this will likely increase in size over time due to the influence of storms or oceanographic dynamics.

Figure 10. Condition of coral reefs in the dispersal area by large bulk carrier ships.

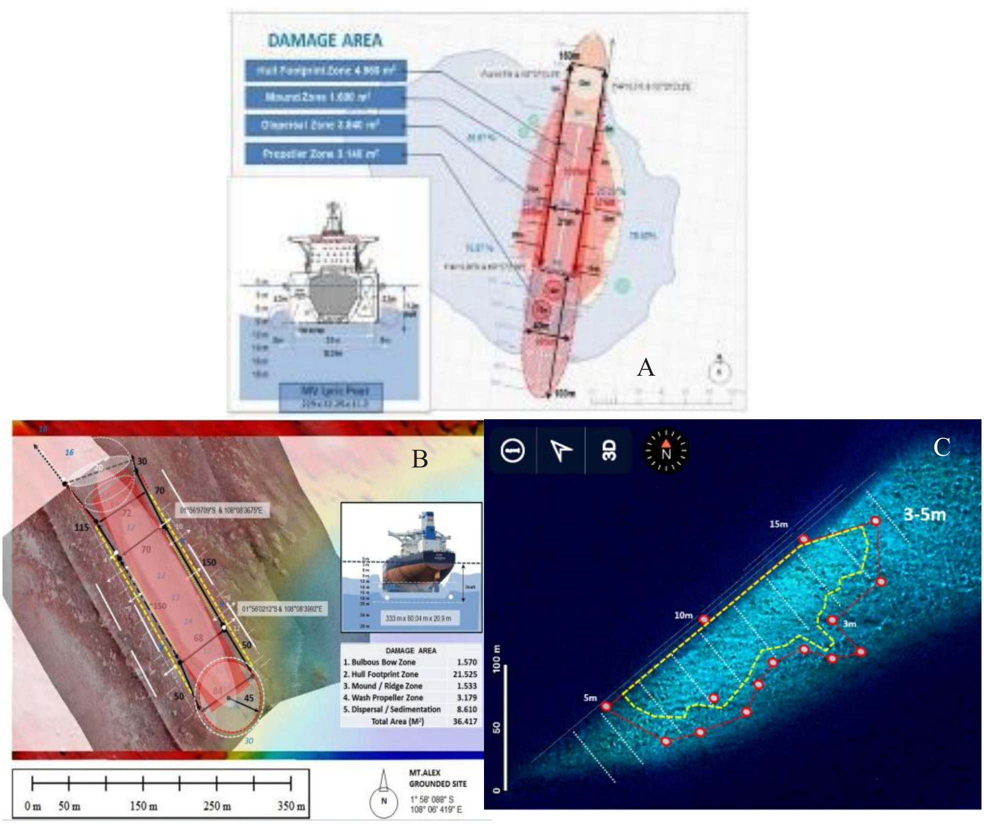

Figure 11. Sketch of the results of measuring the extent of damage to coral reefs by large bulk carrier ships in Indonesia (A= Bangka waters, B= Belitung waters C= Raja Ampat waters)

A complete summary of the extent of damage to coral reefs by large bulk carrier ships in Indonesia is presented in Table 3 and an illustration of the damage is shown in Figure 11.

Table 3. Calculation of the extent of damage to coral reefs by 3 large bulk carrier ships

No	Damage Area	Extent of Damage (m^2)	Persentage of Coral Mortallity (%)
1	Dispersal	18.398	55-98
2	Mound	3.133	99-100
3	Trajectory	41.714	99-100
4	Propeller	6.319	99-100
	Total	69.564	

3.3.2. Medium Vessels (Barge dan LCT)

Observation results showed that the ship had run aground, leaving white coral marks. This mark is used as a point for installing buoys, mapping and assessment. Underwater observations, it was seen that the top of the reef flat was cut or trimmed by the ship's body. There are three areas of coral reef damage were identified based on the trace, type, and level of damage, namely :

a. Trajectory area (Figure 12)
   It is the direct impact area or the main area where the ship's body ran aground, collided, and ran over. Severe damage that occurs on shallow reefs is characterized by the type of damage to coral colonies with various growth forms and species. Conditions of damage and mortality reached 100 percent. The pieces of coral colonies form a flat, white track.

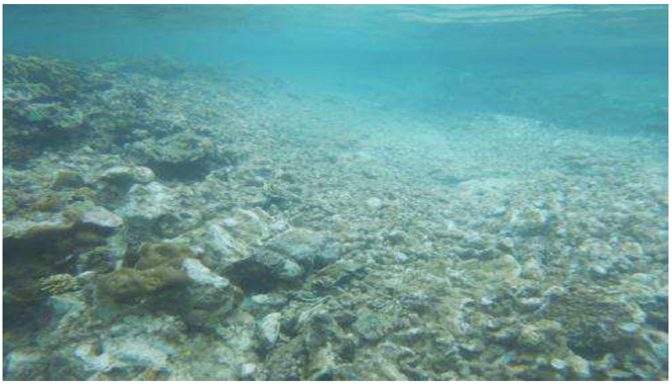

Figure 12. Condition of coral reefs in areas crushed by medium-sized barge and LCT vessels

b. Partial damage area (Figure 13)
   These are points of damage to one or more coral colonies that are spread far apart and occur on relatively deeper coral reefs. The main characteristic is that the coral colony is trimmed or cut, causing the coral colony to break, lift, or turn over, sometimes you can also see pieces of the white limestone skeleton of the coral. For example, several Acropora tabulate and branching were also cut and uprooted, leaving fragments of coral colonies around them. Fractures of coral colonies cover other living corals.

Figure 13. Condition of coral reefs in partial areas by small barge and LCT type vessels

c. Disspersal Area (Figure 14)
This is an area indirectly affected in the form of coral fractures and coral colony fragments that fell around the main point of damage.

Figure 14. Condition of coral reefs in the dispersal area by medium vessels (Barge and LCT types)

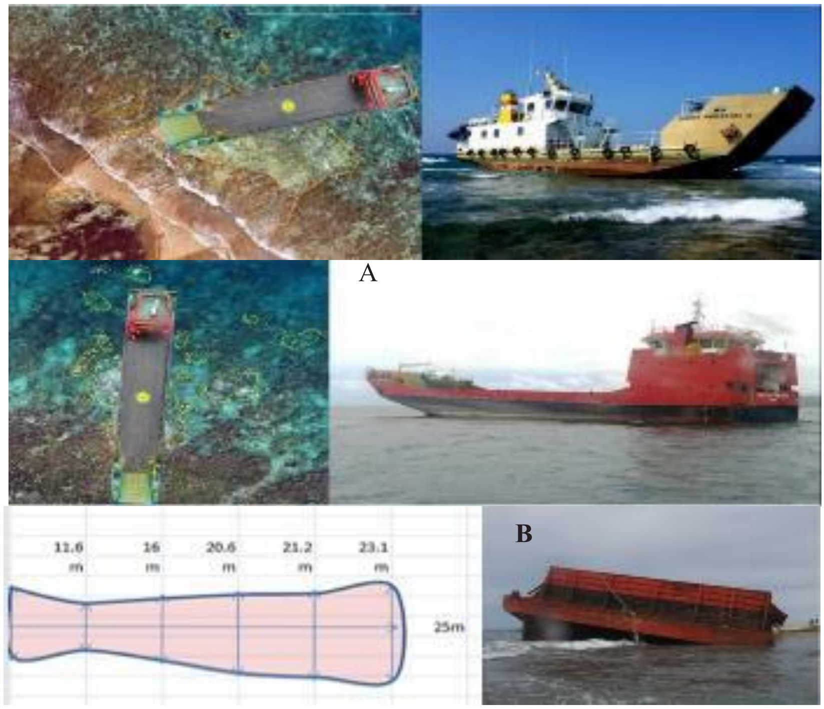

Figure 15. Illustration of the measuring the extent of damage to coral reefs by medium vessels of the LCT (A) and Barge (B) types in Indonesia.

The complete extent of damage to coral reefs by medium vessels is shown in Table 4 and a sketch of damage measurements is shown in Figure 15. The total area of damage recorded was 38,890 m^2.

Table 4. Calculation of the extent of damage to coral reefs due to the grounding of 4 medium vessels (Barge and LCT-type).

No	Damage Area	Extent Damage Area (m2)	Persentage of coral mortallity (%)
1	Dispersal	36.062	50-98
2	Parsial	52,47	99-100
3	Trajectory	2.775,2	99-100
	Total	38.889,67	

3.3.3. Small Vessels (Phinisi Type)

Coral reef damage by this type of ship was identified into 2 areas of coral reef damage based on the trace, type, and level of damage, namely :

a. Trajectory Area (Figure 16)
This is the direct impact area or the main area where the ship's body has run aground, collided, and run over. The crushed coral appears to have died and the coral has turned upside down. Coral colonies split, break, and become large and small chunks.

The force of the impact caused fragments of coral colonies to scatter on the bottom of the waters.

Figure 16. Condition of coral reefs in the area crushed by a small boat (Phinisi type)

b. Dispersal Area (Figure 17)
This is an area indirectly affected by the ship running aground. The main characteristic of the damage is in the form of dead coral colonies that crush or impinge on surrounding living coral colonies, due to oceanographic dynamics. This condition causes several living coral colonies to die and widespread damage.

Figure 17. Condition of coral reefs in the dispersal area by small phinisi type boats.

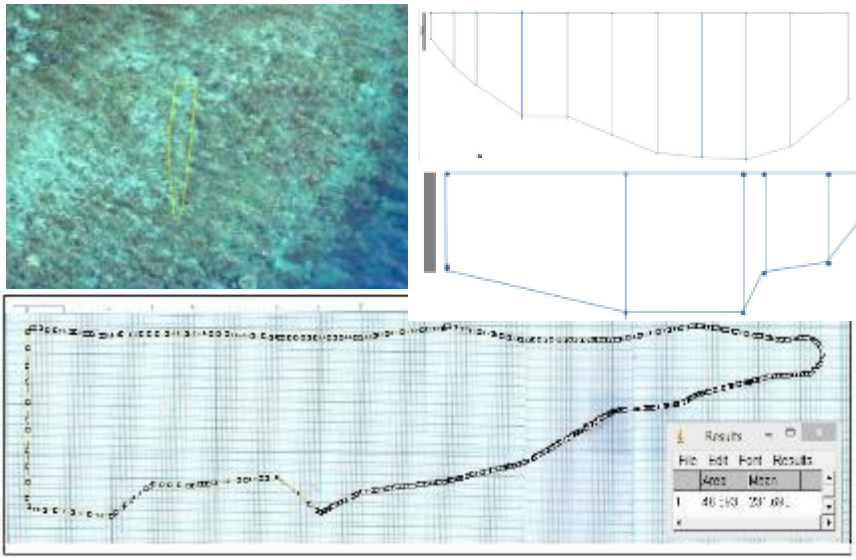

Figure 18. Illustration of the measuring the extent of damage to coral reefs by small vessels (phinisi type) in Indonesia

A complete summary of damage to coral reefs by this type of ship is presented in Table 5 and Figure 18, with a total area of 163.81 m^2.

Table 5. Calculation of the extent of damage to coral reefs due to the grounding by 2 small boats (phinisi type)

No	Damage Area	Extenet of damage (m^2)	Persentage of Coral Mortallity (%)
1	Dispersal	4,59	50-98
2	Trajectory	159,22	100
	Total	163,81	

The extent of damage to coral reefs due to ships running aground varies from just a few hundred meters by small ships to thousands meters caused by medium and large ships. The area of damage caused by each type and size of the ship is mapped into several areas, such as trajectory, mound, propeller, partial, and dispersal. The trajectory, mounded, and propeller areas were very serious damage with death coral reaching ~100% and the dominant bottom substrate being rubble. Partial and dispersal damaged areas are also quite severe damage, but we can still find remaining live coral. According to Yusuf (2014), all coral in the affected area will be eroded flat, with the dominant coral dying and breaking into small pieces (< 25 cm) which are unstable if carried by currents and waves. Several other research results also reveal that careless rescue operations increase damage to coral reefs that should not be affected and cause long-lasting acute effects on the coral reef recovery process [29][30]. The same thing was also stated by Shutler et al., (2006) that the ship ran aground caused coral reefs to break, become detached and unstable, and caused incidental injuries to surrounding animals and plants. Another impact that arises from rescue efforts that guide the movement of ships out of their grounding places will expand coral damage beyond the ship's parking area. After the ship leaves, it will leave "wounded" coral which will kill the coral [31][22].

Based on observations, the coral damage that occurred was massive and acute. The level of damage that occurs is more influenced by the size of the ship, speed, and heavy load. This is in line with the statement of several previous studies that damage to coral reefs is influenced by speed, condition of cargo, and angle of the ship's bow when it hits coral reefs, for example, large ships (>75 ft in length) very easily damage thousands of square meters of coral reefs and benthic biota [25] [32].

3.4 Diversity of coral species and conservation status

Conservation criteria for the protection of species and communities are assessed based on their uniqueness, threat, and usefulness (UU No. 5/1990) using the importance of species, community, and ecosystem approach which is the main consideration in this coral reef ecosystem. Referring to the identification results, almost all coral species found at the location where the ship ran aground were included in the IUCN (International Union for Conservation of Nature) red list.

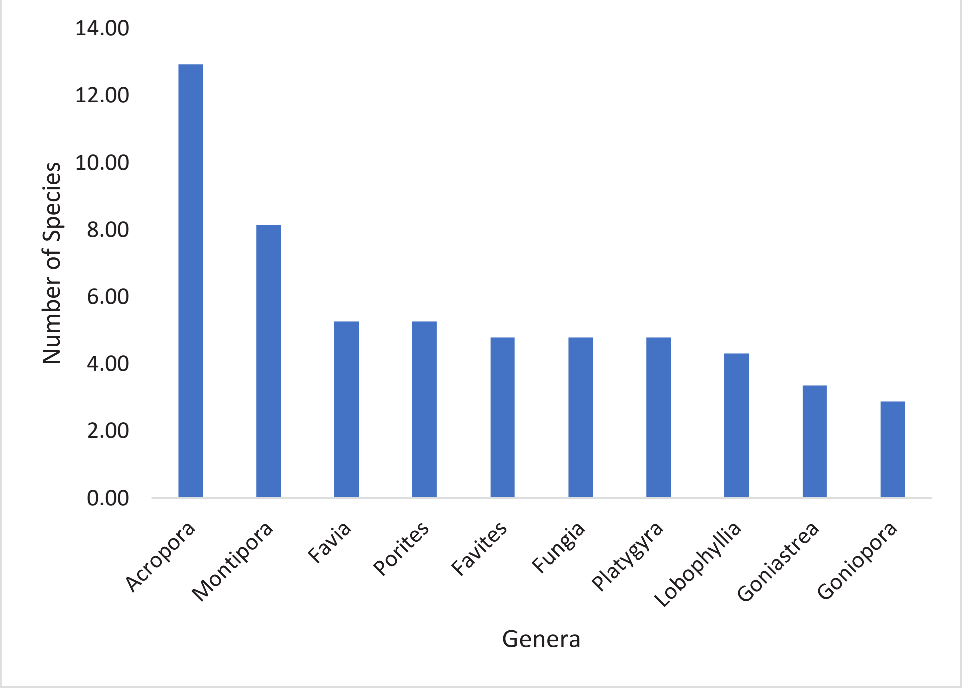

Figure 19. Ten hard coral genera with the highest number of species found in all shipwrecked locations

The results of studies at all locations where ships ran aground have found a total of 49 hard coral genera. A total of 46 hard coral genera are in the Anthozoa class and 3 genera are in the Hydrozoa class. The total number of hard coral species found was 209 species. Overall, the dominant species affected are from the Acropora genus 12.92% (27 species), the Montipora genus 8.13% (17 species), and the Favia and Porites genera 5.26% (11 species), while the remaining genera are below 1% (Figure 19).

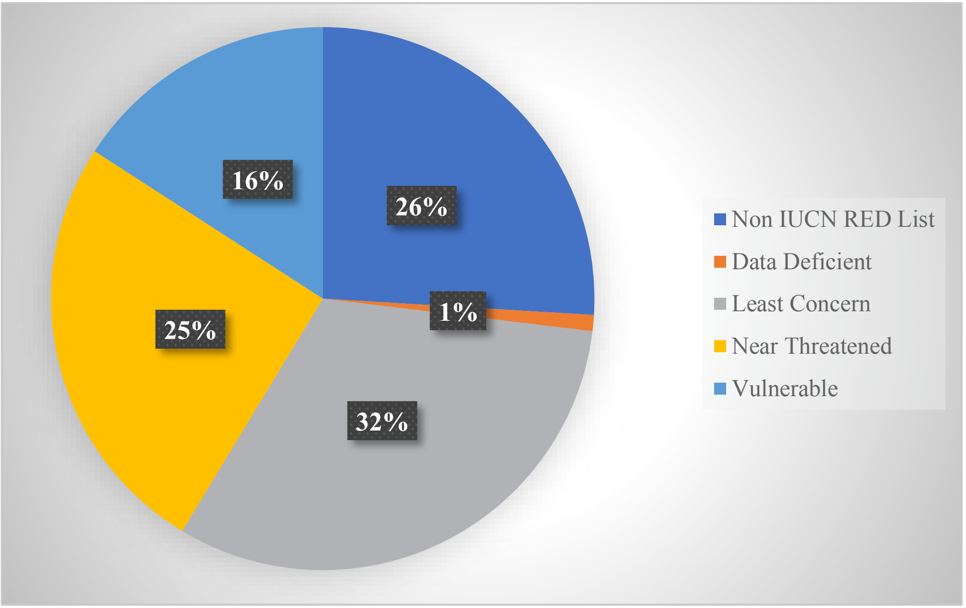

Figure 20. Percentage composition of conservation status of affected corals based on IUCN Red list categories.

The conservation status of coral affected by the ship running aground based on the IUCN-Red list has successfully identified 2 species (0.96%) in the Data Deficient (DD) category; 66 species (31.58%) are in the least concern (LC) category; 53 species (25.36%) are in the near threatened (NT) category; and as many as 34 species (16.26%) are in the vulnerable (VU) category (Figure 20). The dominant corals affected are in the 'threatened' and least concern categories, This means coral species are considered to be close to vulnerable because its population and distribution depend on conservation efforts and must be the focus of attention in monitoring its population and distribution in nature. The focus of attention in this study recommends looking at the 'vulnerable' (vulnerable) category of 34 types of hard coral, which means these types are approaching threatened status, where most of the causes are damage or loss of habitat for these types.

4 Conclussions

1. The dominant profile of coral reefs hit by ships is the patch reef and mostly occurs due to human error.
2. Coral reef damage by large vessels was identified into 4 areas of coral reef damage, namely: (i) a Trajectory area with a very severe level of damage, (ii) a mound area with a very severe level of damage, (iii) a Propeller area, with a very severe level of damage, and (iv) a dispersal area with a level of the damage is quite serious. Live coral cover decreased drastically and rubble cover increased significantly reach ~ 100% and 97 species coral was affected in the 3 locations of study.
3. Coral reef damage by medium vessels was identified into 3 areas of coral reef damage, namely : (i) Trajectory areas with death coral rates reaching 100%, (ii) partial damage areas with death coral rates only in colonies, and (iii) dispersal areas with death coral reaching ~50%. Live hard coral cover decreased significantly, while rubble and dead coral cover was increased and 109 species coral was affected.

4. Coral reef damage by small vessels was identified into 3 areas of coral reef damage, namely : Trajectory areas, with very severe damage, and dispersal areas, with quite severe damage, coral death reached ~50%. Live hard coral cover decreased drastically and rubble cover was increased and 90 coral species was affected.
5. Damage to coral reefs due to ships running aground has caused massive and acute coral damage in Indonesian waters

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Referrences

[1] Hadi, T. A., Giyanto, B. Prayudha, M. Hafizt, A. Budiyanto dan Suharsono. (2018). *Status Terumbu Karang Indonesia.* Jakarta: Puslit Oseanografi-LIPI.
[2] Negri AP, LD Smith, NS Webster, AJ Heyward. 2002. Understanding ship-grounding impacts on a coral reef: potential effects of anti-foulant paint contamination on coral recruitment. Mar Pollut Bull. 44(2); 111-117.
[3] Challenger GE, 2006. International Trends in Injury Assessment and Restoration. In Coral Reef Restoration HandBook (Editor: W.E.Prect). Taylor and Francis. Florida USA.
[4] Jones RJ, 2007. Chemical contamination of a coral reef by the grounding of a cruise ship in Bermuda. Marine Pollution Bulletin 54 (2007) 905–911.
[5] Daud JRP FV, Rattu 2011. The Impact of Land filled (coastal reclamation) on Coral Reefs in Kalasey-Bulo, Manado Bay. Jurnal Ekowisata November 2011. ISSN 1978-452X
[6] Shutler SK, Gitting S, Penn T, Schittone J. 2006. Compensatory Restoration : How Much Each is Enough ? Legal, Economic, and Ecological Consideration. Prect W.F (Editor) : in Coral Reef Restoration Handbook. Taylor and Francis-CRC.
[7] Hill J, C Wilkinson, 2004. Methods for Ecological Monitoring of Coral Reefs. A Resource for Manager ver.1. Reefbase, GCRMN, Reef Check. AIMS publ. ISBN 0642322376. 123p
[8] English, S., C. Wilkinson & V. Baker. 1997. *Survey Manual for Tropical Marine Resources* (2*nd* Edition). Australian Institute of Marine Science, Australia: x + 390 hlm.
[9] Hudson JH, WB Goodwin, 2001. Assessment of vessel grounding injury to coral reef and seagrass habitats in the Florida Keys National Marine Sanctuary, Florida: Protocol and Methods. *Bulletin of Marine Science* 69(2):509-516.
[10] Collier C, Dodge R, Gilliam D, Gracie K, Grgg L, Jaap W, Mastry M, Poulos N 2007. Rapid Response and Restoration for Coral Reef Injuries in Southeast Florida - Guidelines and Recommendations. Florida Department of Environmental
[11] Kohler, K. E: M. Gill.2006. Coral Point Count With Excel extensios (CPCe): A visual basic program for the determination of coral and substrate coverage using random point count metodology. Comput Geosci 32(9):1259-1269.

[12] Giyanto, M. Abrar, T. A. Hadi., A. Budiyanto, M. Hafizt, A. Salatalohy & M. Y. Iswari. 2017. *Status Terumbu Karang Indonesia*. Puslit Oseanografi-LIPI. Jakarta.ix+30 hlm.
[13] Hayasaka-Ramírez, S., & Ortiz-Lozano, L. (2015). Anthropogenic pressure indicators associated with vessel groundings on coral reefs in a marine protected area. Ciencias Marinas, 40(4), 237–249. https://doi.org/10.7773/cm.v40i4.2459
[14] Precht, W.F., Aronson, R.B., Swanson, D.W., 2001. Improving scientific decision-making in the restoration of ship-grounding sites on coral reefs. Bulletin of Marine Science 69, 1001–1012. Precht, W.F., 1998. The art and science of reef restoration. Geotimes 1, 16–20.
[15] Jaap WC, 2000. Coral reef restoration. Ecological Engineering 15, 345–364.
[16] Precht WF, Robbart M, 2006. Coral reef restoration: the rehabilitation of an ecosystem under siege. In: Precht, W.F. (Ed.), Coral Reef Restoration Handbook. Taylor & Francis, Boca Raton, FL (USA), pp. 1–24.
[17] Jaap WC, Hudson, J.H., Gilliam, D., Dodge, R.E., Shaul, R., 2006. Coral reef restoration with case studies from Florida. In: Coˆ te, I.M., Reynolds, J.D. (Eds.), Coral Reef Conservation. Cambridge University Press, Zoological Society of London, pp. 478–514.
[18] Lirman D., N. Gracias, B. Gintert, A. C. R. Gleason, G. Deangelo, M. Dick1, E. Martinez, R. P. Reid. 2010. Damage and recovery assessment of vessel grounding injuries on coral reef habitats by use of georeferenced landscape video mosaics. Limnol. Oceanogr.: Methods. 8: 88–97
[19] Alison L. Moulding, Vladimir N. Kosmynin, David SG. 2012. Coral recruitment to two vessel grounding sites off southeast Florida, USA. Int. J. Trop. Biol.60: 99-108.
[20] Fox HE, Mous PJ, Pet JS, Muljadi AH, Caldwell RL.2005. Experimental assessment of coral reef rehabilitation following blast fishing. Conserv Biol; 19: 98±107.
[21] Raymundo L, Maypa A, Gomez ED, Cadiz P. Can dynamite-blasted reefs recover? A novel, low-tech approach to stimulating natural recovery in fish and coral populations. Mar Pollut Bull. 2007; 54: 1009± 1019. https://doi.org/10.1016/j.marpolbul.2007.02.006 PMID: 17383687
[22] Edwards AJ and ED Gomez, 2008 Reef Restoration Concepts and Guidelines: Making Sensible Management Choices in the Face of Uncertainty. 38p.
[23] Victoria-Salazar I., Hector A., Hernandez A., Jorge A., Meave, Miguel ARZ., Alejandro V Z., Juan PCG., Haydee LA. 2017. Did the community structure of a coral reef patch affected by a ship grounding recover after 15 years? Merging historical and recent data sets. Ocean Coast Manage. 144: 59-70
[24] Bruckner AW, RJ Bruckner. 2001. Condition of restored *Acropora palmata* fragments off Mona Island, Puerto Rico, 2 years after the Fortuna Reefer ship grounding. In Baruch Rinkevich (2005): Conservation of Coral Reefs through Active Restoration Measures: Recent Approaches and Last Decade. Progress**.** Environ. Sci. Technol. 39: 4333-4342
[25] Idris, Zamani, N. P., Suharsono, & Fakhrurrozi. (2020). Coral Reef Degradation Due to Ship Grounding in Indonesia: Case Study of Ship Aground in Bangka-Belitung Waters by Mother Vessel MV Lyric Poet. Jurnal Ilmiah Perikanan dan Kelautan, 12(2):263–275. http://doi.org/10.20473/jipk.v12i2.17947.
[26] Lirman D,. MW Miller, 2003. Modeling and monitoring tools to assess recovery status and convergence rates between restored and undisturbed coral reef habitats. In Baruch Rinkevich (2005): Conservation of Coral Reefs through Active Restoration Measures: Recent Approaches and Last Decade. Progress**.** Environ. Sci. Technol. 39 : 4333-4342
[27] Idris, Fakhrurrozi, J R P Daud and O Sianipar. (2022). The Impact of MT Alex grounding on a patch reef 'Gosong Panjang' in the Manggar waters, Bangka- Belitung

Province. IOP Conf. Series: Earth and Environmental Science 967 (2022) 012024. doi:10.1088/1755-1315/967/1/012024.

[28] Yusuf S. 2014. Investigation Of Coral Reef Degradation Due To ‘Ship Grounding’. Proceeding of International Conference on Marine Science and Fisheries. Makassar.

[29] Aronson RB, DW Swanson.1997. Disturbance and recovery from ship groundings in the Florida Keys National Marine Sanctuary. In Baruch Rinkevich (2005): Conservation of Coral Reefs through Active Restoration Measures: Recent Approaches and Last Decade. Progress**.** Environ. Sci. Technol. 39 : 4333-4342

[30] Wakeford M, TJ Done, CR Johnson, 2008. Decadal trends in a coral community and evidence of changed disturbance regime. Coral Reefs 27:1–13. DOI 10.1007/s00338-007-0284-0

[31] Schuhmacher H.; van Treeck, P.; Eisinger, M.; Paster, M. 2002. Transplantation of coral fragments from ship groundings on electrochemically formed reef structures. In Baruch Rinkevich (2005): Conservation of Coral Reefs through Active Restoration Measures: Recent Approaches and Last Decade. Progress. Environ. Sci. Technol. 39 : 4333-4342

[32] Nguyen, T.-H., Amdahl, J., Leira, B.J., Garr_e, L., 2011. Understanding ship-grounding events. Mar. Struct. 24, 551-569.

[33] Undang-Undang Republik Indonesia. Nomor 5 Tahun 1990. Tentang. Konservasi Sumber Daya Alam Hayati Dan Ekosistemnya.

[34] IUCN .2023. The IUCN Red List of Threatened Species. Version 2022-2. <https://www.iucnredlist.org>