Coral Reef Condition in Relation to Coral Reef Fish Abundances … in Simeuleu Island, Aceh (Wisha, U.J., et al)

**ABSTRACT**

Bordered with the Indian Ocean, Simeuleu Islands is one of the outermost islands in Indonesia located in the west part of Aceh Province. Simeuleu waters are productive areas due to the unpolluted water condition and great biomass. Three regions were particularly observed, those are Simeuleucut, Ganting, and Labuhan Bajau. At those areas, the existing marine tourism activities might affect coral reef ecosystem. This study aimed to evaluate the condition of coral and coral reef fish in those three particular regions before mass bleaching event in 2016 triggered by ENSO. Point Intercept Transect (PIT) method was employed to record the percentage cover of coral, species diversity, and coral reef fish. Ganting waters was a moderate ecosystem area with the percentage cover of coral was up to 45.62%. However, in Simeuleucut and Labuhan Bajau waters, the coral reef communities were excellent with coral coverage reached 83.12% and 81.25%, respectively. The highest abundance genera of coral reef fish was observed in Simeuleucut waters. This condition was changed oppositely in 2016 when the mass bleaching event occurred in Simeuleu waters caused by temperature anomaly triggered by ENSO. The temperature raised almost 3°C for 6 months that undoubtedly induced bleaching whereby about 50% of coral colonies were dramatically declined in coral coverage and coral recruitment.

**Keywords:** Coral monitoring; coral reef fish; Simeuleu Islands; mass coral bleaching; ENSO

**INTRODUCTION**

Indonesian archipelago has affluent resources, which are specifically composed by great biomass (Plass-Johnson et al., 2016). Most of the outermost islands still have high in biodiversity than becoming the main marine resources that support the capture fisheries and aquaculture (Béné et al., 2016). One of the western-most islands is Simeuleu that becomes the marine pivot in Aceh Province (Insacco & Zava, 2017). The most attractive objects in Simeuleu are coral reefs and coral reef fishes that are tremendously rich where the existence of coral reef fishes is related to the resource availability of coral reefs as its habitat (Rizwan et al., 2017).

Geographically, Simeuleu islands is bordered by the Indian Ocean where the ocean-atmosphere interactions directly influences the water conditions in Simeuleu waters (Herdiana et al., 2008). The crucial issue is temperature anomaly occurred in the Indian Ocean that may impact to coral reef ecosystem in the vicinity of Simeuleu waters. The high temperature anomaly happened in the Indian Ocean region, yielding massive coral bleaching phenomenon, caused by El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) phenomena.

Three significant regions in Simeuleu waters becoming the center of marine tourism are Ganting, Simueluecut, and Labuhan Bajau, where the greatest natural resources such as attractive beaches exist. Those areas have been becoming the most visited area by tourists. As the marine tourism destination, those areas are densely populated along the coastal area that directly contribute into the increase of anthropogenic wastes that may influence the coral and coral reef fish conditions (Baird et al., 2005; Campbell et al., 2007). Moreover, the unstable temperature due to climatic factors and the raising level of ocean acidification severely exacerbate the coral reef ecosystem (Guest et al., 2012; Bridge et al., 2014).
Several previous related studies have been published. Herdiana et al. (2008) surveyed the coral reefs and coral reef fishes in Simeulue and Banyak Islands where the condition was great at that time. Water quality monitoring in Ganting Beach was conducted by Mutmainah et al. (2016). Therefore, a study regarding coral reefs and coral reef fishes in Simeulue Island is just preliminary. The previous reports were mostly focused on northern region of Aceh (Rudi et al., 2009; Ulfah, 2011; Baird et al., 2012; Fadli et al, 2014; Alyza et al., 2015). According to the local fishermen in Simeulue, the most serious threats to the coral reefs in Ganting, Simuelucut, and Labuhan Bajau are marine pollution, fishing boats activities, and marine ecotourism.

Based on issues above, a study to assessing the condition before and after bleaching and identifying the anthropogenic pressure influencing coral reefs and coral reef fishes is essential. This study result might become a significant basis for the further of Aceh Province development. Hence, this study aimed to evaluate the condition of coral and coral reef fish in Ganting, Simuelucut, and Labuhan Bajau before mass bleaching occurred during the early 2016 triggered by ENSO. Point Intercept Transect method were used to survey coral reef condition by considering the percentage cover of coral, species diversity, and coral mortality indices. Furthermore coral reef fish identification was described by coral reef fish visual census.

MATERIALS AND METHODS

Study Sites

The surveys were conducted in October 15th, 2015 and January 20th, 2016 in three main sites: Ganting, Simuelucut, and Labuhan Bajau (Figure 1). Both Ganting and Labuhan Bajau waters are located in the southeastern of Simeulue Islands where the surveys were positioned at 96.3616 E, 2.5318 N and 96.5257 E, 2.4316 N, respectively. Simuelucut Island is located in the western part of Simeulue Islands that directly bordered with the Indian Ocean. In this area, the survey was positioned at 95.9603 E, 2.5421 N. Those three waters regions were known as represented areas of great biomass and coral reef ecosystem in Simeulue Islands. Therefore, monitoring and observation of coral reef and coral reef fish conditions to determine the occurrence of damage are essential.

Coral Assessment

Coral reef and coral reef fish were observed using Point Intercept Transect (PIT) method. The PIT was employed to define the benthic community based on life form developed. Firstly, the site location was surveyed using manta tow method to find out the perfect area that will be monitored by establishing PIT. Sampling was carried out twice based on the two depths: 3-5 m and 6-10 m. The line transect was unfurled parallel to the coastline and kept in stable position to get the same depth observation area along 100m each depth. Then the divers observed every biota that passed based on its category and taxa. In this case, one colony is considered into one individual (Biddick et al., 2005).

Benthic habitat and the length of transitional cover observed along the 100 m transect line were grouped by their growth form. The coral percentage cover criteria are shown in Table 1. The calculation by applying the formula from was done to Miller et al. (2009) as follow:

![Figure 1. Survey locations in the Simeulue Island.](image-url)
Moreover, the calculation of the species diversity was done according to Shannon-Wiener formation (Spellerberg & Fedor, 2003) as follow:

\[
H' = \sum \frac{n_i}{N} \log \frac{n_i}{N} \quad (2)
\]

where:
- \(H'\) = diversity index
- \(N\) = total amount of individual
- \(n_i\) = total individual within \(i\)-species

The rate of damaged coral is related to the high rate of condition change (living and dead coral). Coral mortality ratio is obtained by calculating Mortality Index (\(MI\)) as follow:

\[
MI = \frac{\% \text{dead corals}}{\% \text{cover of dead and living corals}} \quad (3)
\]

The value of \(MI\) determines the coral condition (Table 1). If the value of \(MI\) is closer to 0, it means that there is no change in the living coral community, whereas if the \(MI\) value is closer to 1, it indicates that there is a high rate of mortality.

### Table 1. Percentage cover and mortality index criteria

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent cover (%)</th>
<th>Diversity index ((H'))</th>
<th>Mortality Index ((MI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0-24.9</td>
<td>(H' &lt; 1)</td>
<td>0.75-1</td>
</tr>
<tr>
<td>Fair</td>
<td>25-49.9</td>
<td>1&lt;(H') &lt;3</td>
<td>0.5-9.749</td>
</tr>
<tr>
<td>Good</td>
<td>50-74.9</td>
<td>(H' &gt;3)</td>
<td>0.25-0.499</td>
</tr>
<tr>
<td>Excellent</td>
<td>75-100</td>
<td>-</td>
<td>0-0.249</td>
</tr>
</tbody>
</table>

Source: Ministry of Environment and Forestry, Indonesia, Regulation No. 4, 2011.

### Coral Reef Fishes Census

At the same time with PIT survey, we conducted the census for coral fishes along the transect line. Underwater visual census method was employed to monitor coral reef fishes, particularly in remote locations (Sweatman et al., 2005). However, if it is possible, the transect should be combined with a long swim method providing more precise in the estimation of the abundance and biomass of large, high mobile species, patchy or clumped in distribution (Choat & Pears, 2003).

Based on the coral fish census data, coral fishes are grouped into three groups according to its function and role. Those were target fish (economic and edible value fish as the target catch of fishermen), major fish (generally lives in coral reef ecosystem to protecting the balance of ecosystem), and indicator fish (indicating the coral health).

### RESULTS AND DISCUSSION

#### Results

### Percentage Cover of Coral and Coral Reef Fish Abundances

Generally, Ganting waters are dominated by two main coral categories that are living coral non-Acropora (HC) and dead coral that covered by filamentous algae (NIA/Nutrient Indicator Alga) (Figure 2). Several genera identified in Ganting waters were Porites, Acropora, Pavona, Fungia, Favia, Galaxea, and Pocillopora. Ganting waters are categorized into moderate ecosystem according to percentage cover up to 47.25%. Dead coral with filamentous algae was observed reaching 43.125%.

In Simeulucut waters, living hard coral had high percentage mainly in the ecosystem that up to 83.125%, while the other living cover is placed by soft coral (3.75%) and NIA (3.75%). There are several genera identified along the line transect such as Porites, Acropora, Pavona, Fungia, Montipora, and Pocillopora as well (Figure 2).

In Labuhan Bajau, the hard coral reached 81.25% (still highly covered). The other biota, except for non-living coral, were observed, such as soft coral, NIA, and sponge, which reached 0.625%, 15.625%, and 1.875%, respectively. Commonly found coral genera in this site are Porites, Acropora, Pavona, Favites, Montipora, and Pocillopora beside non-coral living acidiant and sponge. Coral condition in Labuhan Bajau was categorized into excellent coral reef community because the percentage cover was very high (82.875%).

Coral reef fishes identified in Ganting waters consisted of 50 genera belonging to 10 families. Three families of them that are mostly identified are Pomacentridae (17 genera), Chaetodontidae (14 genera), and Acanthuridae (7 genera). Major fishes in Ganting waters are mostly found reaching 50% (25 genera), followed by indicator fish of 46% (23 genera) and the target fish was only 4% (2 genera). In the
major fish group, Plectroglyphidodon lacrymatus, Dascyllus carneus, and Chromis caudalis are frequently high specimen number. Whereas, indicator fish families that mostly observed were Chaetodontidae and Labridae families. For target fish, only Zanclus cornutus (Figure 3) was observed.

In Simeulucut waters, about 50 genera of coral reef fishes belong to 9 families are observed. The mostly found families are Chaetodontidae (8 genera), Acanthuridae (9 genera), and Scaridae (9 genera). Generally, in Simeulucut area, mostly found major fish reached 76% (38 genera), followed by indicator fish of 18% (9 genera), and the target fish 6% (3 genera). The major fish category consists of Plectroglyphidodon lacrymatus, Dascyllus carneus, and Chromis caudalis. Indicator fish consists of Chaetodontidae and Labridae, while Zanclus cornutus was the only target fish identified (Figure 3).

In Labuhan Bajau waters, 68 genera of coral reef fishes belonging to 12 families are identified. The main families are Chaetodontidae (14 genera), Acanthuridae (11 genera) and Scaridae (8 genera). The major fish reached 56% (38 genera) the frequently found taxa were Archamia macroptera (recently Taeniamia macroptera (Cuvier, 1828)) from family Apogonidae, and two other families: Pomacentridae and Mullidae. The indicator fish reached 23% (16 genera) from family Chaetodontidae and Labridae, while the target fish reached 21 % (14 genera) the mostly found genera are Acanthurus auraticavus and Pterocaesio tile (Figure 3).
Coral Mortality Indices (MI)

Based on the calculation of percentage cover, Ganting waters is categorized into fair ecosystem area, while Simeuluecut and Labuhan Bajau are categorized into excellent ecosystem condition (Table 2). However, Coral Mortality Index (MI) value for Ganting waters almost reached 1 (0.93). This high coral mortality indicated that the area was threatened by surrounding water conditions (such as water temperature, visibility, etc.) as limiting factors of coral grow and development. In this area, the coral percentage cover was < 50% but the diversity is still in moderate level. Fortunately, the MI values of Simeuluecut and Labuhan Bajau are low, indicated that the ecosystems are very suitable for supporting the coral reef fish survival ability as well its habitat.

Table 2. The analyzed value results from PIT survey

<table>
<thead>
<tr>
<th>Assessment aspects</th>
<th>Ganting waters</th>
<th>Simeuluecut Island</th>
<th>Labuhan bajau waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent cover</td>
<td>46.25 % (Fair)</td>
<td>86.875 % (Excellent)</td>
<td>81.875 (Excellent)</td>
</tr>
<tr>
<td>Diversity index</td>
<td>$H' = 2.75$ (Fair)</td>
<td>$H' = 3.67$ (Good)</td>
<td>$H' = 3.36$ (Good)</td>
</tr>
<tr>
<td>Mortality index</td>
<td>0.93 (Poor)</td>
<td>0.04 (Excellent)</td>
<td>0.18 (Excellent)</td>
</tr>
</tbody>
</table>

Coral Reef Ecosystem Conditions After Mass Bleaching Event

The temperature enhancement has been started in December 2015 and the maximum was in May 2016 that reached 30.55°C (Figure 4). Due to these changes, corals could not tolerant with the dramatically raising temperature (Baird et al., 2009; Brown, 1997; Hoegh-Guldberg, 1999) that caused coral bleaching in the Simeulue Islands in 2016. To correlate the ENSO’s influence and increasing temperature phenomena in coral reef condition, the SOI (Southern Oscillation Index) was used to find the temperature oscillation pattern (Figure 5) using the differences on air pressure between Tahiti and Darwin (Ropelewski & Jones, 1987). The ENSO’s month is characterized by SOI<-10 which directly influences temperature that might be supported by the Indian Ocean Dipole mode (Wisha & Khoirunnisa, 2017).

In general, the bleached coral colony was almost up to 50 %, pale condition reached 20%, and in normal condition was 27%, and the dead coral was observed up to 3 % in all locations (Figure 5). The highest bleached coral colony was observed in Ganting waters, reaching 65%, with coral mortality due to bleaching reached 5 %. Furthermore, 40 % of the most normal coral condition were observed in Simeuluecut Island. The implication of coral bleaching in Simeulue waters in 2016 was the dramatic coral reduction from 78% ± 2.61 SE in 2015 to 35 % ± 4.14 SE in 2016. It was also followed by the decreasing of coral recruitment from 6.5 ind/m ± 1.04 SE in 2015 to 1.37 ind/m ± 0.16 SE in 2016 (Figure 6).
The Existing Condition of Coral Reefs and Fishes Before Mass Bleaching

The coral reef condition in Ganting is getting worse (hard coral cover was 46.6%) compared to Simeuluecut and Labuhan Bajau waters that were over 80%. In Ganting and Labuhan Bajau waters, the anthropogenic pressures have been took place which may affect to wide-scale coral condition (Wooldridge, 2009).

Overall, coral reef fishes are in good condition, even though in Ganting waters the coral cover is lower than those in both Simeuluecut and Labuhan Bajau. The fish abundances were still high, this probably supported by benthic macroalgae and the other organisms that became the main food supply for especially herbivorous coral reef fishes (Lehahn et al., 2016). It is well known that coral fish abundance depends on the coral reef ecosystem as the place for living, spawning, and feeding (Pellissier et al., 2014). Coral reefs may face a diverse array of threats, from eutrophication and overfishing to climate change (Ritchie, 2006; Rosenberg & Ben Haim, 2002; Harvell et al., 2002). This may have important consequences for the survival and growth of reef fish since complex habitats mediate prey interactions (Rogers et al., 2014).

Percentage coral cover condition that has been shown in 2015 indicated that the coral reef ecosystem was in a good condition. Diversity index shows the
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same pattern, in which Ganting waters was moderately diverse, compared to Simueluecut and Labuhan Bajau that have an excellent category of coral diversity. It is because Ganting waters was suffered by a physical pressure due to preoccupied human activity in the coastal area, whereas Simueluecut and Labuhan Bajau are remote areas with low of anthropogenic pressure.

Coral Reefs Conditions After Mass Bleaching

The lesser the value of SOI, the higher the temperature observed (Figure 4). Obviously, in fact that those conditions result in bleached and dead corals in Simeuleue that may impact on ecosystem, such as coral reef fish and other biota. The recruitment of young corals has a significant role in the recovery and decolonization after bleaching. The genera of young corals that are able to survive and recover can give a significant impact to the coral community structure substantially (Westmacott et al., 2000).

Due to the coral cover and recruitment reductions, the fish abundance and biomass may also decline. The dead coral impacts the coral reef fish that depend on the coral reef ecosystem. The coral reef fish are difficult to get their food and shelter due to bleaching (Pratchett et al., 2013). Coral reefs provide homes and protection from predators, especially for small types of fish that affect the pattern of their survival and abundance (Eggleston, 1995). Coral fish and coral reefs have a close relationship in the process of coevolution, where reef fish grow and develop along with the development of coral reefs as their habitat (Muttaqin et al., 2014). Commonly, the coral genera that were found with bleached condition were Acropora and Pocillopora. According to Prachett et al. (2013), Acropora and Pocillopora are the most vulnerable genera if the temperature increases.

The long-term impact of bleaching is if the physical structure of coral reefs is destroyed, it will result in decreased diversity of reef fish species (Garpe et al., 2006; Graham et al., 2007). The recovery process of post bleaching highly depends on the community diversity (Grimsditch & Salm, 2006), especially the abundance of herbivorous fish that feed on algae (Hughes et al., 2006). Herbivorous fish play a role in reducing algae on the hard substrate, so that young and mature corals that are recovering the substrate would be more available to grow again. Post-disturbance hard coral recovery is directly proportional to the recovery of the coral reef fish community (Emslie et al., 2008). The recovery of hard coral after bleaching can occur if there is no intervention interference during its recovery (Pratchett et al., 2013).

CONCLUSION

Coral reef ecosystem observed in Simeuleue, Aceh, is categorized into a good condition, which consist of abundant fish and other biota, and the high coverage of coral. This condition is supported by water quality surrounding the coral area that is very suitable for coral growth. Ganting waters is worse than Simueluecut and Labuhan Bajau because of the pressure of anthropogenic activities such as fishing and marine tourism that was very preoccupied in that region. Simueluecut and Labuhan Bajau are categorized into an excellent water area with a high diversity, high coral coverage, and lower mortality. Coral reef fish abundances are very high especially in Simueluecut that consist of >50 genera. Even though in Ganting waters the coral cover was lower than Simeulucut and Labuhan Bajau, the fish abundant is still high. This is probably caused by the high availability of benthic macroalgae and the other biota that are the main food supply supporting coral fish’s growth. The condition was contrarily changed in 2016, when the ENSO triggered high temperature-induced coral bleaching in several areas of Simeuleue. The temperature increased almost 3°C for 6 month which undoubtedly induced bleaching reached 50% of coral colony causing a dramatic coral cover derivation. Due to coral coverage and recruitment reductions, the fish abundance and biomass may also decline. The dead coral colony had been impacted to the coral reef fishes then might affect to coral reef ecosystem as their habitat.

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