Impacts of sedimentation on coral reefs in Inner Ambon Bay, Indonesia

G V Limmon\textsuperscript{1,2,*} and A M Marasabessy\textsuperscript{1,2}

\textsuperscript{1}Marine Science Department, Faculty of Fisheries and Marine Science, Pattimura University, Ambon, Indonesia, \\
\textsuperscript{2}Maritime and Marine Science Center of Excellence, Pattimura University, Ambon, Indonesia. Jalan Mr. Chr. Soplanit, KampusPoka, 97233

*e-mail: gino.limmon@gmail.com

Abstract. Sedimentation is one of the limiting factors for coral life. Suspended and deposited sediment have negative effects on the coral community. The rate of sedimentation can lead to low coral cover, low growth rate and low recruitment. Sediment that enters inner Ambon bay comes from 8 rivers around the bay. In this research, we assess coral reefs condition, calculate the rate of sedimentation, analyze effects of sedimentation on the coral reefs, and observe the change of coral reefs condition in inner Ambon Bay. Distribution and general condition of coral reefs was observed using manta tow method. Three places were then chosen to be surveyed in detail using line intercept transect to determine the percentage of coral cover. Resuspended sediment were measured by using sediment traps placed on coral reefs for 3 days. Sea water was collected with Niskin bottle, filtered and analyzed in laboratory to determine suspended particulate matter. The results showed that percentage of coral cover in Hunut, Kate-Kate and Halong are 5.62%, 5.26%, and 8.92% respectively and fall into the category of poor coral reef condition. The percentage of coral cover decreased progressively since 1985. The suspended particulate matter in three locations is more than 20 mg/l and resuspension sediment at Kate-kate is 18.39 mg/cm\textsuperscript{2}/day, Hunut 16.29 mg/cm\textsuperscript{2}/day, and Halong 10.12 mg/cm\textsuperscript{2}/day. The degree of sedimentation in inner Ambon Bay is at the level of moderate to severe.

1. Introduction

The importance of modern coral reefs is evidenced by various natural and economical values they have. They produce and protect land, support fisheries and tourism, and provide opportunities for education and research [1,2]. Furthermore, they have cultural value for islander and tropical coastal communities.

Wallace who visited Ambon Bay in 18th century has mentioned the beauty and richness of coral reefs in Ambon Bay. However the coral reefs condition in Ambon bay has been declining significantly nowadays. Specifically, Coral reefs in Inner Ambon Bay (IAB) are undergoing massive degradation due to sedimentation, as reported by Ambon City Government in Selanno (2010) [3].

Research of coral reef condition in IAB has been done in previous years by Anderson and Sapulette (1981) [4], Sutarna (1987a; 1987b) [5,6], Leatemia (1996) [7], UPT-BKBL Ambon (2008) [8], Indrabudi and Alik (2017) [9]. There is very clear trend that the condition of coral reefs in IAB decreasing significantly. Therefore, research on coral reefs condition in IAB needed to be done to unravel the cause of degradation of reefs in IAB.
2. Materials and Methods

2.1 Study site
This research was conducted in February-March 2016, in Inner Ambon Bay with 3 sampling sites (Figure 1). Ambon bay is located in Ambon City, Maluku Province. It is divided into two parts, Inner Ambon Bay (IAB) and Outer Ambon Bay (OAB) that is separated by a narrow sill of Poka-Galala with 15 m depth and the wide is 50 m [3]. OAB has large area and directly facing the Banda sea whereas IAB is a semi enclosed bay.

![Figure 1. Research sites in Inner Ambon Bay](image)

2.2 Coral reef condition
Coral reef condition were assessed by using manta tow and Line Intercept Transect (Life Form) method as described in English et al. (1994) [10]. Manta tow method was used to map coral reef distribution in the bay and Line Intercept Transect was used to calculate the percentage of living coral. The data from both methods combined will determine the condition of coral reefs.

In Line Intecept method, the coral community is characterized using lifeform categories which provide a morphological description of the reef community. All lifeform categories were coded following that described by [10]. At each site, we measured 1 transects at 3 meters and 10 meters depth. The advantages of this method is that it is reliable and efficient for obtaining quantitative percent cover of not only coral but also other associates living in the reef ecosystem. This method also requires relatively simple equipment.

2.3 Suspended particulate matter (SPM)
Suspended particulate matter (SPM) was determined by filtering 1 liter of water sample through milipore filter. These filters had earlier been soaked in slightly acidic water, rinsed with distilled water, dried and weighed. Water samples were taken at 10 to 30 cm from the sea surface using plastic containers. The filtering was conducted in the field using vacuum hand-pump. These filters were then dried in the oven at 60°C overnight and reweighed. The sampling was conducted every week in all sites.
2.4 Resuspended sediment
To determine sediment resuspension, sediment traps were placed at each site ranging from 3 to 5 meter depth. In sites where ocean condition was rough, the sediment traps were placed in a deeper water to prevent waves from tilting the traps. Methods to measure resuspension sediment rate were discussed further by Gardner (1980a; 1980b) [11,12], Bloesch (1995) [13] and Bothner, et al. (2006) [14].

The tubes or cylinders were attached to the metal frame by plastic rope with the openings located at 25, 50 and 75 cm. respectively from the substrate, and left for one day.

Sediment retained in each sediment trap was removed, filtered through prewashed and preweighed milipore filter and washed with distilled water to remove salt. The filters were then dried at 80°C overnight and reweighed. The difference in weigh is the amount of vertical flux of sediment trapped in the sediment trap.

3. Result and Discussion

3.1 Distribution and condition of the reefs
Mapping of coral reefs in Inner Ambon Bay was done using Manta Tow method that suitable to be applied due to considerable size of IAB. A total of 95 tracks were done to cover the whole IAB. The total towing tracks in IAB is 14.9 km. Manta Tow result showed that the distribution of reefs in IAB is not continous but scattered around the bay. Estimated percent coral cover obtained from this method showed that the coral reef in IAB are in very severe condition. The percent coral cover range from category one to category 3. Distribution and percent coral cover in IAB are shown in Figure 2.

![Figure 2](image.png)

**Figure 2.** Distribution and percent coral cover in IAB

3.2 Coral community assessment
To gain more detailed information about the condition of coral communities, Line Intercept (Life Form ) method was used. The results showed that the condition of coral reef communities in IAB is indeed in very severe condition. In all research site, the percent cover of living hard coral was less than
10%. The percent cover in Halong is the highest, (8.92%), followed by Hunuth (5.62%), and Kate-kate (5.26%). Cover percentage of coral reefs in all research sites are listed in Table 1, and Figure 3 depicts the percent cover of the substrate and biotas.

| Location   | Manta Tow | LIT (%) |
|------------|-----------|---------|
| Kate-kate  | Category II | 5.26   |
| Hunut      | Category II | 5.62   |
| Halong     | Category III | 8.92   |

Table 1. Percent cover of coral reefs in all research sites

![Figure 3. Percent cover of substrate and life forms]

Note: CM=coral massive, DC=dead coral, R=ruble, OT=other, RCK=rock, S=sand, SP=sponge, WA=water

Measurement of percent cover of coral life form in all sites revealed that the highest coral life form coverage in Inner bay is massive coral *Porites* sp. The reef in this area clearly shows the characteristics of reefs under siltation stress. Rough ocean conditions cause bottom sediment mixing, resulting in very low visibility. Frequently, a diver could not see his hand in a distance of approximately 50 cm.

Excessive sedimentation in these areas causing reduction of light availability for photosynthesis and limited coral distribution vertically, smothered coral, and lowered coral recruitment which results in low coral cover and species richness. High SPM and resuspended sediment produce turbid water that restricts coral distribution to less than 10 m. Furthermore excessive sedimentation can adversely affect the structure and function of the coral reef ecosystem by altering both physical and biological processes.

3.3 Suspended particulate matter
Suspended particulate matter (SPM) measured in three sites in Inner Ambon Bay range from 22.69 to 48.89 mg/L. The highest SPM value was found in Kate-kate (48.89 mg/L), followed by Hunut (33,85
mg/L) and Halong (22.69 mg/L) (Figure 4). The high SPM value in Kate-Kate and Halong caused by the development of housing and business center around Ambon bay. The runoff of the rivers in IAB are also significantly contributed to high SPM value especially in rainy season. During the rainy season, the sediment covered the whole Ambon Inner bay at low tide. High SPM content resulted in high turbidity that will decrease light penetration to the sea bed and will negatively effects the growth rate of coral. Decrease in light intensity will in turn reduce photosynthesis rate that resulted in reduced metabolism and growth rate of coral.

**Figure 4.** Suspended Particulate Matter (SPM) measured in IAB

### 3.4 Sediment resuspension

The value of resuspended sediment describes the vertical flux of sediment. Resuspended sediments measured in three locations in inner Ambon bay are highest at Kate-Kate (Figure 5). The average values of resuspended sediment in Kate-Kate, Hunuth and Halong are 18.39, 16.29 dan 10.12 mg/cm²/day consecutively. The resuspended sediment value is higher in Kate-Kate is due to clearing of land vegetations and mangroves for housing. Furthermore, in rainy season some small creeks that boil down into the Inner Bay bring high load of sediment. Based on classification developed by Pastorok and Bilyard (1985) [15], the effect of sediment to the coral reefs in Inner Ambon Bay falls into the category of severe. High sediment laden will decrease coral recruitment, coral diversity, and coral growth rate. It will also open the opportunity for invasion of alien species.

**Figure 5.** Sediment Resuspension in IAB
Sediment trapped in the sediment traps in all sites showed the same trend. The highest value of resuspended sediment found in the sediment traps that placed closest to the ocean floor. The value of resuspended sediment is the highest at 25cm followed by 50cm and 75cm respectively. Sediment settled in the bottom can be recirculated or resuspended by ocean dynamics such as current, wave, turbulent, and tide [16].

Extreme effects of the resuspended sediment can cause coral death. When sediment load is much higher than their ability to clean that, layer of sediment settled on coral colony will cause tissue damage that will kill the coral colony. Fine particles of sediment can also lead to reduction of mucus production and kill the coral polyps, because fine sediment that mixed with mucus will form a thick clump that will cover the coral polyp and cannot be removed by coral tentacles [17].

4. Conclusion
The coral reef condition in Inner Ambon bay is now in severe condition caused by multiple anthropogenic stressors. We have identified siltation as the main stressor due to the fact that coral communities in Inner Ambon Bay dominated by massive coral Porites sp. that has been recognized as a survivor in reefs heavily affected by sedimentation. High SPM and resuspended value strengthen our conclusion that the main reason for severe condition of reefs in inner Ambon Bay is Sedimentation.

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