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Early Assessment of Shipping Route and Coral Cover as Drivers of Acroporid White Syndrome Outbreak in Karimunjawa, Java Sea, Indonesia

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Abstract

Coral diseases are increasing throughout the Karimunjawa archipelago because of local anthropogenic stressors concomitant with alterations in coral cover. The present study was carried out to quantify the indicators of coral cover and Acroporid White Syndrome (AWS) prevalence in cruise line waters. The coral cover was calculated based on an Underwater Photo Transect (UPT) survey. Prevalence of AWS was determined by calculating the amount of Acroporid coral affected by AWS disease divided by total coral colonies per 50 m^2 transect quadrant. Results of the study showed that 98 out of a total of 1686 coral colonies were affected by AWS diseases. Prevalence of all AWS diseases observed was 4.99 ± 3.11% SE. There was no significant difference between coral disease prevalence in the cruise line and non-cruise line areas (P-value = 0.667, >0.05). However, a significant difference was found among site locations (P-value = 0.001, <0.05). There was a highly significant correlation between the percentage of coral cover and AWS prevalence (r = 0.775; P-value = 0.004). Although statistically not significant, a higher prevalence of diseases was observed in sites with a close proximity with to shipping lines. More extensive monitoring on several islands with longer intervals are recommended in the shipping routes. The increase of coral cover might be resulting in the high prevalence of coral disease occurrence.

Keywords: Acroporid White Syndrome; coral reefs; shipping route; coral cover; Java sea; Karimunjawa

1. Introduction

Indonesia, the world's largest archipelago, has approximately 2.5 million hectares of coral reefs, or less than 20 % of the total corals in the world (WRI, 2013; Johan *et al.*, 2016). The high diversity of Indonesian corals is considered important because they harbor the greatest biodiversity within all marine ecosystems which provides for the continuity of ecological function (McField, 2016). However, most of the corals in the worlds are now considered in danger. Coral ecosystems were subject to threaten from various pressure from inland activities such as deforestations and waste pollution (Edinger *et al.*, 1998; Lamb and Willis, 2011). These factors cause the more susceptibility of the corals and the more virulence of pathogen (Lafferty and Holt, 2003).

The coral disease causes the decreasing of coral and fish diversity (Jones *et al.*, 2004; Booth and Beretta, 2002; Miller *et al.*, 2009).

Also, the coral mortality cause decrease in coral community composition due to declines in genetic and species diversity (Prada *et al*., 2016; Baskett *et al*., 2009; Baker *et al*., 2008; Chabanet *et al*., 2016). However, the direct impact of coral disease on coral reef biodiversity is still unclear (Weil and Rogers, 2011). Bruno and Selig (2007) stated that the outbreak coral disease contributed to the decline of coral cover. Also, Miller *et al*. (2009) and Roff and Mumby (2012) stated that the diseases have an important role in the declines of the diversity and resilience of coral reef communities. Several previous studies reported that the Acroporid White Syndrome (AWS) was related to tissue loss in the forms of irregular bands of the white skeleton (Willis *et al*., 2004; Williams and Miller, 2005; Raymundo *et al*., 2008; Sussman *et al*., 2008; Yamashiro *et al*., 2016). Aronson and Precht (2001) stated that AWS is the main factor in coral reef degradation in the Caribbean Sea. Karimunjawa archipelago, which forms a chain of 27 islands, represents several ecosystem types such as coral reefs, mangroves, and seagrass (Susanto *et al*., 2014). The four extant hermatypic coral genera that include in Acroporidae family, *Acropora* sp., *Montipora* sp., *Anacropora* sp. and *Astreopora* sp. appear in Karimunjawa (Sabdono and Radjasa, 2006). Although members of the Acroporidae display many colony growth forms on these reefs (personal field observation), the outbreak of AWS discovered in 2016 mainly affected tabular Acroporids. Obvious signs of AWS were recognized around Karimunjawa Park in May 2005. This disease is mainly distributing to the dominant species of tabular Acroporid corals in several islands (Figure 1).

Tourism in Karimunjawa Marine National park has increased remarkably in the last decade. Since the early 2010s, cruise ship travel has experienced nearly continuous growth, exceeding 25% annually (Ridwan, 2016). Associated with the increasing tourism boom has been an increase in the total number of the cruise ships and the routes of ship traffic. Consequently, coral reef ecosystems are subject to continuously stress under this situations. The change in environmental conditions has potentially weakened coral resistance to bacterial infections or increased pathogen virulence (Harvell *et al*., 2007; Muller *et al*., 2012; Altizer *et al*., 2013). To date, there are no studies around the world that assess the impact of cruise ships on coral reef health and disease emergence. Valadez-Rocha and Ortiz-Lozano (2013) reported that port expansion activities forced the main access to vessels and patterns of sediment transport to run across the coral reef zone which caused coral reef degradation. Jones (2011) stated that cruise ships could resuspend large amounts of sediment that have short-term “acute” physiological effects on the nearby coral communities. Also, Stoddart and Stoddart (2005) stated that sediment resuspension affected coral juvenile survival and coral reproduction.

Coral cover, the most common measurement in reef monitoring programs, is the proportion of reef surface covered by live stony coral instead of sponges, algae, or other

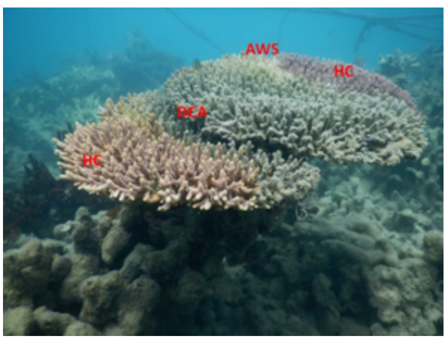

Figure 1. AWS on tabular coral *Acropora* sp.
(DCA: dead coral algae; AWS: acroporid white syndrome; HC: healthy coral)

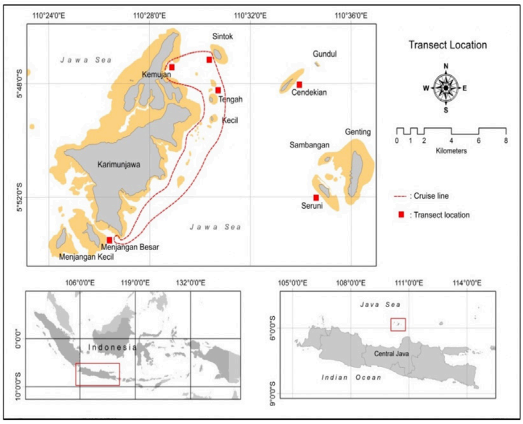

Figure 2. Sampling sites
(Note: Orange area indicate the existed of coral reefs)

organisms. Some previous studies reported that the increased temperature and the high coral cover was the main factors of AWS coral disease outbreaks (Bruno and Selig, 2007). Moreover, Bruno *et al.* (2007) suggested the important of coral cover higher than 50% as a threshold for the AWS outbreak coupled with the occurence of temperature anomalies at GBR. The research aims were to carry out to quantify indicators of coral cover and the routes of shipping regions on coral disease prevalence of AWS.

2. Methods and Study Area

2.1 Study Area

Karimunjawa National Park has located about 100 km (1 km = 1 x 105 m) north of Semarang, Central Java. Only five of the 27 islands in the Karimunjawa archipelago are inhabited, with 9,000 people living in permanent settlements (BTNKJ, 2016). These islands consist of coral reefs that are well-known for their beauty and species diversity. The six reefs identified in this study include three coral cays in the Karimunjawa, a fringing reef flat bordering mangroves in Kemujan and Menjangan Besar, a nearshore coral cay in Sintok, a nearshore fringing reef slope near Cendekian, Tengah and Seruni. All coral cays were transected at 5 m in depth, except Kemujan, which was transected at 3 m only, because coral growth did not extend beyond 5 m depth. Marine and coastal tourism are one of the fastest growing industries in Karimunjawa. However, the exact numbers of marine tourists in Karimunjawa remains unknown. Ridwan (2016) reported that there is nearly 3,000 tourists/ week) with more than 150 ships needed to transport locally in tourist route destinations. There are five ship traffic routes to serve the tourist point of interest. The route II (Menjangan Besar, Kemujan, Sintok, and Tengah) was selected in this early study due to the most favorite tourist destination and the abundance of AWS. Seruni and Cendekia islands were selected in this study as control (no shipping route) (Figure 2).

Surveys were conducted in July 2016 according to previous methods (Sabdono *et al.*, 2014), with the following modifications: each belt transect covered 25×2 m. Three transects with 250 m in the distance were established on the reef of AWS points in each islan.

2.2. Coral disease prevalence

Surveys were conducted in July 2016 according to previous methods (Sabdono *et al.*, 2014), with the following modifications: each belt transect covered 25×2 m. Three transects with 250 m in the distance were established on the reef of AWS points in each island. Transects were established in the bottom of the reef based on the relief of the island. Each coral colony within a transect was counted and recorded as healthy or diseased as a result of AWS. Prevalence of AWS disease was calculated by

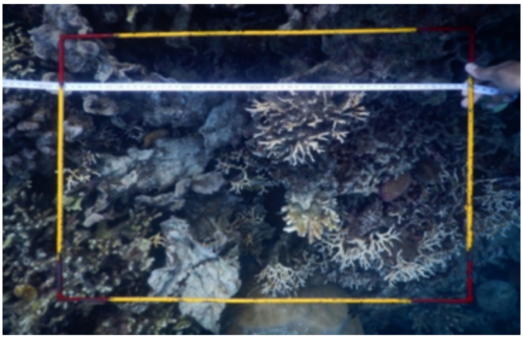

Figure 3. Underwater photo transect of corals
(Note: A photographs the bottom 0.2552 (0.44 x 0.58) m^2 per frame at 1 m interval along 25 m)

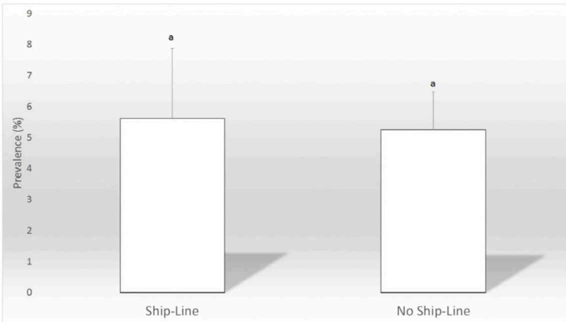

Figure 4. AWS prevalence (%) at shipping-line and no shipping-line waters

dividing the number of AWS diseased colonies by the total number of coral colonies. Means and standard errors were calculated from both of the three transects at each island. Corals were recorded at the genus level.

2.3 Coral cover

The photo-transect survey was carried out to determine the coral cover areas by using digital photography and subsequent image analysis (Giyanto, 2015; Nakajima *et al.*, 2010). This method uses 1 m interval photography along each of 18 horizontal transect lines (25 m long) at a depth of approximately 5-8 m. The nearly 360 images resulted that is enough to reduce the variability of the coral distribution pattern within the transect lines (Suharsono and Sumadhiharga, 2014; Leujak and Ormond, 2007). The photographs and coral data were carried out by two scuba divers. Beginning with laying 18 transects of 2×25 m tape from a permanently marked point by the first diver, the second divers took photographs the bottom 0.2552 (0.44 x 0.58) m^2 per frame at 1 m interval along the tape measures (Figure 3). A quadrat of an area 0.2552 m^2 (i.e., 0.44×0.58 m) was created digitally on the images relative to the markings on the transect line using the computer software Coral Point Count with Excel extensions (CPCe) following Kohler and Gill (2006).

2.4 Statistical analyses

The T-test was used to compare differences in disease prevalence and coral cover in the ship traffic route and non-ship traffic route. One way ANOVA was used to analyze the significant differences among site locations. Tukey Pairwise Comparisons ($p<0.05$) was used to tests for differences of means. Pearson correlation tests were used to analyze the statistically significant relationships between the disease prevalence and coral cover.

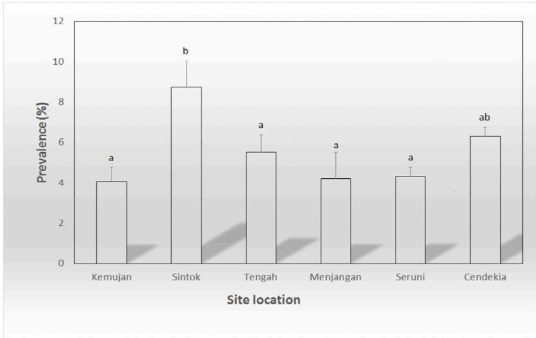

Figure 5. AWS prevalence (%) at each location

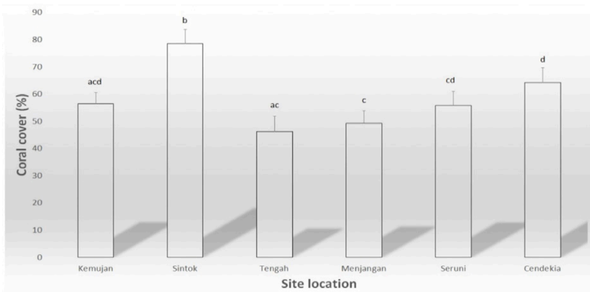

Figure 6. Coral cover (%) at each location

3. Results

3.1 Shipping route

A total of 1,687 coral colonies observed, 98 colonies were affected by AWS in an area of 900 m^2 (eighteen of 2×25 m belt transects). Results of the survey indicated that mean a total of AWS prevalence's observed on all reefs in the six islands was 4.99 ± 3.11% SE. The AWS prevalence in the ship traffic sites was similar to that of non-shipping traffic site. The t-test statistical analysis showed that reefs with ship traffic route were not significantly different to the non-shipping traffic site (P-value= 0.667, >0.05) in AWS prevalence (Figure 4).

The AWS prevalence observed on Kemujan, Sintok, Tengah, Menjangan Besar, Seruni and Cendekia islands were presented in Figure 5. Statistical analysis of 1-way ANOVA showed that significant difference was found among site locations (P-value=0.001,<0.05). Also, Tukey Pairwise Comparisons (p<0.05) resulted that Sintok island was a significant difference to other islands, Cendekia for an exception.

3.2 Coral cover influence

The mean % coral cover in the shipping route (57.6±13.8 %) sites was similar to that of non-shipping traffic site (60.34±6.60 %). The t-test statistical analysis showed that reefs with ship traffic were not significantly different to the non-shipping traffic site (T-value = -0.56, P-value = 0.581). Coral cover observed on Kemujan, Sintok, Tengah, Menjangan Besar, Seruni and Cendekia islands were presented in Figure 6. There were significant differences among the locations (F-value: 16.95, p<0.01).

3.3. Coral cover-prevalence relationships

AWS increased dramatically in Karimunjawa. However, the peak of the outbreak was considerably varied in prevalence among the islands. Sintok Island with relatively high coral cover had the highest AWS prevalence. There is high variability in disease prevalence and potentially no correlation to cruise ship traffic. All the observed percentage of coral cover-prevalence relationships of the corals from these islands assumed linear. Statistical result of the estimated correlation

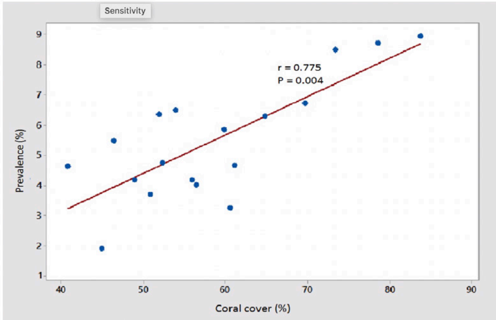

Figure 7. The relationship between coral cover and coral disease prevalence

for the percentage of coral cover-prevalence relationships was high (r = 0.775; significance with P-value= 0.004; Figure 7).

4. Discussion

An increase in the number of tourists in Karimunjawa is followed by an increase in the size and number of the cruise ships and inter-island ship traffic (BPS-Statistics of Jepara Regency, 2016). Around 518 ships navigate the waters around Karimunjawa each year, either servicing ports adjacent or passing through to the favorite destinations such as Kemujan, Sintok, Sintok, Tengah or Menjangan Besar islands (Ridwan, 2016). These islands became a popular destination for passenger ships due to its coral beauty. It was hypothesized that AWS prevalence during an outbreak would be associated with cruise ship routes. However, with the data currently available, this hypothesis was not supported. Statistical tests showed that there was no significant difference in the AWS prevalence between reefs with route line of ship traffics and the non-shipping traffic site (P-value=0.667, >0.05; Figure 4). The reasons were the low number transects conducted in the survey (3 transects at every six islands) where AWS outbreak occurred. Furthermore, coral disease outbreaks are difficult to detect, they occur quickly, and the resources for monitoring and responding to coral disease outbreaks are unfortunately under-developed. Menjangan Besar, Sintok, Tengah and Kemujan islands as route line of ship traffic sites were navigated about 160 ships or passed through to other island destinations weekly. The increased cruise ship traffic can cause a significant ecological menace to corals due to groundings, sediment resuspension (Jones *et al.*, 2016), anchor placement (Rogers and Garrison, 2001), and the oil and toxic antifouling chemicals released (Connelly *et al.*, 2001). Moreover, the attractiveness of the corals in Sintok island draws in tourists in who wish to snorkel or dive, which poses a potential threat to corals due to increased pressure on endangered species and heightened vulnerability to degradation (Davenport and Davenport, 2006). No previous study assesses the effect of the cruise ships on coral disease outbreak.

The geographic variability of coral prevalence and coral cover were presented in Figure 5 and 6, respectively. This preliminary survey showed that the highest AWS prevalence was found in the highest coral cover of Sintok island. Statistical analyses showed that there was a significant difference among site locations. Tukey Pairwise Comparisons ($p<0.05$) indicated that both AWS prevalence and coral cover in Sintok were a significant difference to other islands. Some previous studies on coral diseases reported that the higher levels of coral cover, water temperature, and nutrient runoff would be followed by the higher level of coral disease prevalence (Patterson *et al.*, 2002; Kaczmarsky, 2006; Heron *et al.*, 2010). In this study, Sintok island had the highest percentage of coral cover, followed by Cendekian, Seruni, Menjangan Besar, Kemujan, and Tengah island. The percentages of coral cover at all sampling sites were higher than 50%, except Kemujan and

Tengah islands. Bruno and Selig (2007) reported that White Syndrome occurred and was more frequent when the coral cover was 50% or higher. Figure 7 showed that there was a positive correlation between the disease prevalence and coral cover. There was a significant difference ($r=0.775$; $p=0.004$) in the percentage of coral cover-disease prevalence relationships. This preliminary result was supported by the results of previous studies. Aeby *et al.* (2010) also found that high coral cover was a significant factor in the occurrence of *Montipora* White Syndrome outbreaks. Connell *et al.* (2004) stated that the high percentage of coral cover would increase the potential for horizontal disease transmission between infected and healthy corals. Moreover, the reduction of the distances among the coral colonies facilitate the disease vectors to spread out easily (William and Miller, 2005). Accordingly, it has been found in our study that AWS prevalence could not be affected by cruise ship traffic. For that reason, the number of ship traffic route, transects and locations should be evaluated.

5. Conclusions

The data support the idea that there was high variability in disease prevalence among sites and potentially no association with cruise ship traffic. The increase of coral cover might be resulting in the high prevalence of coral disease occurrence.

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