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Regional Studies in Marine Science 30 (2019) 100704

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Preliminary study of the effect of nutrient enrichment, released by marine floating cages, on the coral disease outbreak in Karimunjawa, Indonesia

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ARTICLE INFO

Article history:
Received 2 April 2018
Received in revised form 30 May 2019
Accepted 30 May 2019
Available online 3 June 2019

Keywords:
Coral disease
Karimunjawa
Prevalence
Floating cage
Nutrient enrichment
Mariculture

ABSTRACT

Coral disease is a significant factor causing the degradation of Karimunjawa coral reefs. The objective of this study was to determine the possible effects of nutrient enrichment, released by floating cages used for fish culture, on the coral disease outbreak in Karimunjawa National Park, Java Sea. The islands of Genting, Sambangan, and Seruni were selected as study sites as they represent islands with human habitation and a high intensity of mariculture activity, no human habitation and a high intensity of mariculture activity, and no human habitation or mariculture activity, respectively. The results show that the prevalence of coral diseases in Genting, Sambangan, and Seruni were significantly different ($p < 0.01$). However, there was no significant correlation between the nutrient concentrations (N and P) and coral disease prevalence ($R^2 = 0.39$; $p = 0.07$ for nitrate and $R^2 = 0.42$; $p = 0.058$ for phosphate). The nutrients on the islands affected by marine fish cages tended to increase. We suggest that the continuation of orderly ecosystem monitoring, with increasing sample sizes, in Karimunjawa is urgently needed.

1. Introduction

Karimunjawa National Park, which is composed of 27 islands, is one of seven marine national parks in Indonesia. This archipelago is located about 100 km north of Semarang, Central Java. Only five of the 27 islands are inhabited, with a total of 9000 people living in permanent settlements (Susanto et al., 2014). These islands consist of coral reefs, which attract a large number of tourists. Increasing populations and mariculture activities are leading to a decline in the coral reefs (Heery et al., 2018). Genting, Sambangan, and Seruni islands were selected as study sites as they represent islands with human habitation and a high intensity of mariculture activity, no human habitation and a high mariculture activity, and no human habitation or mariculture activity, respectively.

During the last few decades, mariculture development in Indonesia has increased and is considered an important factor for supporting rural economic development (Sukadi, 2006). In Karimunjawa, floating net cages for fish cultivation (Fig. 1) were expanded by the private sector, to develop large-scale pond cultures (Purwaningsih, 2006). The cage rearing of the *Humpback/Polka Dot grouper (Cromileptes altivelis)* and *Brown-marbled grouper (Epinephelus fuscoguttatus)* has been growing rapidly near several islands. The fishery sectors are very economically important (Suryono et al., 2017). These situations cause changes in the environment that have increased host susceptibility, pathogen virulence, and have been immediately followed by the outbreak of coral diseases (Harvell et al., 2007; Muller et al., 2012). Presently, coral diseases are a significant factor contributing to the decline of coral reefs in all marine ecosystems. The identification of coral diseases was carried out by visual observations of coral lesions (Raymundo et al., 2008; Haapkylä et al., 2009). The worldwide survey of coral diseases for the years 2005, 2006, and 2007 revealed that the prevalence levels of coral diseases have increased dramatically in many regions of the world (Raymundo et al., 2005; Sato et al., 2009; Cróquer and Weil, 2009b). However, the prevalence of coral diseases in the Pacific was lower than that in the Caribbean (Croquer and Weil, 2009a; Ruiz-Moreno et al., 2012). A strong relationship between elevated nutrient levels, organic matter, sewage effluent, and outbreaks of coral diseases

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https://doi.org/10.1016/j.rsma.2019.100704
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Fig. 1. Floating net cage of fish cultivation in Karimunjawa.

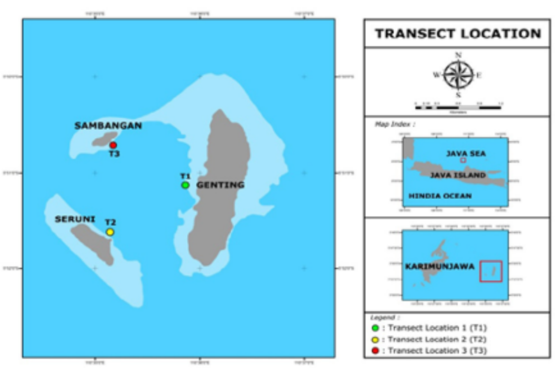

Fig. 2. Map of study area Karimunjawa Marine National Park.

has been found (Kaczmarsky, 2006; Kline et al., 2006). Increased nutrient levels, such as nitrate and phosphate, in coastal waters has been suggested as a cause of coral degradation (Rosenberg et al., 2007). Additionally, Bruno et al. (2003) reported that increasing the concentrations of inorganic nitrogen and phosphate in coral ecosystems elevated the severity of aspergillosis and yellow blotch disease. Humans have had a significant effect on the coral reef ecosystems in the Java Sea, through pollution and mariculture activities, since nutrient enrichment has a negative effect on coral reefs (Sabdono et al., 2007, 2012; Takarina et al., 2004). Elevated nutrient levels may trigger the corals to be more susceptible to diseases (Fabricius, 2005; Higuchi et al., 2015). Several studies have reported on coral disease prevalence in Indonesia. Sabdono et al. (2014) reported on the high prevalence of coral diseases in Panjang island, Java Sea. Meanwhile, Wijayanti et al. (2016) reported that tourism activity might cause corals to be more susceptible to diseases at Pasir Putih beach, Situbondo. The rapid assessment in the present study is aimed to determine the potential effects on coral disease outbreaks of nutrient enrichment, released by floating cages for marine fish culture, in Karimunjawa National Park, Java Sea.

2. Materials and methods

2.1. Study area

Coral disease assessment was conducted at three islands, Genting, Seruni, and Sambangan, of the Karimunjawa Archipelago in July 2016 (Fig. 2). This study provides preliminary information regarding the distribution, environmental stressors, and prevalence of coral diseases in Karimunjawa. Genting island (110°36′1.70″E, 5°50′43.18″S) represents inhabited islands with a high intensity of mariculture activity. In this area, marine aquaculture and sewage produce a large amount of organic waste, mostly from excess feed, household waste, and feces. This waste is normally released into the nearby coastal waters and reduces the water quality. Branching corals and seagrass meadows occur near the floating fish cages. Sambangan island (110°35′1.8″E, 45°50′34″S) is a tourist island with exclusive bungalows. However, this island is not for rent anymore, since Pura farms were established in this area in 2002. The coastal waters of this island are covered by floating net cages for fish cultivation. Seruni island (110°36′1.10″E, 5°50′43.12″S) is the control area, as it is without mariculture activity or human inhabitants. Reef flats occur to the northeast of Sambangan island. Comparison islands are conditionally defined as the reefs within coastal waters that are affected by anthropogenic stress. Garbage processing facilities have not been built on this small island. Thus, there is untreated domestic sewage that discharges directly into the coastal waters. The study sites include two islands with fish farm activities (Genting and Sambangan) and one that is not affected (Seruni). Several previous studies have reported that temperature greatly influences disease outbreaks. In this region, normally the dry season (March-August) is warmer than the rainy season (September-February). However, the temperatures did not vary significantly during this study, as it rained intermittently all year long during the study period.

2.2. Measurements of environmental parameters

The total nitrate and phosphate concentrations in the water column were measured at the three study sites, to evaluate the potential site-specific effects of sewage discharge and excess feed from coastal and floating cages used for fish cultivation. Water samples were collected from a water column around the cages (1 m in depth) by using a dark-glass bottle (Pyrex). A UV-visible spectrophotometer (UV-1280 spectrophotometer from Shimadzu), with a 1 cm path length quartz cell, was used to analyze the nutrients. Nitrate and phosphate concentrations were determined using the cadmium reduction and ascorbic acid methods, respectively (Greenberg et al., 1985). In the period between sampling and analysis, samples were stored in a refrigerator at 4 °C for three days. All samples were tested in triplicates and data are presented as the mean ± standard deviation (SD). A water Quality Checker U-22XD (Horiba Co. Ltd, Japan) was used to measure the water temperature, pH, and salinity. A Secchi disk, used to measure the water turbidity, was slowly lowered into the water body until it disappeared. This depth was noted in meters (m). A buoy and timer were used to determine the current. The buoy was allowed to move, then stopped after the timer reached 10 s. Data for the current were obtained by dividing the distance that the object traveled by the time.

2.3. Live coral cover and disease prevalence

Nine transects, distributed across three islands (Genting, Sambangan, and Seruni), were studied. The transect sites were assessed by snorkeling in the shallow areas (Genting and Sambangan, depth: 1–4 m) and scuba diving in the deep area (Seruni, depth: 4–7 m). All site transects were established close to floating cages used for fish cultivation, except for the Seruni transects. The starting points of the transects were selected randomly using the timed-swim method around the cage. The starting point of the transect was established at the first coral lesion found. The coral disease prevalence was investigated at each island with three 25 × 2 m belt transects. The line intercept transect method was used to determine the percentage of live coral cover by placing a line transect in the middle of the belt transects. This sampling protocol has previously been used in a different area of study (Sabdono et al., 2014; Wijayanti et al., 2016). All corals were identified to the genus level *in situ*, according to Veron (2000). The total number of healthy and diseased colonies for each transect were recorded to find the disease prevalence (the ratio of the number of infected colonies to the total number of observed colonies). Underwater photographs of infected colonies were documented using a Canon PowerShot S110 camera in a Canon WP-DC 47.

2.4. Statistical analyses

A one-way ANOVA was used to analyze the comparisons of the coral disease prevalence among the islands, followed by the Tukey Test to determine the significance of the variation among the treatment averages. The normality of the data and homogeneity of the variances were checked before the ANOVA analyses. If the data were not normal, the arcsine was used to transform the data. A Pearson correlation test was used to analyze the statistically significant relationships between the prevalence of coral diseases and nutrient concentrations. The ANOVA was performed with a 5% level of significance ($p < 0.05$). Statistical analyses were performed using SPSS version 16 computer software.

3. Results and discussion

3.1. Environmental parameters

The data concerning the physicochemical parameters are shown in Table 1. The mean and standard deviation of the nitrate concentrations (mg L^{-1}) at Genting, Sambangan, and Seruni were 0.059 ± 0.014, 0.046 ± 0.004, and 0.04 ± 0.007, respectively, while the mean and standard deviation of the phosphate concentrations (mg L^{-1}) at Genting, Sambangan, and Seruni were 0.032 ± 0.010, 0.022 ± 0.001, and 0.012 ± 0.002, respectively. Based on Regulation Law no.51 2004 of the Indonesian Environmental Ministry, the concentrations of N and P exceed the permitted levels, which were set to prevent eutrophication being induced. Limits for N and P have been proposed at 0.008 mg L^{-1} and 0.015 mg L^{-1}, respectively, for seawater. Several previous studies have shown that high concentrations of nutrients were detected in fish cage areas, while low concentrations were found in areas with no fish cages (Yucel-Gier et al., 2007; Neofitou and Klaoudatos, 2008). N and P are released abundantly from cage cultures (Islam, 2005), often causing the nutrients to increase on an island affected by marine fish cages. However, the statistical analyses (one-way ANOVA) showed that the levels of N and P at Genting were not significantly different compared to those in the water column around the cages of Seruni and Sambangan ($p > 0.05$).

3.2. Coral cover and disease

Approximately 23.66% of the coral (297 of 1255 colonies) was affected by diseases in all areas of the nine belt transects. The six disease states detected within the transects were as follows: White Band Disease (WBD), Black Band Disease (BBD), Pigmentation Response (PR), White Plague (WP), Ulcerative White Spot (UWS), and Growth Anomaly (GA). Coral bleaching, growth anomaly, and *Drupella* predation were found outside the transects. BBD had the highest prevalence, followed by WBD, WP, PR, UWS, and GA (Table 2 and Fig. 3).

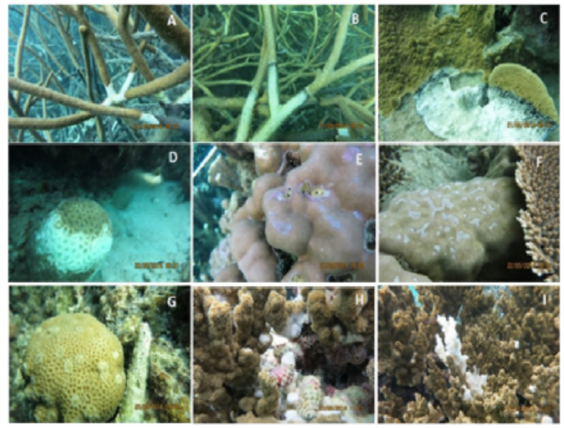

Fig. 3. Coral disease states present on Karimunjawa National Park (Note: A = White Band Disease; B, C = Black Band Disease; D = White Plague; E = Pigmented Response; F = Ulcerative White Spot; G = Growth Anomaly; H = Predation *Drupella* sp.; I = Bleaching).

The different values of coral disease prevalence at Genting (41.61 ± 3.93%), Sambangan (15.92 ± 5.04%), and Seruni (6.89 ± 1.00%) are presented in Fig. 4. This figure also shows the percent of live coral cover on each island. The statistical analyses (one-way ANOVA) shows that the disease prevalence is significantly different among these islands. However, there were no significant differences in the percentage of live coral cover. The coral genus *Acropora* sp. was the most affected by diseases. This genus was affected by five disease types, whereas the other five coral genera were affected by only one disease type. This rapid assessment shows a high prevalence of coral diseases in Karimunjawa National Park. However, the prevalence value in this assessment was the lowest when compared to previous studies conducted at Panjang island and Pasir Putih beach, Situbondo (Sabdono et al., 2014; Wijayanti et al., 2016). In the prior studies, there was quantitative evidence for a strong relationship between the coral disease prevalence and increasing human over-exploitation (Aeby et al., 2011), land-based pollution (Edinger et al., 1998), and global climate change (Hughes et al., 2003). Moreover, the expanding human population and its activities, such as urbanization and agriculture, lead to increased sedimentation and nutrient inputs, which can influence the condition of corals (NOAA, 2014).

The results for the prevalence of coral diseases were higher than those of reported cases in Wakatobi National Park (Haapkylä et al., 2007). The coral genus *Acropora* sp. was the most affected by diseases. The other five coral genera were affected by only one disease type (data not presented). On the other hand, Raymundo et al. (2005) and Thinesh et al. (2011) reported that *Porites* sp. was the most susceptible host. It is not surprising that the coral disease prevalence for Genting and Sambangan was high as both of these islands are continuously threatened by high-intensity mariculture. Several previous studies have shown that the regions near inhabited islands are more susceptible to coral diseases (Bruno et al., 2007). Similarly, both of these islands are surrounded by a high density of coastal mariculture.

3.3. Nutrient and coral disease correlation

The samples were analyzed after three days of refrigeration. According to the U.S. Environmental Protection Agency (1983), the maximum recommended holding time for N and P samples, to ensure they are properly preserved, is 28 days at 4 °C. The

Table 1
Mean and standard deviation of ecological parameters (n = 9) in Karimunjawa.

Oceanographic parameters	Sampling site location		
	Genting	Sambangan	Seruni
Temperature (°C)	30.0 ± 0.05	30.5 ± 0.05	30 ± 1.0
Salinity ($^0/_{00}$)	30.5 ± 0.05	31.0 ± 1.0	31 ± 1.5
pH	7.2 ± 0.03	7.8 ± 0.10	7.9 ± 0.2
Turbidity (m)	3.5 ± 0.25	4.4 ± 0.25	7.6 ± 0.5
Current (m/s)	0. 22 ± 0.04 (northwest)	0.65 ± 0.02 (west)	0.75 ± 015 (west)
Nitrate (mg/L)	0.059 ± 0.014	0.046 ± 0.004	0.020 ± 0.008
Phosphate (mg/L)	0.032 ± 0.010	0.022 ± 0.001	0.012 ± 0.002

Table 2
Total colonies on each disease types of three sampling locations.

Location	Transect	Coral disease					Diseased corals	Total colonies
		WBD	BBD	WP	PR	UWS		
Genting	GE1	8	27	13	5	14	66	144
	GE2	16	22	10	9	10	65	161
	GE3	31	32			6	69	180
Seruni	SE1	26	10	1	1		38	181
	SE2	5	19			1	25	157
	SE3	12	1				13	115
Sambangan	SA1			4	4	1	9	111
	SA2		3	1	5		8	126
	SA3		1		4		5	80
		98	115	29	28	32	298	1255

Note:
WBD = White Band Disease; BBD = Black Band Disease; WP = White Plague; PR = Pigmented Response; UWS = Ulcerative White Spot.

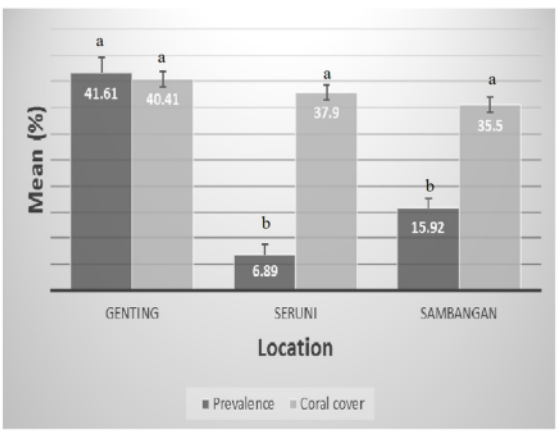

Fig. 4. The mean and standard deviation of prevalence and live coral cover on three islands.

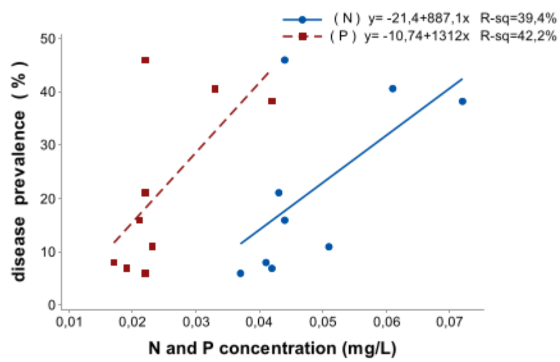

Fig. 5. The relationship between disease prevalence and N–P concentration.

relationship between the nutrient concentrations (N and P) and prevalence of coral diseases is presented in Fig. 5.

Correlation analyses revealed no significant positive relationships between the disease prevalence and concentrations of N ($R^2 = 0.39$, $p = 0.07$) or P ($R^2 = 0.42$, $p = 0.058$) in the water column. In contrast to these findings, Kaczmarsky and Richardson (2011) reported that there was a significant correlation between the elevated total N, P, and C concentrations and prevalence of coral diseases. Some previous studies have also reported that elevated nutrient levels increase the progression of Black Band Disease (Voss and Richardson, 2006). Kuntz et al. (2005) reported that organic carbon and nutrient stressors increase the pathology and mortality rate of Caribbean corals. The results of this rapid assessment show that coral regions closer to inhabited islands with high mariculture activities tend to be more heavily affected by coral diseases. The nutrient levels near an island that is affected by human activity are often high. However, there was no clear relationship between the nutrient concentrations and disease prevalence in this study.

4. Conclusion

In this rapid assessment, the degradation of water qualities due to marine floating cages for fish cultivation was investigated, with consideration for the environmental parameters and coral disease prevalence of three islands. Significant differences regarding the coral disease prevalence were found among the islands in Karimunjawa Park. However, there were no significant differences in the percentage coral cover and total nutrients (N and P) among these islands. It was difficult to estimate the differences among the islands owing to the small sample sizes for the water quality parameters, coral cover, and coral disease prevalence. This suggests that continuation of orderly ecosystem monitoring, with increasing sample sizes, in Karimunjawa is needed.

Acknowledgment

This study was supported by a grant from the Directorate for Research and Community Services, Directorate General for Strengthening Research and Development, Ministry of Research, Technology and Higher Education. DRPM, No.: 344-66/UN7.5.1/PP/2017.

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