INTERNATIONAL JOURNAL
OF
CONSERVATION SCIENCE
ISSN: 2067-533X Volume 14, Issue 4, October-December 2023: 1609-1618 www.ijcs.ro
DOI: 10.36868/IJCS.2023.04.23

BIOLOGICAL IMPACTS OF ANCHORING ON SPECIES DIVERSITY, ABUNDANCE, AND DISEASE PREVALENCE OF CORAL REEFS IN KARIMUNJAWA, INDONESIA

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Abstract

Karimunjawa National Park (KNP) has increasing tourist visits and shipping traffic as its main tourist destination. These conditions have the potential to the degradation of coral reef ecosystems. Hence, the objective of this study was to investigate the biological effects of anchorage on disease prevalence, % coral cover, abundance, and diversity of corals. The six islands with high, medium, and low anchoring intensities were selected. The survey method was carried out by scuba diving on each selected island at depths of 3 and 8m by establishing a 2x25m line and belt transects with three replications. The statistical results indicated that there were significant differences among anchoring levels in disease prevalence. Even the coral abundance and diversity tend to be lower on the island with high anchoring activity. However, there were no significant differences in species richness, diversity index, or relative abundance among anchoring levels. Moreover, the different levels of anchoring also made no difference in the percentage of coral cover (p 0.087 >0.05). This study revealed that anchoring damage might be indirectly responsible for the dispersal and elevated levels of disease. Further study is needed to identify anchoring activity and coral disease in wider areas to conserve the coral reefs of KNP.

Keywords*: Boat anchoring; Coral reefs; Coral disease; Coral cover; Biodiversity*

Introduction

Karimunjawa islands are an archipelago with a nature conservation area that has a distinctive ecosystem. These islands are magical places, unmatched in grandeur due to their highly diverse, beautiful, and unique coral reefs. This reef is important for protecting the seashore and provides a crucial source of income for thousands of Karimunjawa settlements. In recent times, however, the Karimunjawa waters have been continuously threatened by local and global pressures [1]. Within the park, fishermen using rocks, ropes, cables, chains, or crowbars as anchors are damaging coral reefs widely (Fig. 1). Based on Minister of Forestry Decree No. 78/Kpts-II/1999 dated February 22, 1999, this archipelago status changed to Karimunjawa National Park (KNP). This area includes 27 coral islands that are supplied with more than 100 species of corals and is one of seven marine parks in Indonesia [2]. Boat anchoring is an indication of rising tourist visits that might lead to coral destruction. The active promotion of Karimunjawa as the main tourist attraction improved local economic income and job opportunities [3].

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Accordingly, tourism increased dramatically in this park, from about 10,000 visitors in 2008 to tenfold in 2016 [4]. Subsequently, tourism impacts on Karimunjawa's reefs include diving, snorkelling activities, and boat anchoring, which damaged the coral reef and caused declines in water quality [5, 6].

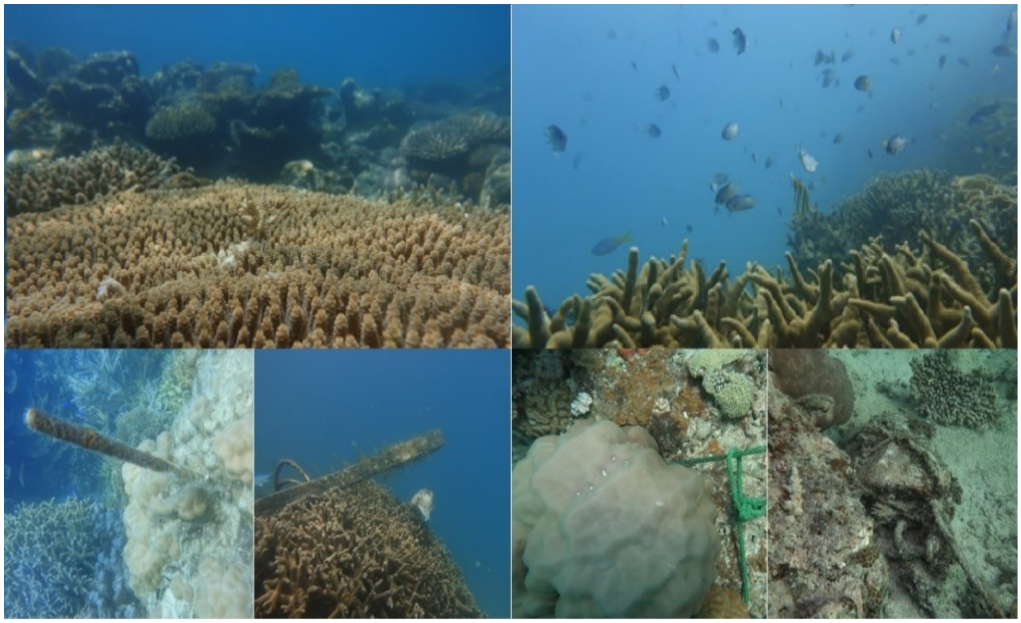

Fig. 1. Karimunjawa coral reef ecosystem (upper), abandoned anchors in coral habitat (lower)

Most of the previous studies on anchors from boats were focused on physical damage such as fragmentation and direct injury to the corals. *J. Maynard et al*. [7] demonstrated that anchoring was more destructive to the coral reef ecosystem than overfishing. While *V.J. Giglio et al.* [8] revealed that anchor cables caused more destruction than anchors. Only a few studies have dealt with the biological impacts of anchoring damage. *E.V. Kennedy et al*. [1] revealed that nearly 10% of the coral cover of Karimunjawa decreased during 2014–2017. While *C. Rogers and V. Garrison* [9] reported that the percentage of coral cover had not increased significantly in the Virgin Islands during the last 10 years due to damage from cruise ship anchors. Hence, the objective of this early assessment was to investigate the richness, evenness, coral cover, and indirect impact, i.e., disease prevalence, among islands with different levels of anchoring intensities.

Experimental part

This study was conducted on six islands of KNP between the 4th and 13th of April 2022, under SIMAKSI Permit numbers 1477/T.34/SIMAKSI/04/2021. In this research, anchor mooring was determined as the factor influencing coral disease prevalence, % coral cover, genus richness, relative abundance, diversity, and evenness. The anchorage factor was grouped into 3 levels: high, medium, and low, according to *R.L. Flynn and G.E. Forrester* [10]. Sites with regular, occasional, and little or no anchorage were classified into high, medium, and low anchorage, respectively.

By using the Sentinel-1 satellite, Google Earth Pro, and data on tourist visits from the Indonesian Guides Association (HPI), the six islands, namely Menjangan Besar and Menjangan Kecil, Sintok and Tengah, and Sambangan and Seruni islands, were categorised as having high, medium, and low anchorage site levels, respectively (Fig. 2). At each island, a Line Intercept Transect (LIT) and 25x2m Belt Transect with six replications were established (Fig. 3).

Fig. 2. Coral disease of Karimunjawa (Note: A-white syndrome, B-white blotch, C-ulcerative white spot, D-black band, E-ulcerative white spot, F-black disease, G-growth anomaly, H-pigmentation response, I-white plaque, J-scheleton erode, K-pigmentation response, L-black band)

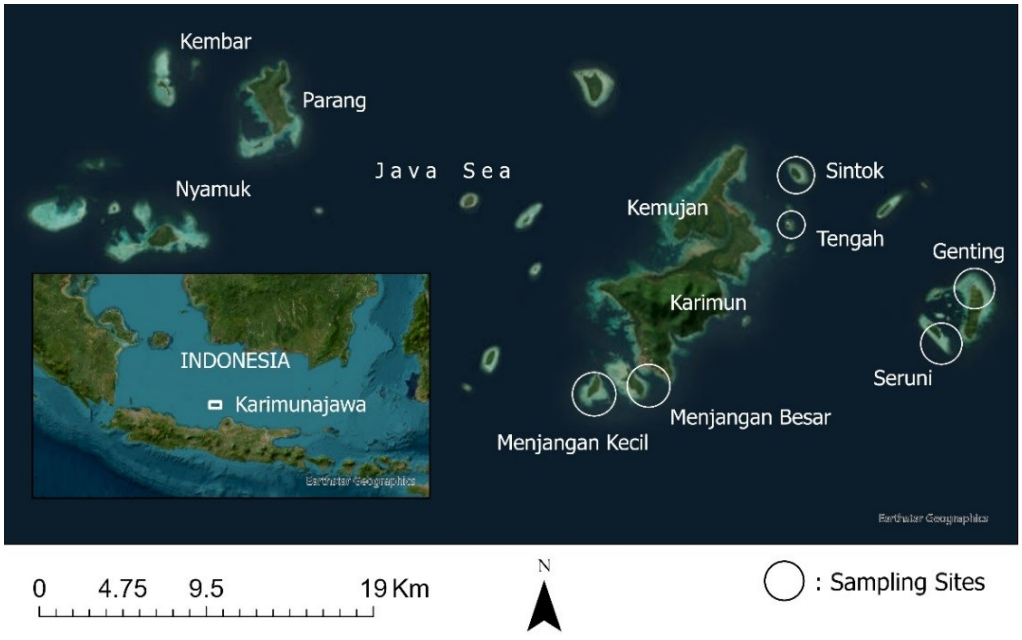

Fig. 3. Sampling site locations of Karimunjawa, Indonesia

The start points of the transect were determined by the presence of symptom-anchored activities such as broken or scarred coral colonies. Observations on each transect were carried out by scuba diving. Parameters observed included coral damage, underwater photography, oceanographic parameters, type and number of corals per transect, number (healthy or sick coral), and percent coral cover.

To determine the prevalence and coral cover on each island, the formula used was adopted from *L. Raymundo et al.* [11]:

$$Percent\ Prevalence = \frac{\sum Diseased\ coral\ colonies}{\sum Total\ colonies} \times 100 \quad (1)$$

$$Percent\ Coverage\ = \frac{Lifeform\ coverage\ length}{Total\ transect\ length} \times 100 \quad (2)$$

While the Shannon-Weaver index was used to measure the Diversity index (H'), genus richness (S), and Evenness (E) of coral reefs [12, 13]:

$$H' = \sum_{i=1}^{s} \mathrm{Pi} ln \mathrm{Pi} \quad (3)$$

$$E = \frac{H\prime}{lnS} \quad (4)$$

One way-ANOVA was used to analyze the impact of anchoring in terms of disease prevalence, coral cover, and biological diversity of corals among islands by using SPSS-22 software.

Results and discussion

Impact of anchoring activity on coral abundance and diversity

Karimunjawa corals are reported to be more diverse than in other parts of Indonesian reefs. In this study, a total of 2741 coral colonies belonging to 36 genera and 15 families were recorded on the six islands of Karimunjawa (Table 1).

Table 1. Genus composition of corals in Karimunjawa National Park

No.	Family	Coral genus	High		Medium		Low	
			Menjangan Besar	Menjangan Kecil	Sintok	Tengah	Seruni	Sambangan
1.	*Acroporidae*	*Acropora*	110	126	143	101	100	122
2.		*Alveopora*	1	1	0	0	2	7
3.		*Anacropora*	1	0	3	3	0	0
4.		*Astreopora*	22	21	30	0	26	11
5.		*Montipora*	50	96	134	36	97	56
6.	*Fungidae*	*Ctenactis*	0	0	0	0	1	7
7.		*Fungia*	30	90	14	2	31	37
8.		*Halomitra*	1	0	0	0	1	0

No.	Family	Coral genus	High		Medium		Low	
			Menjangan Besar	Menjangan Kecil	Sintok	Tengah	Seruni	Sambangan
9.		*Lithophyllon*	1	0	0	1	0	0
10.	*Merulinidae*	*Cyphastrea*	0	0	0	1	0	8
11.		*Echinopora*	2	11	0	0	1	5
12.		*Favites*	13	7	13	4	10	12
13.		*Goniastrea*	15	2	8	4	9	26
14.		*Oulophyllia*	2	0	0	0	0	0
15.		*Pectinia*	0	0	0	0	0	4
16.		*Platygyra*	3	0	0	0	0	8
17.	*Euphylliidae*	*Euphillia*	0	0	1	1	0	0
18.		*Galaxea*	16	6	2	0	4	15
19.		*Plerogyra*	0	1	0	0	2	0
20.	*Agariciidae*	*Gardineroseris*	0	8	0	0	0	1
21.		*Leptoseris*	3	0	18	1	3	0
22.		*Pachyseris*	0	7	5	0	10	24
23.		*Pavona*	0	13	27	48	10	8
24.	*Pocilloporidae*	*Pocillopora*	55	1	11	9	1	16
25.		*Seriatopora*	0	0	52	0	0	10
26.		*Stylloporа*	10	2	1	1	0	5
27.	*Poritidae*	*Porites*	51	40	78	69	108	106
28.		*Goniopora*	0	0	1	0	3	6
31.	*Psammocoridae*	*Psammocora*	0	1	0	0	3	0
29.	*Euphorbiaceae*	*Symphyllia*	2	3	2	1	5	26
30.	*Lobophylliidae*	*Lobophyllia*	0	0	1	0	0	5
32.	*Milleporidaeille*	*Milleopora*	10	0	5	1	8	6
33.	*Montastraeidae*	*Montastrea*	0	0	0	7	0	4
34.	*Plerogyridae*	*Physogyra*	0	0	2	0	0	1
35.	*Diploastraeidae*	*Diploastrea*	3	0	3	0	3	15
36.	*Mussidae*	*Favia*	25	5	11	4	6	19
	Relative Abundance (RA)		868		859		1014	
	Genus Richness (G)		28		29		30	
	H-indexes(H ')		1.99 ± 0.35 [a]		2.08 ± 0.33 [a]		2.13 ± 0.48 [a]	
	Evenness (E)		0.76 ± 0.08 [a]		0.79 ± 0.05 [a]		0.80 ± 0.04 [a]	

Note: the same characters show no significant differences among anchoring levels on H', GR. and E

Among them, the family *Acroporidae* is dominant, as it is represented by 692 coral colonies of five genera, including the genera Acropora, Alveopora, Anacropora, Astreopora, and Montipora. The highest coral abundance (RA) and genus richness (G) were recorded in the low-site anchoring activity, followed by medium- and high-site anchoring activities. Biodiversity refers to the variety of living species that can be found in a particular place. The loss of benthic organisms due to mechanical damage by anchors has an indirect impact on the associated faunal community. In Karimunjawa, some previous studies related to the change in species diversity were reported. *E.V. Kennedy et al.* [1] revealed that the massive reduction in coral diversity was due to declining water quality associated with tourism and mariculture. While *R. Januardi et al.* [14] demonstrated that the coral condition of Menjangan Besar Island decreased by nearly 8ha

within 2 years (2013–2015), with a coral cover and diversity index classified as moderate and a dominance of about 0.6. Moreover, *A.B. Kusuma et al*. [15] showed that coral diversity at 3m in depth was higher than that at 10m on Tengah Island. *M. Munasik et al*. [16] reported that the coral reef condition in the protected area (PA) had the highest diversity among the three zones (MPA, utilise, and Non-MPA) of Karimunjawa National Park. *M.S. Pratchett et al.* [17] stated that declines in the abundance and diversity of coral reefs led to declines in fish diversity. In contrast, *A. Wijayanto et al.* [6] reported that the abundance of reef fish was higher in poor reef conditions. The results outlined above showed how species have responded and will respond to environmental change across time and space. Unfortunately, a comprehensive understanding of how and why coral diversity changes was lacking. *M.A. Timmers et al.* [18] stated that to predict responses to the change in the coral reef community, information on ecological functions, life histories, and coral distributions is important.

Impact of anchoring activity on disease prevalence

Boat anchoring is an indication of rising tourist visits that might lead to coral destruction [19]. Sadly, only a few previous studies regarding anchoring impacts on corals have been reported. In this assessment, the indirect impacts of boat anchoring, such as disease prevalence, were assessed. No previous studies have addressed the impacts of chronic anchor damage on coral disease prevalence. A similar study was carried out by using coral disease prevalence to assess the effects of concentrating tourism activities on offshore reefs [20].

Approximately 7.9% of the coral (216 of 2741 colonies) was affected by diseases in all areas of the 36 belt transects. The eight disease states detected within the transects were as follows: white syndrome, white blotch, black band disease, pigmentation response, white plague, ulcerative white spot, black disease, growth anomaly, and skeleton erosion (Fig. 2).

The statistical analyses showed a significant difference in disease prevalence among levels of anchoring activities. The Post-hoc Tukey LSD α (0.05) statistical analysis resulted in a significant difference between site-high vs. medium and low anchoring. However, there were no significant differences between medium and low anchoring activity in disease prevalence (Fig. 4).

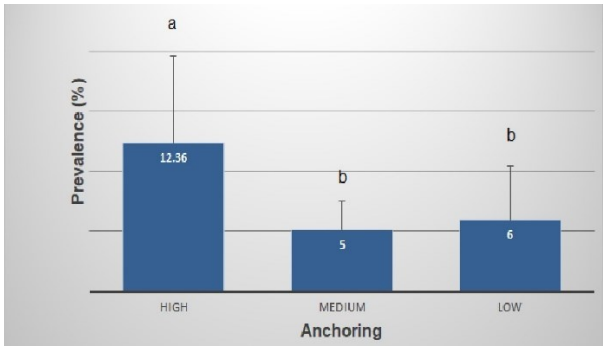

Fig. 4. Disease prevalence of coral on the different levels of anchoring activity (Note: the different characters show significant differences among anchoring levels on disease prevalence)

Some previous studies on the impact of anchoring activity in relation to coral damage and coral loss have been widely reported [8, 10, 21]. Coral breakage, fragmentation, scratching, and injury are symptoms of anchor damage. Coral susceptibility to several diseases can be initiated

by the presence of injury to coral tissue. *M. Contardi et al.* [22] stated that the sloughing off of coral tissue causes the skeleton to open and is a gateway for pathogens to enter, which in turn allows infection. High anchoring activity on coral reefs may increase coral injuries, resulting in coral susceptibility. *B. Guzner et al.* [23] stated that coral colonies with frequent mechanical injury led to enhanced susceptibility to predation and possibly to coral disease. In this study, even though there was a significant difference among levels of anchoring activity, it is difficult to reliably separate the effects of anchoring from other factors that might impact coral diseases, such as pathogen identity, virulence, and transmission. Hence, further study is urgently needed to address these factors.

Impact of anchoring activity on coral cover

The coral cover represents the proportion of an area occupied by corals. It means that reduced coral cover will reduce biological diversity and reef structure and increase the spatial and temporal extent of algae. Some previous studies on the anchoring impacts on corals demonstrated that the higher the anchoring activities, the more the coral cover percentage decreased [7, 10]. Differently, this study revealed no significant impact of anchoring on the decline of percentage coral cover. Statistical analyses showed that the % coral cover of sites with high, medium, and low anchoring activities was no significant difference, even though the % coral cover in the islands with high anchoring activity tends to increase (Fig. 5). It might be due to the anchoring impacts occurring only inside the area affected or at the anchored sites. Moreover, the installation of the "Mooring Buoy" mooring facility by the Transportation Service of Central Java Province on KNP since 2017 has significantly reduced the anchoring impacts on corals.

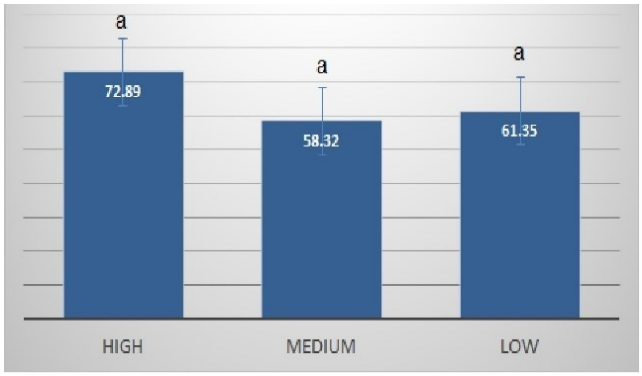

Fig. 5. The effect of anchoring on coral cover conditions (Note: the same characters show no significant differences among anchoring levels on each parameter)

However, *J. Maynard et al*. [7] showed that anchoring impacts could be extensive. The large rock anchoring could destroy the reef totally. Contrarily, *R.L. Flynn and G.E. Forrester* [10] reported that the percentage of coral cover, the coral colony's size, and coral colony density at highly anchored sites were reduced relative to sites experiencing medium or little anchoring. *While E.A. Dinsdale and V.J. Harriot* [24] revealed that in describing the effect of anchoring, the measurement of the wound on coral colonies was better than coral cover.

Conclusions

Karimunjawa's coral reefs are essential for about 10.000 settlements, providing jobs, a source of food, new medicines, and recreation. However, they are threatened by a range of pressures, including overfishing, pollution, ocean acidification, tourism, and boat anchoring. In this study, the anchoring impacts on coral reefs were investigated. The results revealed that the increase in the disease prevalence of corals was mostly conducted at a site with high anchoring activity. The percentage of coral cover, abundance, and diversity were not significantly affected. It means that the coral reefs of Karimunjawa still tolerate any disturbances, including the impact of anchoring activities. However, as anchoring activity becomes an ever more serious threat to the reef, regular monitoring is important for tracking the impacts of anchoring and tourism activities that seem to already be influencing the KNP coral ecosystem.

Acknowledgement

We thank the staff of the Indonesian Guides Association (HPI) on the KNP for supporting tourist visit data. This work was funded by the Institute for Research and Community Service, Diponegoro University, under RPI scheme No. 569-70/UN7.D2/PP/VII/2022.

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Received: December 05, 2022
Accepted: September 18, 2023