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Changes in reef benthic communities in Sumba Timur, East Nusa Tenggara, Indonesia

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Abstract. *Utama RS, Hadi TA, Hermanto B, Giyanto, Budiyanto A. 2022. Changes in reef benthic communities in Sumba Timur, East Nusa Tenggara, Indonesia. Biodiversitas 23: 697-707.* Anthropogenic impacts and coral bleaching due to rising sea surface temperature have been severe and often, as of late on the worldwide scale, influencing the composition of coral reef benthic communities from coral to algal-ruled reefs (phase shift). In any case, coral reef phase shift does not continuously happen, considering corals can recoup when stressors occur. This considers points to examine the alteration in coral reef benthic communities and the relationship among benthic categories. The study was carried out in 2018 and 2021 at 10 stations within East Sumba, and East Nusa Tenggara. Underwater photo transect (UPT) was used to examine benthic cover at a depth of 6 to 9 m in reef slope. The result demonstrated that the benthic communities were slightly altered, especially hard coral, sponge, and other biotas. A slight recovery of hard coral cover is shown in 2021, followed by the decline of sponge and fleshy seaweed cover, which is shown in most observation sites. *Acropora* spp., *Seriatopora* spp., and *Stylophora* spp. were the three genera that increased in cover. The study also found the relationship between the benthic gradient and species richness and the number of colonies, which is gradient changes in benthic composition were in line with the change in hard coral species richness and colony numbers. Although hard coral increase significantly changes over time, it's not altered the coral communities.

Keywords: Benthic gradient, coral communities, percent cover, species richness

INTRODUCTION

The coral reef is a coastal ecosystem with high productivity and biodiversity, which has various ecological functions for coastal communities and reef-dwelling organisms (Harvey et al. 2018; Williams et al. 2019). Globally, marine services and products derived from coral reefs generate 375 million dollars worldwide through tourist markets, coastal protection, and fisheries (Costanza et al. 2014; Woodhead et al. 2019). In developing countries, 25% of total captured fisheries were from the coral reef fisheries sector, while in Indonesia itself, the estimated annual economic value of coral fisheries was 1.5 million (Burke et al. 2012; Teh et al. 2013). These advantages are dynamic in response to coral reef health, necessitating competent management of the reefs and awareness of the reefs' trajectory on the part of the stakeholders.

Coral reef declines have been inevitable recently due to intense and continuous anthropogenic factors (De'Ath et al. 2012; Browne et al. 2015; Richmond et al. 2018). Moreover, instant changes in coral cover and habitat complexity have been affected by natural catastrophes such as cyclones (Ceccarelli et al. 2019). Declines in coral cover were followed by a phase shift to algae-dominated communities commonly occurring, especially resulting from poor water quality and low density of herbivore fish due to overfishing (Browne et al. 2015; Polonia et al. 2015). Changes in coral complexity and rugosity decreased 40% of coral reef function as coastline protection from high waves (Ferrario et al. 2014; Reguero et al. 2019). Reduction due to damage to coral reefs will have an impact on decreasing fishery productivity by up to 35% compared to healthy coral reefs (Rogers et al. 2018). Despite declines in coral cover globally, coral reef shows the ability to recover and result in different coral community structure (Gilmour et al. 2013; Adjeroud et al. 2018). Therefore, it shows that coral reefs were dynamic ecosystems and have to have a thorough awareness of the current situation of coral reefs.

In Southeast Asia, most of the coral reefs were at risk due to massive coastal development, sedimentation, pollution, overfishing, and destructive fishing (Burke et al. 2012), including the risk from El Nino that has occurred periodically since 1998. Coral reef degradation has been reportedly in Indonesia as the result of environmental degradation due to pollution and land-based activities (Farhan and Lim 2012; Heery et al. 2018). The ecosystem in small islands has been damaged by the focus on economically oriented activities as a result of the transfer of control from the central government to the local governments (Farhan and Lim 2010). Moreover, there have been reports of coral bleaching in Indonesian waters in 1988 and 2010, which resulted in the widespread loss of corals in this area (Wouthuyzen et al. 2018; Chaijaroen 2019). Recent coral bleaching in this region occurred in

2016, which caused a dramatic decline in coral cover (Ampou et al. 2017).

East Nusa Tenggara, located in the southern part of the Coral Triangle, have been studied from various point of view (Abrar et al. 2012; Putra et al. 2015; Asaad et al. 2018; Johan and Sianipar 2022). However, the studies do not account for the changes in coral reef conditions, which is essential knowledge for decision-makers. East Sumba has a high potential for natural resources, including coral reefs, pelagic mangrove fisheries, and megafauna, with potential fisheries of around 66 tonnes/year (DKP Sumba Timur 2019). East Sumba is bordered by open waters (Savu sea), which affects the dynamic of the coral reef due to high waves and good water motion past the reefs. Moreover, the southern part of Indonesia, particularly East Sumba, was vulnerable to natural disturbances and climate changes, such as cyclones and the increase of sea surface temperature, which regularly occurred recently. Monitoring is essential to understand the change in coral reef conditions before feasible solutions are developed since these complex conditions may have an impact on the conditions of the coral reef, especially the benthic communities. This study aims to investigate the change in coral reef benthic communities.

MATERIALS AND METHODS

Study area

The study was carried out on the east coast of Sumba Island (East Sumba Regency) in October 2018 and October 2021, ten sites were deployed along sides the shorelines with mostly residences by local fishermen (Figure 1). The observation stations were purposely selected in the fringing reef with the occurrence of coral reef and located within the marine protected areas of the Savu Seas in East Sumba. At the time of observation, the water condition at East Sumba had current visibility of around 10 meters, and the waves and current were quite high due to the location that bordered the Savu Sea. All of the sites were deployed on the fringing reef and not close to the populated residence area, except for the two sites (W09 and W10) that are near residential areas, the seaweed farm, and the river mouth, which occasionally brings sediment and nutrient from the land.

Protocol

The benthic reef community condition was quantified based on the percent covers using Underwater Photo Transect (UPT) with an iron frame size of 44x58 cm (Giyanto et al. 2010). The frame was put on the 50 m transect line, which was installed parallel to the coastline at around 6-8 m in depth, starting from 1x5 m with an interval of 1 m and set up and down of transect line for odd and even numbers, respectively.

Data analyses

The frame photos were then examined with Coral Point Count with Excel extensions (CPCe) software to calculate the percentage of benthic components (±SE) and substrates (Kohler and Gill 2006). Thirty random points were spread on each frame (1500 points per transect), and which substrate and benthic categories picked were identified following the given categories (Table 1).

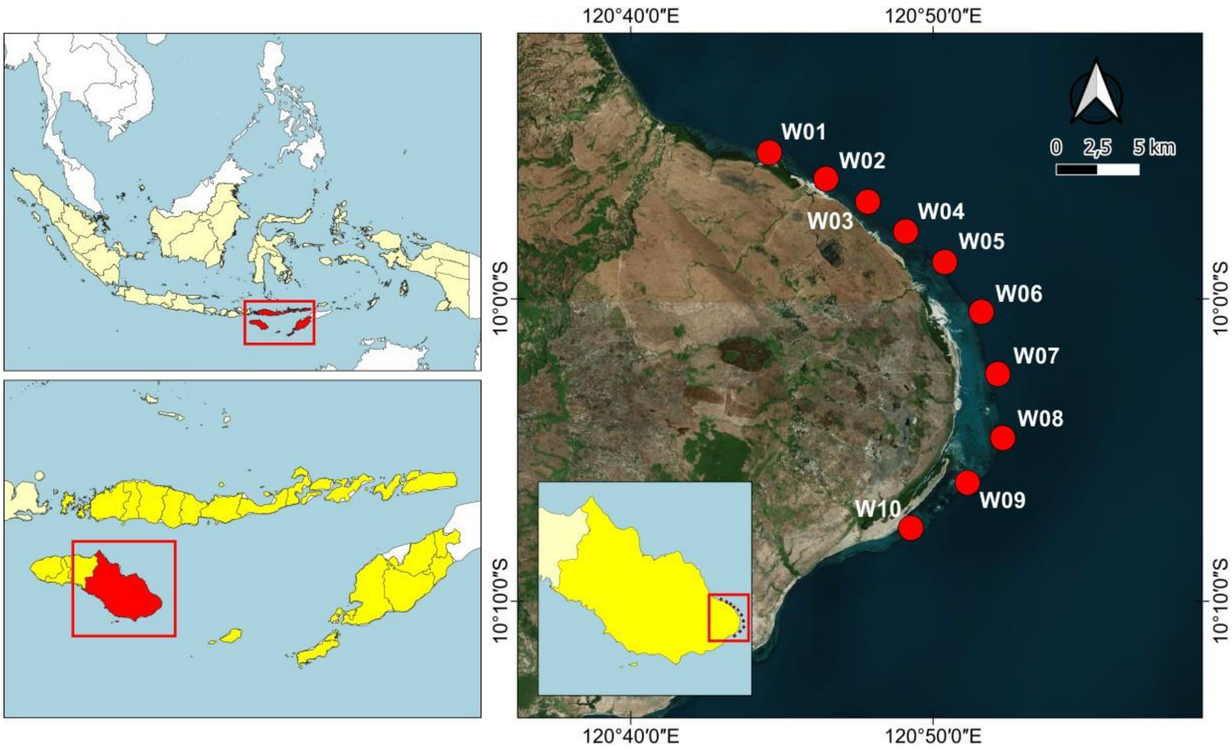


Figure 1. Study sites in East Sumba, East Nusa Tenggara, Indonesia

Table 1. codes of benthic and substrate categories

Benthic and substrate categories	Code	Descriptions
Live coral	LC	All live hard coral
Acropora	AC	*Acropora* spp. coral
Non-*Acropora*	NA	All non-*Acropora* spp coral.
Dead coral	DC	Recently dead coral (pale appearance)
Dead coral with algae	DCA	Dead coral colonies that overgrown by the turf algae
Turf algae	TA	Turf algae
Soft coral	SC	Soft coral (Octocorallia)
Sponge	SP	Sponges
Fleshy seaweed	FS	Macroalgae
Others	OT	Other benthic biotas
Rubble	R	Fractions of dead coral
Sand	S	Sand
Silt	Si	Silt
Rock	RK	Natural rocks

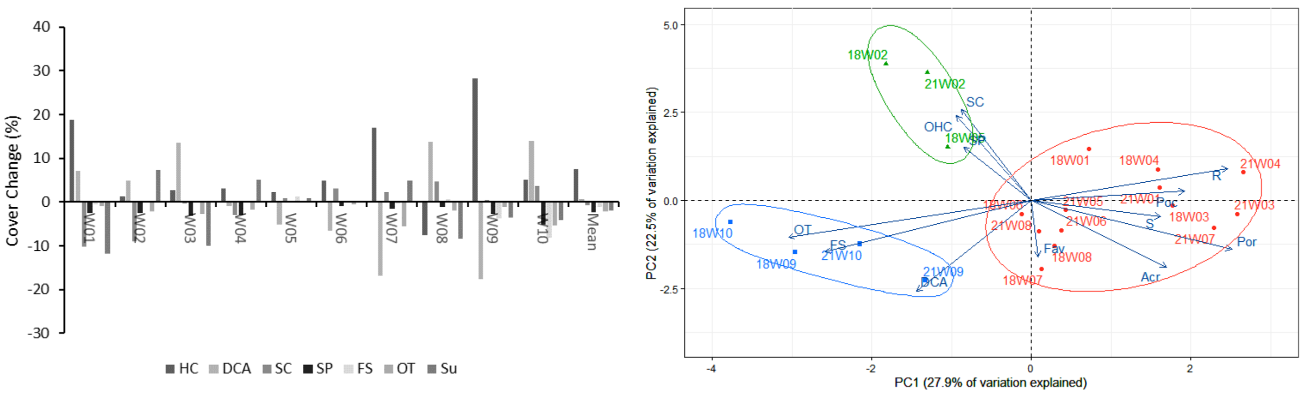
Live corals were identified into species or genus levels following Veron and Stafford-Smith (2000). The application automatically counts the percentage of benthos and substrate classifications in the Excel extension. The number of coral colonies was also counted by counting the total number of occurrences from the 50 photos, with rule one colony only counted once in each photo.

To examine the difference in coral reefs across time Kruskal Wallis test was applied, and the variable was the percent cover. Then, Principal Component Analysis (PCA) on Euclidean distance and grouped by overlapping slices generated from hierarchical cluster analysis were used to assess the change in benthic populations and substrates between the locations over time. Previously, the percent cover data were transformed log(x+1) to minimize the deviation from normality. The relationship between the changes in coral species richness and colony number (N) and changes in reef communities was viewed from the change in gradient composition of the PCA axis (PC1). Moreover, the further relationship among the categories was also examined. All the statistical analyses were performed in R with vegan packages (Oksanen et al. 2016).

RESULTS AND DISCUSSION

Change of benthic covers and substrates

Based on the Kruskal Wallis result, benthic and substrate covers were not changed essentially between 2018 and 202, especially dead coral with algae (*p*:1), a soft coral (*p*:0.85), fleshy seaweed (*p*:0.61), and substrate (*p*:0.56). On the other hand, hard coral, sponges, and other biota contrasted altogether over the observing period, with p values 0.037, 0.0019, and 0.0039, respectively. The overall hard coral cover over observation stations increased with the overall rise cover by 7.6% (Figure 1A). The slight increase also showed by the dead coral with algae cover by 0.59%. In contrast, the declines occurred in other categories, including soft coral, sponge, fleshy seaweed, and other biotas, with a decline of 0.73%, 2.27%, 1.06%, and 2.17%, respectively.



A B

Figure 2. A. Cover change of benthic and substrates categories between 2018 and 2021; B. Principal component analysis (PCA) for benthic and substrate categories from ten different sites in 2018 and 2021. HC represents hard coral, Acr: Acroporidae; Poc: Pocilloporidae; Fav: Faviidae; Por: Poritiidae; OHC: other hard corals; DCA: dead corals with algae; SC: soft coral; SP: sponge; FS: fleshy seaweed; OT: others; Su: substrates (rubble and sand); S sand; R: rubble

Change in benthic and substrate composition

The composition of benthic and substrates was variable from rubble domination in positive and negative scores, respectively (Figure 2B). The principal component 1 (PC1), accounting for 27.9% of the variation, with the most contributing categories were other biotas, fleshy seaweed, Poritidae, and rubble, with scores from negative to positive. The second principal component (PC2) separates soft coral with positive scores from dead coral with algae with negative scores, having around 22.5% of the variation and other hard coral and Acroporidae were other contributing categories.

Overall, the benthic categories were not shown changes over the period (Figure 2B), which shows the benthic and substate composition in nine sites were not different between the years (indicated by the close distance). However, the benthic composition between sites was grouped into three different clusters. Soft coral and other biota were two categories that contributed to distinguishing group1 (W02) and group2 (W09 and W10) from group3 (other sites). In contrast, changes in benthic composition were marked in W05, described mainly by the change of coral communities, particularly increases in Acroporidae cover and declines of other corals' cover.

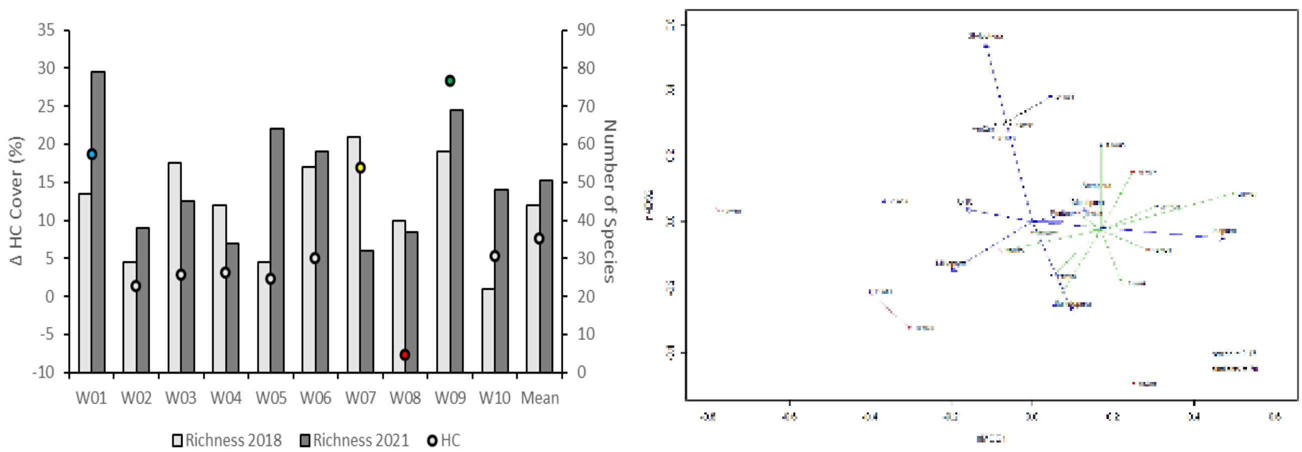
Change in coral community structure

A total of 282 species from genera were identified at ten sites between 2018 and 2021 (Table 2). Three genera had the most species, 62 species belonged to *Acropora* spp., 29 *Montipora* spp., and 21 *Porites* spp. Most of the species show an increase in hard coral cover, except station W09, which might be a result of the increased number of species (Figure 3A). East Sumba species richness averaged 47 overall sites and year. The lowest species richness was shown on W02, whilst W01 had the highest richness among all sites and years (Figure 3A). In 2018, 70% of sites had a species richness >40 species per site, and it decreased by 10% of sites that had a species richness >40 on average in 2021.

In general, the percentage of coral cover was slightly improved by 7.6% and significantly different than in 2015 (*p*: 0.037). The highest increases in coral cover were showed in station W09 by 28.33%, while station W08 was the only station that suffered a coral decline by 7.97%. The most of rising coral cover might result from the increases in species richness, which is marked in six stations (Figure 3A), while two sites (W03 and W04) had a slight decrease in species richness, and W07 was the most declined site. In term of coral composition, particularly the genera level, the hard coral cover in East Sumba were differentiated into six clusters with only 30% of similarity (Figure 3B). The largest cluster contained half of the sites in East Sumba, the second group consisted of sites W01 and W06, and the last three only consisted of one site (W05 and W10). Moreover, it shows that the coral community structure did not vary over time, which shows that in the different time frames, the sites were still relatively close together and assembled in one group, except for station W05 where there is a change from *Porites* spp. and *Seriatopora* spp. into *Acropora* spp. Consequently, it can be assumed that composition does not change during the monitoring period but varies over sites.

Relationship between the gradient composition (PC1) and species richness and the number of the coral colony (N) and among the benthic categories and substrate

The number of coral species discovered in 2018 and 2021 was slightly different, counting 197 and 220 species, respectively. The average colony number was 96 and 126 in 2018 and 2021, which is linked to the change in gradient composition of benthic and substrates, starting from high complexity structure dominated by Poritids, Acroporidae, and Pocilloporidae in the positive scores to the reef that dominated with the other biota and fleshy seaweed to low structure that dominated mainly by fleshy seaweed and other biotas, apparently the change of benthic gradient led to similar patterns to species richness and colony number. In this case, slight upward trends occurred in colony number and species richness, indicating that the lower structure of complexity has lower colony number and species richness.



A B

Figure 3. Percentage changes of hard coral cover (A) and nMDS (B) of coral community structure at ten sites from 2018 and 2021

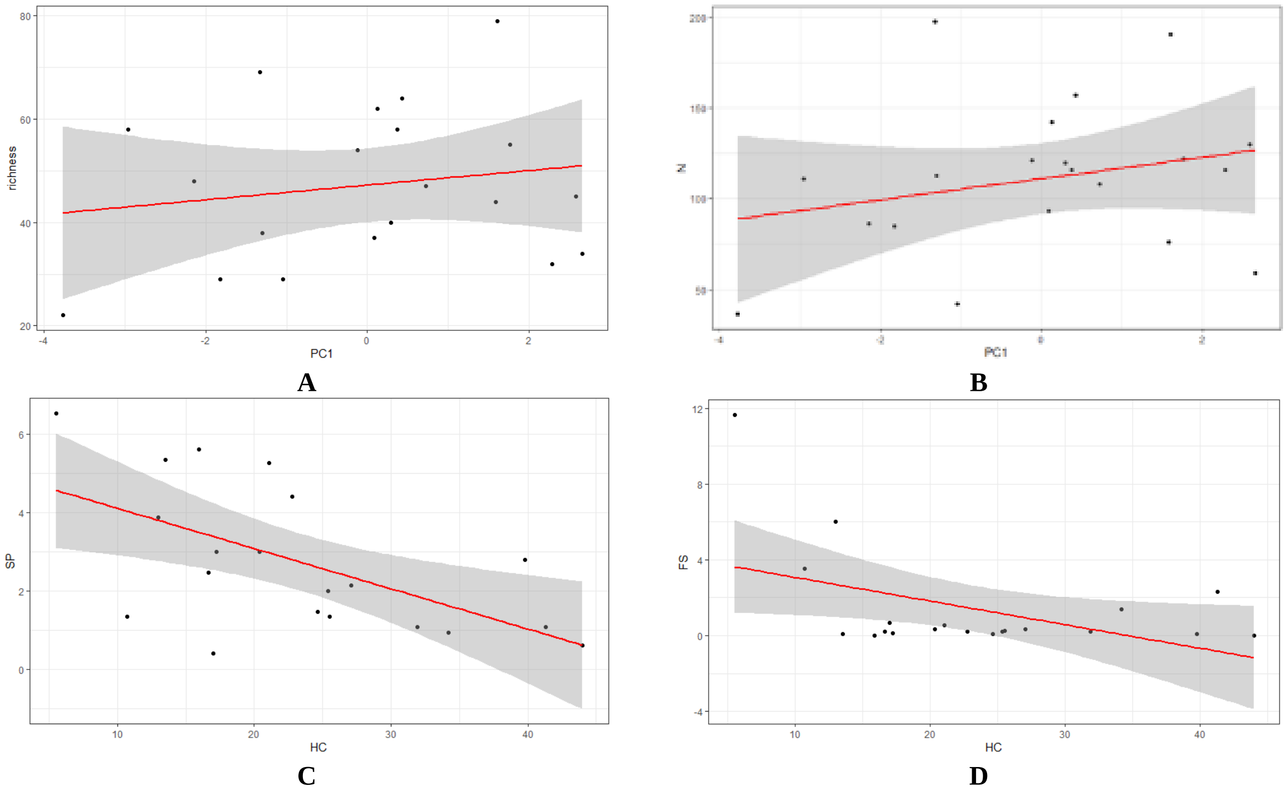


Figure 4. Relationship between gradient change and substrate composition with hard coral species richness (A) and the number of the colony (N) (B); the relationship between hard coral cover (HC) and sponge (SP) (C); and fleshy seaweed (FS) (D)

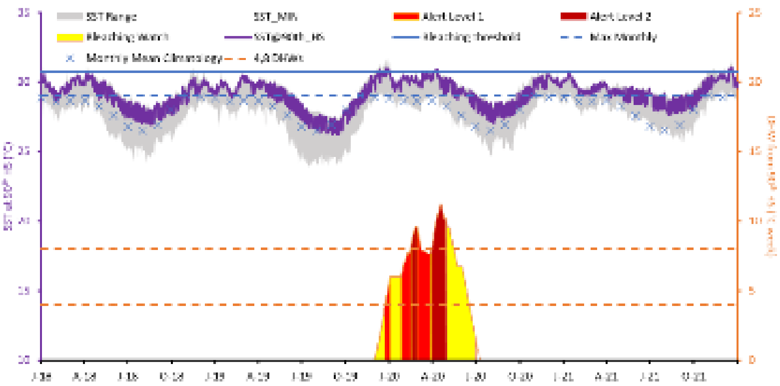


Figure 5. Sea surface temperature patterns and degree heating weeks (DHW) in Belitung waters between 2015-2018 (NOAA Reef Watch 2022)

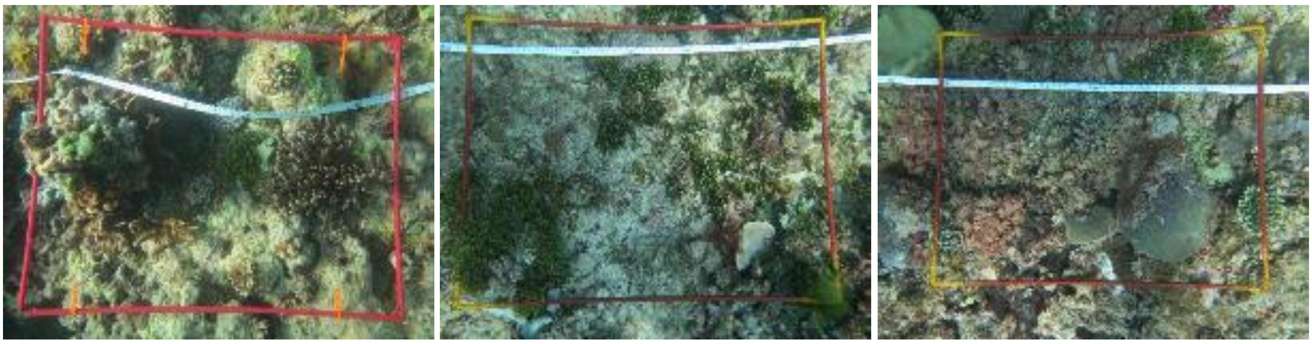


Figure 6. *Halimeda*, fleshy and sponge occupying the spaces and overtopping the surrounding benthos

Among the benthic and substrate categories, a significant negative relationship occurred between hard coral cover and sponge (*p*: 0.007) and fleshy seaweed (*p*: 0.04), where an increase in the coral cover was associated with the decline of sponges and fleshy seaweed cover. It shows the competition of spaces over benthic organisms. In contrast, the relation between hard coral cover with other categories, such as dead coral with algae (*p*: 0.817), soft coral (*p*: 0.351), other biotas (*p*: 0.09), sand (*p*: 0.205) and rubble (*p*: 0.55). This suggested that the increase in hard coral cover was associated with the decline of the sponge and fleshy seaweed cover (Figure 4).

Discussion

As dynamic ecosystems, coral reefs respond differently to changes in environmental conditions (Perry and Alvarez-Filip 2019). In this study, the benthic communities were changing differently, given that hard coral and DCA were increasing while the rest of the benthic communities seemed to decline. The increment of hard corals cover was also reported on the east coast of Sumatera Island and most areas in Indonesia (Souter et al. 2020; Siringoringo et al. 2022). The increase in coral cover was dominantly shown by Acroporidae and Pocilloporidae, which is known as coral that has fast-growing rates with average growth rates of 100-150 mm/year and 50 mm/year, respectively (Siqueira et al. 2022). The natural disturbances were recorded in East Sumba before the survey in 2021, such as rising sea surface temperature (alert level 2 bleaching) at the end of 2020 and the Seroja cyclone in early 2021 (Kurniawan et al. 2021). As the study was not conducted in 2020, the increase in coral cover in 2021 cannot be categorized as recovery from the disturbances. Although we cannot presume that the reef recovery, East Sumba reef condition that is close to the open water (Savu sea), brings continuous flow that allows oxygen radicals and their derivate to move from the cell through a diffusion process which is important to the coral recovery after disturbances (Rodgers et al. 2017).

The incline of coral cover was also related to the decrease of other benthic categories, particularly sponge (*p*: 0.002) and other biotas (*p*: 0.004) (*Halimeda*), which significantly declined between 2018 and 2021 (Figure 3C and D; Figure 5). The availability of stable substrates induced competition between coral and other benthic categories. The strong relationship between coral and sponge cover on competition was shown in this study (Figure 3C). The condition of the coral affected the competition of spaces between coral and sponge. In prime condition coral, coral can overgrow nearby sponges, on the contrary, a sponge can overgrow coral under stress conditions (Marulanda-Gómez et al. 2017; Chaves-Fonnegra et al. 2018). Reef conditions in East Sumba receive high flushing with clear water offshore, carrying away sediments and nutrients onto coral (Ceccarelli et al. 2019), which affects the fleshy seaweed, sponge, and other biota growth that need nutrients and sediment to grow, except on the sites W09 and W10 were near to river output, fleshy seaweed and *Halimeda* spp. cover in this location was high.

In general, the benthic and substrate composition did not change over time. However, station W05 was shown to change decisively from other hard coral to Acroporidae-dominated reefs. It was likely due to the increased cover of Acroporidae, which is influenced by the good movement of water mas that enhances the Acropora growth. Spatial changes in reef benthic communities among the study sites have occurred. Gradient environment conditions between sites were the main influences on the clustering (Figure 1B). Interaction among biotas, environmental conditions, and microhabitats might configure the benthic composition (Barott and Rohwer 2012; Brodie et al. 2017). The presence of a river mouth near sites W09 and W10 brings the organic material that reshapes the community in those locations. Excess of the nutrient might enhance the growth of macroalgae and might dominate the reefs, which is shown by the macroalgae cover that >3% indicated low resilience (Neves et al. 2016; Giyanto et al. 2017; Teichberg et al. 2018). Yet, offshore water that comes to the reef areas help flush the excessive nutrient and sediment from the river and allows coral to grow, which is shown by the drastic increase of coral cover in sites W09.

The change of benthic and substrates communities responded similarly to the coral community structure, particularly the patterns over monitoring time, where changes were not spotted. Most of the sites were close to each other in terms of the period, except stations W10 and W05, which were different between years (Figure 2B). The shift in the coral community was mainly influenced by the increase in species richness and coral cover, particularly coral from Acroporidae. Coral juveniles might also influence the increased cover and species richness (Figure 6), which is almost abundant in most of the sites. Similarly, coral juvenile and imported larvae were key processes for replenishing Acropora in Palau (Gouezo et al. 2019). Unfortunately, the density of coral juveniles was not counted in this study. However, the number of coral colonies increased by 30% compared to 2018, which might come from imported larvae.

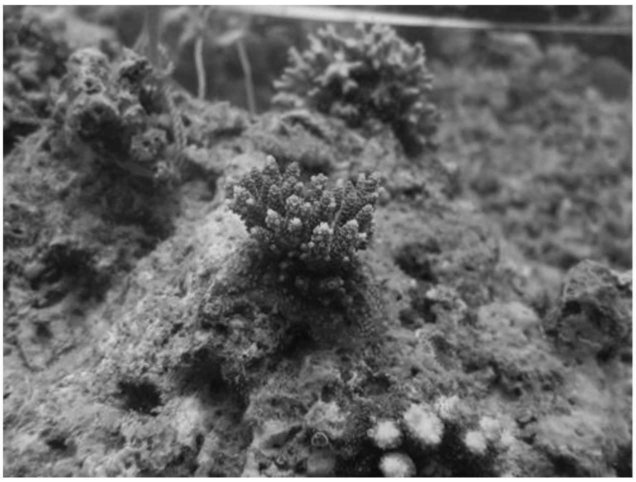
The increase in the coral colonies number (*p*: 0.27) and the species richness (*p*: 0.47) were not affected the benthic and substrate composition. Although, the number of coral colonies and species richness increased as the composition became more complex. Furthermore, the changes of other categories (other than coral) were most influenced that altered the reef composition transformation, particularly DCA (*p*: 0.36) and fleshy seaweed (*p*: 0.0004). Macroalgae and turf algae are well known negatively impact the reef, especially settlement, recruitment, and coral growth rates (Speare et al. 2019). Macroalgae and turf algae had been reportedly interfered with the coral recovery and community shift (algae-dominated state) in many reefs worldwide when the ecological process is disrupted, or the environmental driver is degraded (e.g., water quality) (Schmitt et al. 2022; Teichberg et al. 2018). The importance of space availability solidified the competition among benthic categories, which affected the success of coral recruitment.

Table 2. Occurances of hard coral species in each station between 2018 and 2021

No.	Species	2018	2021
I	Acroporidae		
i	*Acropora*		
1	*Acropora minuta*	23	42
2	*Acropora subglabra*	19	34
3	*Acropora gemmifera*	5	25
4	*Acropora danai*	6	20
5	*Acropora indonesia*	13	7
6	*Acropora teres*	5	14
7	*Acropora divaricata*	4	14
8	*Acropora rambleri*	3	13
9	*Acropora stoddarti*	1	13
10	*Acropora donei*	8	5
11	*Acropora glauca*	4	9
12	*Acropora speciosa*	8	4
13	*Acropora pectinatus*	4	7
14	*Acropora sekiseiensis*	5	6
15	*Acropora intermedia*	3	7
16	*Acropora austera*	1	7
17	*Acropora rosaria*	4	4
18	*Acropora ocellata*	0	7
19	*Acropora subulata*	0	7
20	*Acropora aculeus*	1	5
21	*Acropora chesterfieldensis*	3	3
22	*Acropora lovelli*	5	1
23	*Acropora proximalis*	3	3
24	*Acropora kirstyae*	1	4
25	*Acropora carduus*	0	4
26	*Acropora copiosa*	0	4
27	*Acropora granulosa*	1	3
28	*Acropora yongei*	1	3
29	*Acropora abrotanoides*	3	0
30	*Acropora awi*	2	1
31	*Acropora convexa*	0	3
32	*Acropora formosa*	1	2
33	*Acropora grandis*	0	3
34	*Acropora lianae*	1	2
35	*Acropora navini*	1	2
36	*Acropora scherzerina*	2	1
37	*Acropora walindii*	1	2
38	*Acropora acuminata*	0	2
39	*Acropora echinata*	0	2
40	*Acropora hyacinthus*	2	0
41	*Acropora insignis*	0	2
42	*Acropora millepora*	1	1
43	*Acropora multiacuta*	0	2
44	*Acropora papillare*	2	0
45	*Acropora rudis*	0	2
46	*Acropora sarmentosa*	0	2
47	*Acropora striata*	1	1
48	*Acropora tortuosa*	0	2
49	*Acropora variabilis*	0	2
50	*Acropora akajimensis*	1	0
51	*Acropora aspera*	0	1
52	*Acropora cylindrica*	0	1
53	*Acropora derawanensis*	1	0
54	*Acropora horrida*	0	1
55	*Acropora loisetteae*	1	0
56	*Acropora microphthalma*	0	1
57	*Acropora paniculata*	0	1
58	*Acropora seriata*	0	1
59	*Acropora solitaryensis*	1	0
60	*Acropora sp.*	1	0
61	*Acropora tizardi*	1	0
62	*Acropora valencinennesi*	1	0
ii	*Anacropora*		
63	*Anacropora puertogelerae*	0	2
64	*Anacropora reticulata*	1	0
iii	*Astreopora*		
65	*Astreopora randalli*	1	1
iv	*Isopora*		
66	*Isopora palifera*	65	43
67	*Isopora brueggemanni*	8	9
68	*Isopora cuneata*	1	1
v	*Montipora*		
69	*Montipora turgescens*	24	9
70	*Montipora caliculata*	9	13
71	*Montipora tuberculosa*	17	1
72	*Montipora hodgsoni*	1	10
73	*Montipora monasteriata*	2	5
74	*Montipora calcarea*	6	0
75	*Montipora foliosa*	1	5
76	*Montipora informis*	3	2
77	*Montipora sp.*	4	1
78	*Montipora cocosensis*	4	0
79	*Montipora efflorescens*	4	0
80	*Montipora orientalis*	0	4
81	*Montipora crassituberculata*	1	2
82	*Montipora millepora*	3	0
83	*Montipora stellata*	1	2
84	*Montipora undata*	2	1
85	*Montipora venosa*	2	1
86	*Montipora confusa*	2	0
87	*Montipora grisea*	2	0
88	*Montipora spumosa*	0	2
89	*Montipora corbettensis*	0	1
90	*Montipora effusa*	0	1
91	*Montipora floweri*	1	0
92	*Montipora foveolata*	1	0
93	*Montipora friabilis*	0	1
94	*Montipora hirsuta*	0	1
95	*Montipora hoffmeisteri*	1	0
96	*Montipora nodosa*	0	1
97	*Montipora peltiformis*	1	0
II	Agariciidae		
vi	*Coeloseris*		
98	*Coeloseris mayeri*	3	4
vii	*Gardineroseris*		
99	*Gardineroseris planulata*	1	0
viii	*Pachyseris*		
100	*Pachyseris speciosa*	1	6
ix	*Pavona*		
101	*Pavona venosa*	9	7
102	*Pavona cactus*	2	4
103	*Pavona varians*	3	3
104	*Pavona explanulata*	2	0
105	*Pavona clavus*	1	0
106	*Pavona decussata*	0	1
107	*Pavona maldivensis*	0	1
III	Astrocoeniidae		
x	*Madracis*		
108	*Madracis kirbyi*	1	0
xi	*Stylocoeniella*		
109	*Stylocoeniella armata*	1	1
110	*Stylocoeniella guentheri*	0	2
111	*Stylocoeniella cocosensis*	0	1
IV	*Dendrophylliidae*		
xii	*Turbinaria*		
112	*Turbinaria mesenterina*	0	2
113	*Turbinaria stellulata*	1	1

114	*Turbinaria radicalis*	1	0
V	Euphylliidae		
xiii	*Euphyllia*		
113	*Euphyllia glabrescens*	0	2
VI	Faviidae		
xiv	*Cyphastrea*		
114	*Cyphastrea microphthalma*	2	5
115	*Cyphastrea serailia*	2	3
116	*Cyphastrea chalcidicum*	3	1
117	*Cyphastrea japonica*	3	1
118	*Cyphastrea ocellina*	3	0
xv	*Diploastrea*		
119	*Diploastrea heliopora*	1	1
xvi	*Echinopora*		
120	*Echinopora gemmacea*	1	13
121	*Echinopora lamellosa*	5	4
122	*Echinopora pacificus*	2	1
123	*Echinopora hirsutissima*	0	1
124	*Echinopora mammiformis*	1	0
xvii	*Favia*		
125	*Favia speciosa*	5	11
126	*Favia pallida*	8	6
127	*Favia matthaii*	6	2
128	*Favia veroni*	3	2
129	*Favia helianthoides*	1	2
130	*Favia stelligera*	2	1
131	*Favia danae*	0	2
132	*Favia lizardensis*	0	2
133	*Favia maritima*	0	2
134	*Favia marshae*	0	2
135	*Favia rotumana*	0	1
136	*Favia sp.*	0	1
xviii	*Favites*		
137	*Favites russelli*	8	7
138	*Favites abdita*	4	8
139	*Favites complanata*	2	5
140	*Favites acuticollis*	0	6
141	*Favites halicora*	3	3
142	*Favites micropentagona*	3	1
143	*Favites flexuosa*	1	2
144	*Favites chinensis*	1	1
145	*Favites paraflexuosa*	2	0
146	*Favites pentagona*	1	1
147	*Favites bestae*	0	1
148	*Favites sp.*	1	0
xix	*Goniastrea*		
149	*Goniastrea pectinata*	9	4
150	*Goniastrea retiformis*	3	3
151	*Goniastrea edwardsi*	0	4
152	*Goniastrea australensis*	0	3
153	*Goniastrea favulus*	1	1
154	*Goniastrea palauensis*	1	1
155	*Goniastrea minuta*	1	0
156	*Goniastrea ramosa*	1	0
xx	*Leptastrea*		
157	*Leptastrea purpurea*	2	5
158	*Leptastrea transversa*	0	2
159	*Leptastrea bottae*	1	0
160	*Leptastrea inaequalis*	1	0
xxi	*Leptoria*		
161	*Leptoria phrygia*	2	1
xxii	*Montastrea*		
162	*Montastrea valenciennesi*	6	2
163	*Montastrea maginistellata*	2	2
164	*Montastrea annuligera*	1	0
165	*Montastrea colemani*	1	0
166	*Montastrea curta*	1	0
xxiii	*Oulophyllia*		
167	*Oulophyllia crispa*	2	1
168	*Oulophyllia levis*	1	1
xxiv	*Platygyra*		
169	*Platygyra contorta*	10	4
170	*Platygyra pini*	4	2
171	*Platygyra lamellina*	3	0
172	*Platygyra acuta*	0	2
173	*Platygyra daedalea*	2	0
174	*Platygyra sinensis*	1	1
175	*Platygyra verweyi*	2	0
176	*Platygyra carnosus*	0	1
177	*Platygyra ryukyuensis*	1	0
178	*Platygyra yaeyamaensis*	1	0
xxv	*Plesiastrea*		
179	*Plesiastrea versipora*	1	0
VII	Fungiidae		
xxvi	*Ctenactis*		
180	*Ctenactis echinata*	3	6
181	*Ctenactis albitentacula*	0	1
182	*Ctenactis crassa*	0	1
xxvii	*Cycloseris*		
183	*Cycloseris echinata*	0	1
184	*Cycloseris patelliformis*	0	1
185	*Cycloseris vaughani*	0	1
xxviii	*Fungia*		
186	*Fungia danai*	26	19
187	*Fungia scabra*	3	26
188	*Fungia klunzingeri*	7	5
189	*Fungia fungites*	5	6
190	*Fungia paumotensis*	4	5
191	*Fungia concinna*	3	4
192	*Fungia repanda*	0	7
193	*Fungia granulosa*	0	3
194	*Fungia fralinae*	1	1
195	*Fungia horrida*	0	2
196	*Fungia corona*	1	0
xxix	*Herpolitha*		
197	*Herpolitha weberi*	0	1
xxx	*Sandalolitha*		
198	*Sandalolitha dentata*	0	1
199	*Sandalolitha robusta*	1	0
VIII	Helioporidae		
xxxi	*Heliopora*		
200	*Heliopora coerulea*	30	28
IX	Merulinidae		
xxxii	*Hydnophora*		
201	*Hydnophora exesa*	2	4
202	*Hydnophora rigida*	1	4
203	*Hydnophora microconos*	3	1
204	*Hydnophora pilosa*	2	0
xxxiii	*Merulina*		
205	*Merulina scabricula*	2	3
206	*Merulina ampliata*	0	4
X	Milleporidae		
xxxiv	*Millepora*		
207	*Millepora tenella*	34	39
208	*Millepora platyphylla*	33	13
209	*Millepora exaesa*	0	4
210	*Millepora sp.*	0	2
211	*Millepora dichotoma*	1	0
XI	Mussidae		
xxxv	*Acanthastrea*		
212	*Acanthastrea faviaformis*	1	0
213	*Acanthastrea hillae*	1	0
214	*Acanthastrea rotundoflora*	0	1
xxxvi	*Lobophyllia*		

215	*Lobophyllia hataii*	0	2
216	*Lobophyllia hemprichii*	0	2
217	*Lobophyllia flabelliformis*	0	1
xxxvii	*Symphyllia*		
218	*Symphyllia radians*	2	2
219	*Symphyllia recta*	3	1
220	*Symphyllia agaricia*	0	1
XII	Oculinidae		
xxxviii	*Galaxea*		
219	*Galaxea fascicularis*	19	32
220	*Galaxea astreata*	7	6
221	*Galaxea paucisepta*	1	0
XIII	Pectiniidae		
xxxix	*Echinophyllia*		
222	*Echinophyllia aspera*	1	1
223	*Echinophyllia costata*	0	2
xxxx	*Mycedium*		
224	*Mycedium elephantotus*	2	0
225	*Mycedium robokaki*	0	1
xxxxi	*Oxypora*		
226	*Oxypora lacera*	1	0
xxxxii	*Pectinia*		
227	*Pectinia ayleni*	4	4
228	*Pectinia lactuca*	4	2
XIV	Pocilloporidae		
xxxxiii	*Pocillopora*		
229	*Pocillopora verrucosa*	10	11
230	*Pocillopora damicornis*	2	16
231	*Pocillopora danae*	8	1
232	*Pocillopora ankeli*	2	2
233	*Pocillopora elegans*	0	3
xxxxiv	*Seriatopora*		
234	*Seriatopora hystrix*	10	75
235	*Seriatopora caliendrum*	27	31
236	*Seriatopora stellata*	9	0
237	*Seriatopora guttatus*	0	4
238	*Seriatopora aculeata*	0	1
239	*Seriatopora* sp.	0	1
xxxxv	*Stylophora*		
240	*Stylophora pistillata*	10	33
241	*Stylophora subseriata*	17	23
XV	Poritidae		
xxxxvii	*Alveopora*		
242	*Alveopora spongiosa*	1	0
xxxxvi	*Goniopora*		
243	*Goniopora minor*	1	3
244	*Goniopora lobata*	0	2
245	*Goniopora planulata*	0	2
246	*Goniopora columna*	1	0
247	*Goniopora sp.*	0	1
248	*Goniopora stutchburyi*	1	0
xxxxviii	*Porites*		
249	*Porites lutea*	81	54
250	*Porites lobata*	30	27
251	*Porites cylindrica*	18	17
252	*Porites monticulosa*	4	18
253	*Porites profundus*	0	12
254	*Porites annae*	5	5
255	*Porites stephensoni*	3	7
256	*Porites attenuata*	0	9
257	*Porites solida*	4	5
258	*Porites vaughani*	0	9
259	*Porites rus*	2	5
260	*Porites horizontalata*	2	2
261	*Porites nigrescens*	3	1
262	*Porites lichen*	0	3
263	*Porites murrayensis*	0	3
264	*Porites negrosensis*	2	1
265	*Porites australiensis*	0	2
266	*Porites mayeri*	0	2
267	*Porites* sp.	0	2
268	*Porites tuberculosa*	0	2
269	*Porites deformis*	1	0
XVI	Siderastreidae		
xxxxix	*Coscinaraea*		
270	*Coscinaraea columna*	1	0
271	*Coscinaraea monile*	0	1
272	*Coscinaraea wellsi*	1	0
xxxxx	*Psammocora*		
273	*Psammocora superficialis*	9	2
274	*Psammocora haimeana*	1	1
275	*Psammocora nierstraszi*	1	1
276	*Psammocora profundacella*	2	0
278	*Psammocora* sp.	1	0
XVII	Tubiporidae		
xxxxxi	*Tubipora*		
279	*Tubipora musica*	1	0
Total number of colonies		440	504


A


B

Figure 7. A. Young colony of *Acropora* spp.; B. Juvenile of *Fungia* spp.

A total of 279 species from 51 genera were identified at 10 sites between 2018 and 2021 (Table 2). Almost half of the species recognized in this region were found in this study (Veron et al. 2015). The observed coral species richness was low than in the literature books, as it only accounts for species than appear in the transect with 7-9 m depth. Hence, the observed species richness not represented the coral diversity in this location, where most coral is found in depths between 10-20m and gradually declines beyond the ranges (Waheed and Hoeksema 2014). Furthermore, the species richness in East Sumba was slightly lower than in other studies in this region, such as Lembata (331) and Komodo (408) (Abrar et al. 2012; Hadi et al. 2019). The high richness of both areas is related to the fact close to the heart of the Coral Triangle and in Indonesian Through Flow trajectories that might be affected by larva supply from the hot spot diversity areas.

The strong relationship between hard coral cover and sponge and fleshy seaweed was confirmed in this study. Furthermore, the declines of sponges and fleshy seaweed were positively correlated to the rise of coral cover. Those facts are due to the competition of space between those benthic life forms (Chaves-Fonnegra et al. 2018; Speare et al. 2019). Sponge and fleshy seaweed are less vulnerable than coral to disturbances such as cyclones, bleaching, and anthropogenic factors (Carballo et al. 2013; Neves et al. 2016). Moreover, sponges produce chemical compounds that help to compete for space (Helber et al. 2018). Seasonal environment changes such as the rainy season that brought nutrients from the land might enhance the growth of fleshy seaweed and sponges (Neves et al. 2016), such as shown in stations W10 and W09 were located near the river mouth and high cover of sponges and fleshy seaweed.

In conclusion, temporal changes in the benthic reef and coral community have not appeared in East Sumba. The spatial differences between the reef and benthic communities were influenced by the increase of dominant hard coral families, such as Acroporidae. East Sumba location, bordered by open water areas (Savu Sea), has a positive impact on the condition of the reef, particularly imported larvae to this region, and gives good circulation and flushing to maintain the water quality from excess nutrients. This condition can boost the reef condition by increasing the number of colonies and species richness and controlling fleshy seaweed and sponge growth. Hence, understanding the dynamic of coral reef benthic communities was important to predict the future conditions of the coral reefs. Coral juvenile density was essential for successive coral reef recovery, which is why it needed to include the study of juvenile density. Moreover, observation of the benthic communities in different depths can obtain a comprehensive understanding of the dynamic of reef benthic communities in the future.

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