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Variation on the morphological features of coral *Echinopora lamellosa* population suggests corals survivorship mechanisms in Alas Strait, Indonesia

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Abstract. Morphological features of coral are excellent in reflecting the influences of environmental factors and the coral physiology condition. Several major bleaching episode have occurs in Lombok waters and Alas Strait, and morphological features of the surviving coral could provide information related to their survivorship mechanism. We assessed both the non-morphometric and morphometric aspects of 30 photo samples of *Echinopora lamellosa* coral from northern and southern region of the Alas Strait. The UPGMA (Unweighted-Pair Group Method with Arithmetic Mean) dendogram was constructed by using IBM SPSS v2.1 to cluster the coral morphological variation. The results showed that the morphology of *E. lamellosa* from northern region was more varied than those from southern region. Examination on both morphometric and non-morphometric aspect indicate the possibility of corals in the Alas Strait (especially corals from northern region of the strait) to have survived the bleaching episode through the presence of varied coral symbiont and water turbidity. Thus, the results of this study are crucial to confirm a posibble explanation for corals survivorship mechanisms in Alas Strait.

Key Words: Alas Strait, coral bleaching, coral morphology.

Introduction. Coral morphology can potray the significant implications of coral physiology, as well as the environmental influences to the coral. Scleractinian coral, as dominant inhabitant of reef ecosystem biotopes, are tightly connected with the morphological and functional properties of the reef ecosystem itself (McWilliam et al 2018). The shape and size of corals determines their interaction and relationship to the physical world and other organisms (Gischler et al 2013; Kramer et al 2020), such as the performance of corals in survival and coping with the environmental stressor (Scheufen et al 2017).

Many species of scleractinian corals exhibits very high morphological variation (García et al 2017; Doszpot et al 2019) and it represents their respond to the environmental changes (Todd 2008). Despite the fact that the genetic factor plays a major role in restricting and controling the morphological variation in coral (Budd et al 2011; Smith et al 2017), a very distinctive traits may also occurs due to a morphological plasticity within species driven by the interactions with local environmental conditions (Soto et al 2018). In *Pocillopora* spp., their diverse morphological traits are the result of certain environmental factors such as strong current, water turbidity, or depth (Paz-García et al 2015; Soto et al 2018). Different type of coral life form appears to be specifically suited in dealing with specific environmental conditions. Recent studies report that the branching corals are more susceptible to bleach than other coral life form (Yusuf & Jompa 2012; Schoepf et al 2015; Razak et al 2020), suggesting a critical role of colony morph in maintaining coral resilience. Thus, the morphological variations of succession corals can also provide various information related to the historical environmental stress that corals have experienced (Cantin & Lough 2014; Zawada et al 2019).

Corals in Lombok and nearby waters have experienced bleaching several time, specifically for the major bleaching episodes in 1983, 1998, 2010 and 2016 (Bachtiar 2000; Bachtiar & Jufri 2019), as any other reefs in Indonesia. Bachtiar and Hadi (2019) reported that coral *Echinopora lamellosa* is one of a few coral species that survived the 2016 mass bleaching in Lombok waters. Observation conducted by Wildlife Conservation Society NTB NGO reported that majority of coral survived the bleaching in eastern Lombok waters, especially in Alas Strait and its adjacent waters (Tarigan et al 2019). Several hypotheses for coral survival mechanisms in Alas Strait were proposed by Bachtiar et al (2019) as follows: 1) the involvement of heat-resistant symbiont; 2) the presence of coastal vegetation as shelter, such as mangrove; 3) UV shade provided by water turbidity for coral survivorship. Bachtiar et al (2019) proved the ability of coral *E. lamellosa* in hosting different symbiont clade, presume it as the reason for *E. lamellosa* survival in nature. Here we provide the evidence based on morphological studies of *E. lamellosa* in the Alas Strait, which is likely to support the possible role of hypotheses 1 and 3 that previously proposed on the coral survival mechanism in Alas Strait.

Material and Method

Study location. In-situ observation for coral *Echinopora lamellosa* colony was conducted in two different areas, as shown in Figure 1. The first site group is situated in the northern Alas Strait (labeled as SAU) and the second site is in southern Alas Strait (labeled as SAS), furthermore referred to as northern colony and southern colony, respectively. The two areas are approximately 56.23 km apart.

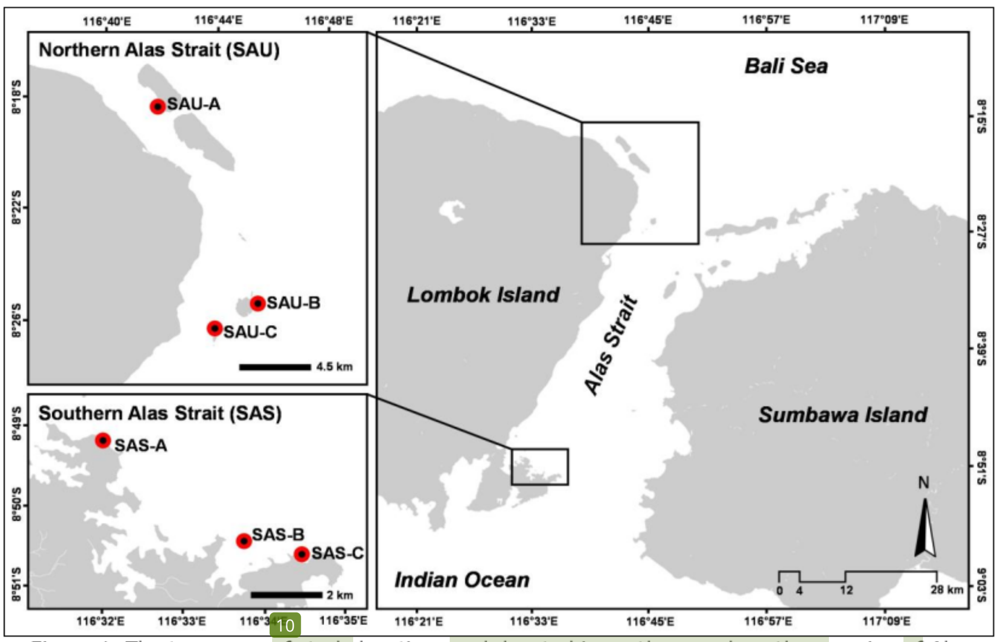

Figure 1. The two areas of study location, each located in northern and southern region of Alas Strait, Indonesia (map generated using ArcGIS software).

Data collection. The observation on *Echinopora lamellosa* colonies was carried out in all site via SCUBA diving at 3 to 5 m depth, parallel to the coastline. The distance of each observed colonies at least 3 m apart in order to prevent the possibility of observing clones colonies. Each observation on the colony of *E. lamellosa* was performed by three types of photo shoot using Fujifilm XQ2. The first type of photo shoot must showed the entire colony and surrounding, the second shows the colony only, and third photograph should be a 'close-up macro', which shows corallite of *E. lamellosa* clearly. Photographs of *E. lamellosa* colonies, their code label, CoralWatch Coral Health Chart, and white ruler (as manual photo scale) were taken in the same photo area. The observed colonies were labeled based on their site and observation order.

***Ex-situ* observation and data analysis**. The color of sample photo that was taken needs to be enhanced before getting into further analysis. The color correction for sample photos of *Echinopora lamellosa* was performed by using Photoshop CS5 software with reference to Pateman (2009). The analysis then continued with the observation of the non-morphometric aspects, measurement of morphometric features, and dendrogram construction.

Observation on the non-morphometric aspects included identification of the colony life form (LF), polyp growth type (TPG), corallite type (CT), tissue color (TC), and mouth-disk/columellae color (CC). The color of tissue and mouth-disk was identified according to Oladi et al (2017), by matching the color histogram values of both sampled photo and color block on the CoralWatch Coral Health Chart (www.coralwatch-old.org).

The measurement of morphometric features is intended to determine mouth disk diameter (MD), corallite diameter (CD), inter-corallite distance (ICD), and polyp density (PD). The measurement was carried out using AutoCAD 2016 (modified from Hagerty 2019). The measurement technique to estimate the size of MD, CD, and ICD using AutoCAD 2016 as shown in Figure 2, by calculating the rate of MD, CD, and ICD value from ten haphazardly selected adjacent corallite per sample picture. Polyp density is determined by the number of polyps counted in a selected area (ind cm^{-2}). All data gained were tabulated in a spreadsheet by using Microsoft Excel 2010, and then used to construct the UPGMA dendogram with Squared-Euclidian Distance by means of IBM SPSS v2.1.

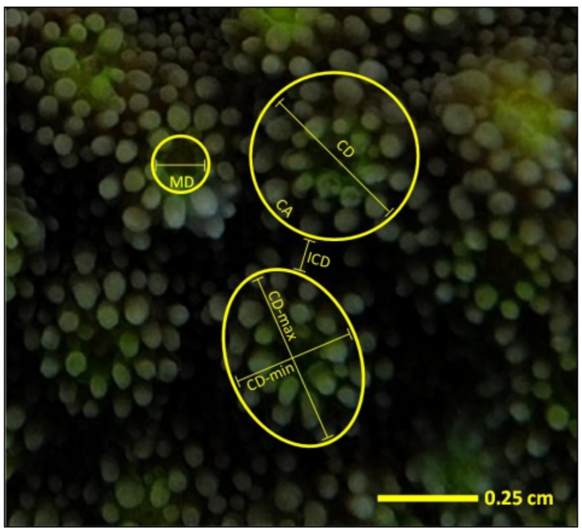

Figure 2. Measurement technique on protruded corallites of *Echinopora lamellosa* by using AutoCAD 2016. MD=mouth disk/columellae, CA=corallite area, CD=corallite diameter, CD-min=corallite minimum diameter, CD-max=corallite maximum diameter, ICD=inter-corallite distance. The average value of CD-max + CD-min was used to determine the CD value of oval-shaped CA.

Results

Variation on the morphological features. The result on the morphological assessment shows that the northern and southern colony exhibits various life form, as shown in Figure 3. The tissue color ranging from reddish (C5) to greenish brown (E5), while greenish (B5) to greenish brown (E5) dominate mouth-disk color, as represent in Figure 4. In both locations, the colony morph varies from laminar (tube or tier), foliaceous to encrusting form. The size of corallite among the southern colony (colony of SAS) is relatively smaller than those from northern colonies (colony of SAU). As many as 66.77% (n=10) of the total southern colonies had MD (mouth-disk) size ranging from 0.10 ± 0.006 to 0.10 ± 0.018 cm. In contrast, only 20% (n=3) of northern colony members had an MD size of ≤0.10 cm. The highest and the lowest morphometric value displayed by northern colonies population. The morphological data of *Echinopora lamellosa* from both northern and southern population is summerized in Table 1 .

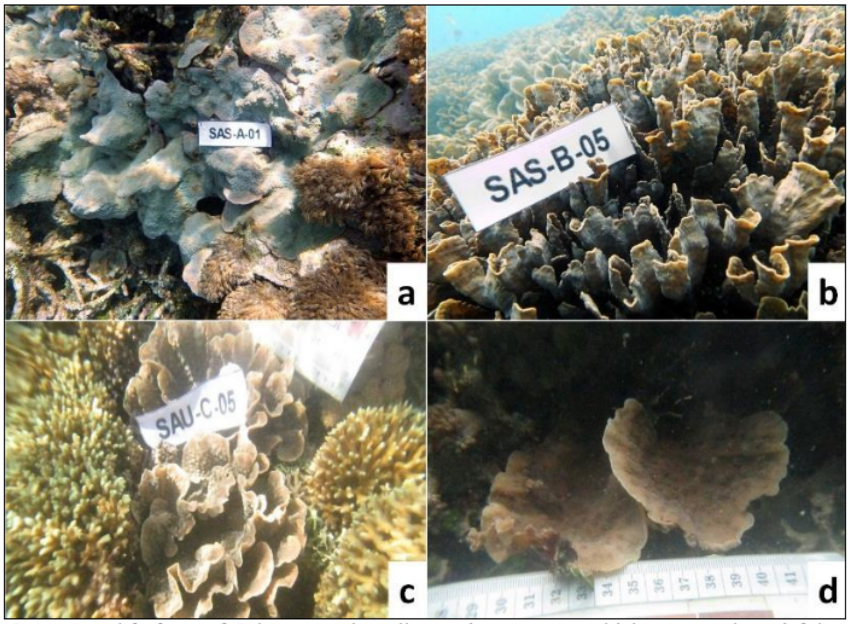

Figure 3. Various life form of *Echinopora lamellosa*: a) encrusting; b) laminar tube; c) foliose; d) laminar tier.

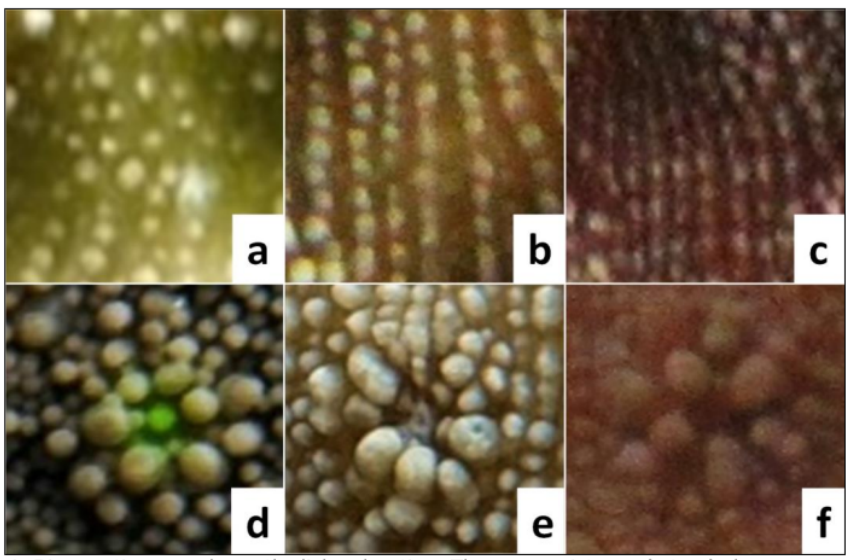

Figure 4. Diverse tissue and mouth-disk coloration. The upper pictures (a to c) shows comparison of tissue color: a) greenish brown (E5); b) brownish (D6); c) reddish (C6). The bottom pictures (d to f) presents the variety of mouth-disk color: d) greenish (B5); e) brownish (D5); reddish (C5).

Table 1
Tabulated data on the morphological features of coral *Echinopora lamellosa* from Alas Strait

No.	Sample code	Non-morphometric aspect					Morphometric aspect			
		LF	*TPG*	*TC*	*CC*	*CT*	*MD (cm)*	*CD (cm)*	*ICD (cm)*	*PD (ind cm^{-2})*
1	SAU-A-01	Enc	Uni	E5	E5	Pro	0.13±0.022	0.38±0.035	0.09±0.012	4.74±0.463
2	SAU-A-02	Enc	Uni	E5	B5	Pro	0.13±0.008	0.43±0.025	0.12±0.027	4.26±0.390
3	SAU-A-03	Tub	Uni	E5	B5	Pro	0.11±0.011	0.31±0.014	0.17±0.031	4.96±0.501
4	SAU-A-04	Fol	Uni	D3	D6	Im	0.06±0.006	0.19±0.011	0.18±0.016	7.63±0.559
5	SAU-A-05	Fol	Uni	D4	D6	Im	0.13±0.021	0.31±0.015	0.22±0.052	3.56±0.444
6	SAU-B-01	Fol	Uni	D6	B5	Pro	0.10±0.008	0.39±0.034	0.13±0.035	4.37±0.231
7	SAU-B-02	Fol	Uni	D5	D5	Pro	0.15±0.017	0.49±0.029	0.30±0.069	1.89±0.111
8	SAU-B-03	Tub	Bi	D6	D6	Pro	0.14±0.011	0.39±0.015	0.13±0.020	2.96±0.257
9	SAU-B-04	Fol	Uni	D5	B5	Pro	0.11±0.013	0.37±0.022	0.15±0.020	3.07±0.280
10	SAU-B-05	Tie	Uni	D5	B5	Pro	0.10±0.006	0.40±0.044	0.13±0.038	4.81±0.064
11	SAU-C-01	Tie	Uni	C5	C5	Im	0.07±0.014	0.23±0.032	0.16±0.013	6.00±0.588
12	SAU-C-02	Fol	Uni	C6	B6	Pro	0.11±0.032	0.36±0.067	0.11±0.027	4.63±0.740
13	SAU-C-03	Fol	Uni	C6	B6	Im	0.12±0.013	0.35±0.034	0.07±0.007	6.22±0.444
14	SAU-C-04	Fol	Uni	D4	D4	Pro	0.11±0.006	0.43±0.017	0.13±0.041	3.33±0.222
15	SAU-C-05	Fol	Uni	C6	C6	Im	0.11±0.017	0.32±0.038	0.15±0.037	4.44±0.222
16	SAS-A-01	Enc	Uni	C5	B6	Im	0.10±0.018	0.38±0.014	0.11±0.038	4.74±0.339
17	SAS-A-02	Enc	Uni	C5	B6	Im	0.13±0.015	0.42±0.032	0.09±0.032	4.67±0.801
18	SAS-A-03	Fol	Uni	D5	D6	Im	0.10±0.019	0.27±0.011	0.18±0.052	4.00±0.222
19	SAS-A-04	Enc	Uni	D5	B6	Im	0.10±0.006	0.42±0.024	0.11±0.027	4.56±0.294
20	SAS-A-05	Fol	Uni	D4	D6	Im	0.10±0.008	0.26±0.031	0.13±0.054	6.00±0.694
21	SAS-B-01	Enc	Uni	C5	B5	Im	0.10±0.009	0.34±0.019	0.13±0.014	4.52±0.339
22	SAS-B-02	Fol	Uni	D5	B6	Im	0.10±0.011	0.31±0.057	0.14±0.051	5.11±0.969
23	SAS-B-03	Enc	Uni	D5	B6	Pro	0.12±0.009	0.37±0.022	0.11±0.016	4.81±0.280
24	SAS-B-04	Fol	Uni	D5	B6	Im	0.10±0.018	0.25±0.051	0.14±0.042	7.59±0.170
25	SAS-B-05	Tub	Uni	D5	D6	Pro	0.10±0.007	0.29±0.020	0.16±0.019	4.89±0.444
26	SAS-C-01	Enc	Uni	C5	B5	Im	0.10±0.008	0.33±0.028	0.13±0.005	4.52±0.339
27	SAS-C-02	Fol	Uni	D4	D6	Im	0.10±0.013	0.31±0.031	0.15±0.045	4.04±0.612
28	SAS-C-03	Enc	Uni	C5	B6	Im	0.11±0.009	0.39±0.009	0.12±0.038	3.26±0.339
29	SAS-C-04	Enc	Uni	C5	B6	Im	0.12±0.023	0.33±0021	0.12±0.059	5.37±0.723
30	SAS-C-05	Fol	Uni	D6	D5	Im	0.12±0.022	0.33±0.024	0.20±0.055	3.33±0.801

Note: LF (coral life form), TPG (type of polyp growth), TC (tissue color), CC (mouth-disk color), CT (corallite type), Enc (encrusting), Fol (foliaceous), Tub (laminar tube), Tie (laminar tier), Pro (protrude corallite), Im (immersed corallite), MD (mouth-disk diameter), CD (corallite diameter), ICD (inter-corallite distance), PD (polyp density).

Clusterization of morphological variation. The constructed dendogram shows there are 5 fit clusterization among the northern and southern colony of *Echinopora lamellosa*, as presented in Figure 5. For clusters 4 and 5, each cluster consists of only single OTU and belong to northern colony. Clusters 4 and 5 are characterized by very low polyp density with very large corallite size, folios or laminar colony forms. Based on the dendrogram construction, cluster 5 excluded firstly from the other cluster groups (outgrouped). This early separation is due to bifascial polyp growth (polyps grow on both sides of the tissue), which is very distinct characteristic exhibited by cluster 5. Clusters 2 and 3 are dominated by northern colonies with only 2 OTUs that belong to southern colonies. Both clusters have moderate polyp density. Cluster 1 consisted of several sub-cluster, where the northern and southern colonies share very similar characteristics. The polyps grew very densely with small submerged coral in cluster 1. All clusters have protruded corallite except for cluster 1, which is characterized by immersed corallite in its OTUs.

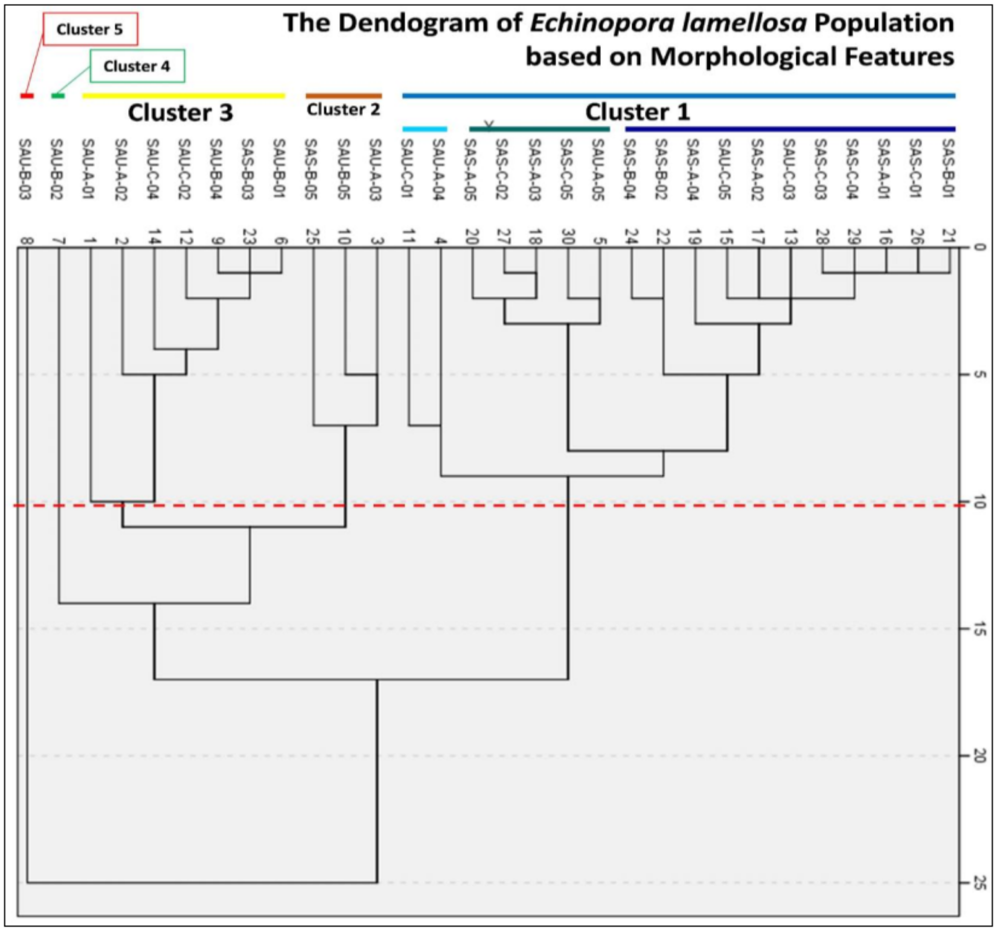

Figure 5. The dendogram of *Echinopora lamellosa* population of Alas Strait based on their morphological features. The northern colonies dominate the number of cluster variations by making up the majority of clusters 2, 3, 4 and 5, while cluster 1 consists of mixed colonies from northern and southern colonies.

Discussion. In general, the results show that the northern colonies exhibits higher morphological variation compared to their southern counterpart. Based on the dendogram, the northern colonies form all 5 clusters. In the other hand, the southern colonies form only 3 clusters, by the majority of 86.67% (n=13) of their total OTUs belong to cluster 1. The highest and lowest value of morphometric aspects, such as polyp density, mouth-disk size, corallite diameter and spacing, were found only in northern colonies. This fact indicates a large range of morphometric variations within the northern colonies. Diverse morphological variation may lead to the assumption that the northern colony could still have the local or even cryptic traits, as those called 'ecomorphs' features sometimes hidden among the diverse coral reef (Arrigoni et al 2019; Bongaerts et al 2020). Nevertheless, many local or cryptic traits will likely prone to bleach if they disperse on a regional scale as their survival is related to the local factors (Cacciapaglia &

van Woesik 2015). The presumption of cryptic traits among *Echinopora lamellosa* colonies in Northern Alas Strait based on morphological diversity needs to be treated cautiously and elaborated deeply through molecular data.

The coloration of tissue and mouth-disk displayed by *Echinopora lamellosa* were varied between B, C, and D color blocks of CoralWatch Coral Health Chart. Variation in color appearance of *E. lamellosa* confirm the ability of this coral in hosting more than 1 type of symbiont clade, as reported by Bachtiar et al (2019). The northern colonies had all types of B, C, or D color blocks on their tissue or mouth-disk, whereas the southern colony only exhibits C or D color block for tissue colors and B or D color block for mouth-disk colors. The reddish and brownish (C or D) color dominated the appearance of southern colony tissue are associated with the involvement of heat-tolerant symbiont, resulting in more adaptive corals physiology (Innis et al 2018; Bahr et al 2020).

Adaptation to the environmental factors can be seen from differences within the morphological variations of each cluster throughout the dendrogram. All cluster, except for cluster 1, has protruded corallite. According to Wijsman-Best (1977), the protruded corallite of *Plesiastrea urvillei* tend to occur in calmer and deeper water, but it is hard to generalize whether the same mechanism also influences the morphs of *Echinopora lamellosa* in Alas Strait due to lack of environmental data. Smith et al (2017) suggested that certain morphology features of coral may be linked to the bleaching susceptibility. It has assumed that members of cluster 1, especially the southern colony, are more capable to deal with the heat-induced bleaching. This is evidenced by the high level of polyp density, as well as smaller size of the corallite diameter and spacing among the southern colony. Small corallite size, narrow corallite spacing, and high polyp density of hermaphrodite coral have shown to be linked with more resilience properties during bleaching (Shenkar et al 2005; Ng et al 2020).

Although no available scientific records regarding coral bleaching in the Southern Alas Strait to date, traces of coral bleaching can be seen during field observation in. The bleaching trace in southern colonies habitat indicated by bleached corals and domination of rubble, turf algae and soft corals (Figures 6). Algae and the opportunistic soft coral dominate the substrate as the result of coral-algal phase shift (Jompa & Cook 2003; Vercelloni et al 2020), a strong evidence of post-bleaching condition (Vieira et al 2016; Roth et al 2018). Even so, Swierts and Vermeij (2016) reported that the encrusting and plating coral are often win in coral-algae competition, leaving to the assumption that this reason may explain the present of coral *Echinopora lamellosa* in southern habitat. In contrast, the northern colonies habitat was still dominated by hard coral cover. The majority clusters (clusters 2 to 5) seems to be concentrated on the Northern Alas Strait, which means that the area could have more suitable environmental parameter compared to the southern region, which allow the colonies of those cluster to survive the coral bleaching event.

The environmental factors were thought to induce larger corallite and mouth-disks diameter, as well as coral life form among the northern colonies. The environmental factors related to fluctuation of light intensity can be put forward as reasons, such as the influence of depth (Crabbe & Smith 2006; Klaus et al 2007) or water turbidity (Todd et al 2001). However, it seems that the effect of water turbidity is more likely to affect the larger size of corallite and mouth-disk among the colonies. This is due to the fact that the observed colonies grow in almost the same level of depth (between 3 to 5 m depth), so that the light intensity obtained may not differ significantly. The source of turbidity in the northern region may come from mangrove forests that dominate nearby islets. Mangroves are well known to be able to withstand the mud sedimentation, but the effectiveness of mangroves in holding sediment is no more than 30% (Kathiresan 2003). It is also possible for some amount of mangrove's sediment to be released into the surrounding waters during high tides or rainfall (Asp et al 2018), causing the turbid water in the area. Sediment loads from mangrove forest may contribute to the decreasing water clarity by attenuating solar irradiance through water (Lovelock et al 2015; Hadi 2017) in northern habitat. Coral with larger size corallite and mouth-disk are commonly occur in turbid water, as larger corallite and mouth-disk are thought to be more effective for light absorption in low light condition (Ow & Todd 2010; Fordyce et al 2021). Majority of *Echinopora lamellosa* found in this study have either encrusting or foliose life form. It is also reported that encrusting and foliose corals are abundant in turbid water (Guest et al 2016; Syahrir et al 2018), presumably due to their excellent capability in dealing with sediment deposition (Jones et al 2019) and horizontal posture that provides the advantage in maximizing downwelling light capture (Duckworth et al 2017). Moreover, the turbid water can increase coral resilience by becoming shelter or refugia for most corals during the bleaching event (Cacciapaglia & van Woesik 2015; Guest et al 2016; Morgan et al 2017). Mulyani et al (2018) reported that the level of turbidity at depth of 2 to 5 m (as in this study) is not as high as in deeper water, possibly creating a perfect haven for coral to survive trough shading mechanism. This assumption leading to the reason for most varied coral can survive in northern region, but not in the southern region.

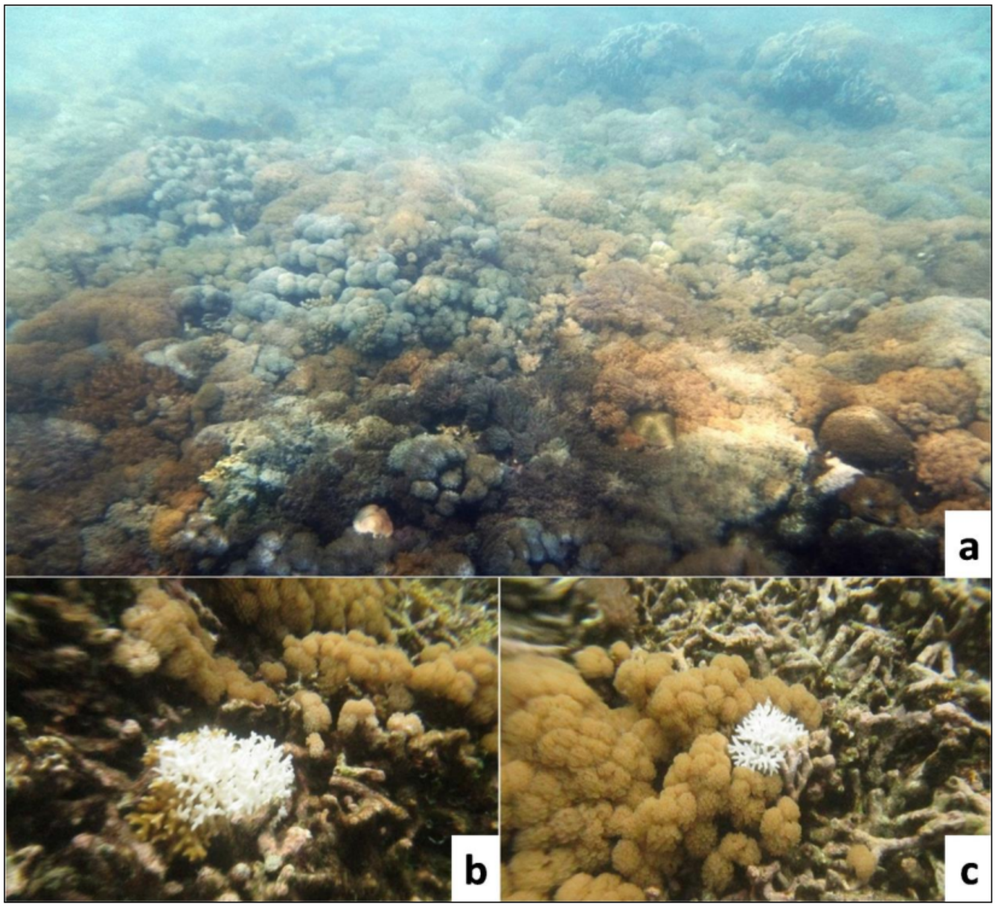

Figure 6. The condition of southern colonies habitat: a) a photograph of underwater view dominated by soft coral and algae; small colony of *Pocillopora* spp. that b) partially bleach and c) fully bleach found in southern habitat.

Conclusions. The observation on the non-morphometric variations in *Echinopora lamellosa* shows the tissue and mouth-disk color were varied, represents the variations in symbiont clade types that may contribute to coral survivorship. In addition, the morphometric aspects of *E. lamellosa* suggest the involvement of turbidity in enhancing coral resilience by becoming shade for direct light exposure. The most varied symbiont and the effect of turbidity in supporting the coral resilience can be seen through diverse morphological variations exhibits by *E. lamellosa* corals, especially those from Northern Alas Strait.

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Conflict of Interest. The authors declare that there is no conflict of interest.

References

Arrigoni R., Berumen M. L., Stolarski J., Terraneo T. I., Benzoni F., 2019 Uncovering hidden coral diversity: a new cryptic lobophylliid scleractinian from the Indian Ocean. Cladistics 35(3):301-328.

Asp N. E., Gomes V. J., Schettini C. A., Souza-Filho P. W., Siegle E., Ogston A. S., Nittrouer C. A., Silva J. N. S., Nascimento W. R., Souza S. R., Pereira L. C. C., Queiroz M. C., 2018 Sediment dynamics of a tropical tide-dominated estuary: Turbidity maximum, mangroves and the role of the Amazon River sediment load. Estuarine, Coastal and Shelf Science 214:10-24.

Bachtiar I., 2000 Promoting recruitment of scieractinian corals using artificial substrate in the Gill Indah, Lombok Barat, Indonesia. Proceedings of the 9th International Coral Reef Symposium, Kuta, Vol. I, pp. 425-430.

Bachtiar I., Hadi T. A., 2019 Differential impacts of 2016 coral bleaching on coral reef benthic communities at Sekotong Bay, Lombok Barat, Indonesia. Biodiversitas 20(2):570-575.

Bachtiar I., Jufri A. W., 2020 [The health of coral reef and related ecosystem in Sekotong Bay, West Lombok Regency]. Mataram University Press, Mataram. ISBN 9786237608400 [in Indonesian].

Bachtiar I., Ghafari M. I. A., Rahman I., Hilda B., Mahrus, 2019 Coral *Echinopora lamellosa* hosts multiple clades of symbionts in western Alas Strait, Indonesia. Proceedings of the 2nd International Conference on Bioscience, Biotechnology, and Biometrics, Mataram, Vol. 2199, pp. 070013-1–070013-10.

Bahr K. D., Severino S. J., Tsang A. O., Han J. J., Dona A. R., Stender Y. O., Weible R. M., Graham A., McGowan A. E., Rodgers K. S., 2020 The Hawaiian Koʻa Card: coral health and bleaching assessment color reference card for Hawaiian corals. SN Applied Sciences 2(1706).

Bongaerts P., Cooke I. R., Ying H., Wels D., Haan den S., Hernandez-Agreda A., Brunner C. A., Dove S., Englebert N., Eyal G., Forêt S., Grinblat M., Hay K. B., Harii S., Hayward D. C., Lin Y., Mihaljević M., Moya A., Muir P., Sinniger F., Smallhorn-West P., Torda G., Ragan M. A., van Oppen M. J. H., Hoegh-Guldberg O., 2020 Cryptic diversity masks ecologically distinct coral species on tropical reefs. bioRxiv. doi:10.1101/2020.09.04.260208.

Budd A. F., Nunes F. L., Weil E., Pandolfi J. M., 2011 Polymorphism in a common Atlantic reef coral (*Montastraea cavernosa*) and its long-term evolutionary implications. Evolutionary Ecology 26(2):265–290.

Cacciapaglia C., van Woesik R., 2015 Reef-coral refugia in a rapidly changing ocean. Global Change Biology 21(6):2272-2282.

Cantin N. E., Lough J. M., 2014 Surviving coral bleaching events: *Porites* growth anomalies on the Great Barrier Reef. PLoS ONE 9(2):e88720. doi:10.1371/journal.pone.0088720.

Crabbe M. J., Smith D. J., 2006 Modelling variations in corallite morphology of *Galaxea fascicularis* coral colonies with depth and light on coastal fringing reefs in the

Wakatobi Marine National Park (S.E. Sulawesi, Indonesia). Computational Biology and Chemistry 30(2):155-159.
Doszpot N. E., McWilliam M. J., Pratchett M. S., Hoey A. S., Figueira W. F., 2019 Plasticity in three-dimensional geometry of branching corals along a cross-shelf gradient. Diversity 11(3):44-55.
Duckworth A., Giofre N., Jones R., 2017 Coral morphology and sedimentation. Marine Pollution Bulletin 125(1-2):289-300.
Fordyce A. J., Ainsworth T. D., Leggat W., 2021 Light capture, skeletal morphology, and the biomass of corals' boring endoliths. mSphere 6(1):e00060-21. doi:10.1128/msphere.00060-21.
García N. A., Campos J. E., Musi J. L., Forsman Z. H., Muñoz J. L., Reyes A. M., González J. E., 2017 Comparative molecular and morphological variation analysis of *Siderastrea* (Anthozoa, Scleractinia) reveals the presence of *Siderastrea stellata* in the Gulf of Mexico. The Biological Bulletin 232(1):58-70.
Gischler E., Storz D., Schmitt D., 2013 Sizes, shapes, and patterns of coral reefs in the Maldives, Indian Ocean: the influence of wind, storms, and precipitation on a major tropical carbonate platform. Carbonates and Evaporites 29(1):73–87.
Guest J. R., Low J., Tun K., Wilson B., Ng C., Raingeard D., Ulstrup K. E., Tanzil J. T. I., Todd P. A., Toh T. C., McDougald D., Chou L. M., Steinberg P. D., 2016 Coral community response to bleaching on a highly disturbed reef. Scientific Reports 6(1):20717 1-10.
Guest J. R., Tun K., Low J., Vergés A., Marzinelli E. M., Campbell A. H., Bauman A. G., Feary D. A., Chou L. M., Steinberg P. D., 2016 27 years of benthic and coral community dynamics on turbid, highly urbanised reefs off Singapore. Scientific Reports 6(1):36260 1-10. doi: 10.1038/srep36260.
Hadi T. A., 2017 Impacts of sedimentation on stony corals. Oseana 42(2):45-58.
Hagerty J., 2019 A Guide to Aerial Photo Interpretation. ARA Press, Livermore. ISBN 9780989991483.
Innis T., Cunning R., Ritson-Williams R., Wall C. B., Gates, R. D., 2018 Coral color and depth drive symbiosis ecology of *Montipora capitata* in Kāneʻohe Bay, Oʻahu, Hawaiʻi. Coral Reefs 37(2):423–430.
Jompa J., McCook L. J., 2003 Coral-algal competition: macroalgae with different properties have different effects on corals. Marine Ecology Progress Series 258:87-95.
Jones R., Fisher R., Bessell-Browne P., 2019 Sediment deposition and coral smothering. PloS ONE 14(6):e0216248. doi:10.1371/journal.pone.0216248.
Kathiresan K., 2003 How do mangrove forests induce sedimentation?. Revista de Biología Tropical 51(2):355-360.
Klaus J. S., Budd A. F., Heikoop J. M., Fouke B. W., 2007 Environmental controls on corallite morphology in the reef coral *Montastraea annularis*. Bulletin of Marine Science 80(1):233–260.
Kramer N., Tamir R., Eyal G., Loya Y., 2020 Coral morphology portrays the spatial distribution and population size-structure along a 5–100 m depth gradient. Frontiers in Marine Science 7(615). doi:10.3389/fmars.2020.00615.
Lovelock C. E., Adame M. F., Bennion V., Hayes M., Reef R., Santini N., Cahoon D. R., 2015 Sea level and turbidity controls on mangrove soil surface elevation change. Estuarine, Coastal and Shelf Science 153:1–9.
McWilliam M., Hoogenboom M. O., Baird A. H., Kuo C.-Y., Madin J. S., Hughes T. P., 2018 Biogeographical disparity in the functional diversity and redundancy of corals. Proceedings of the National Academy of Sciences 115(12):3084–3089.
Morgan K. M., Perry C. T., Johnson J. A., Smithers S. G., 2017 Nearshore turbid-zone corals exhibit high bleaching tolerance on the Great Barrier Reef following the 2016 ocean warming event. Frontiers in Marine Science 4:224-237.
Mulyani S., Tuwo A., Syamsuddin R., Jompa J., 2018 Effect of seaweed *Kappaphycus alvarezii* aquaculture on growth and survival of coral *Acropora muricata*. AACL Bioflux 11(6):1792-1798.

Ng C. S., Huang D., Toh K. B., Sam S. Q., Kikuzawa Y. P., Toh T. C., Taira D., Chan Y. K. S., Hung L. Z. T., Sim W. T., Rashid A. R., Afiq-Rosli L., Ng N. K., Chou L. M., 2020 Responses of urban reef corals during the 2016 mass bleaching event. Marine Pollution Bulletin 154:1111-1123.
Oladi M., Shokri M. R., Rajabi-Maham H., 2017 Application of the Coral Health Chart to Determine Bleaching Status of *Acropora downingi* in a Subtropical Coral Reef. Ocean Science Journal 52(2). doi:10.1007/s12601-017-0025-4.
Ow Y. X., Todd P. A., 2010 Light-induced morphological plasticity in the scleractinian coral *Goniastrea pectinata* and its functional significance. Coral Reefs 29(3):797-808.
Pateman V., 2009 Color correction for underwater photography. Bachelor Thesis, Graphic Communication Department, California Polytechnic State University, San Luis Ubispo, California.
Paz-García D. A., Hellberg M. E., García-de-León F. J., Balart E. F., 2015 Switch between morphospecies of *Pocillopora* corals. The American Naturalist 186(3):434-440.
Razak T. B., Roff G., Lough J. M., Mumby P. J., 2020 Growth responses of branching versus massive corals to ocean warming on the Great Barrier Reef, Australia. Science of The Total Environment 705(135908). doi:10.1016/j.scitotenv.2019.135908.
Roth F., Saalmann F., Thomson T., Coker D. J., Villalobos R., Jones B. H., Wild C., Carvalho S., 2018 Coral reef degradation affects the potential for reef recovery after disturbance. Marine Environmental Research 142:48-58.
Scheufen T., Iglesias-Prieto R., Enríquez S., 2017 Changes in the number of symbionts and *Symbiodinium* cell pigmentation modulate differentially coral light absorption and photosynthetic performance. Frontiers in Marine Science 4.
Schoepf V., Stat M., Falter J. L., McCulloch M. T., 2015 Limits to the thermal tolerance of corals adapted to a highly fluctuating, naturally extreme temperature environment. Scientific Reports 5(1):17639 1-14.
Shenkar N., Fine M., Loya Y., 2005 Size matters: Bleaching dynamics of the coral *Oculina patagonica*. Marine Ecology Progress Series 294:181-188.
Smith H., Epstein H., Torda G., 2017 The molecular basis of differential morphology and bleaching thresholds in two morphs of the coral *Pocillopora acuta*. Scientific Reports 7(1):10066. doi:10.1038/s41598-017-10560-2.
Soto D., de Palmas S., Ho M. J., Denis V., Chen C. A., 2018 Spatial variation in the morphological traits of *Pocillopora verrucosa* along a depth gradient in Taiwan. PLoS ONE 13(8):e0202586. doi:10.1371/journal.pone.0202586.
Swierts T., Vermeij M. J. A., 2016 Competitive interactions between corals and turf algae depend on coral colony form. PeerJ 4:e1984. doi:10.7717/peerj.1984.
Syahrir M. R., Hanjoko T., Adnan A., Yasser M., Efendi M., Budiarsa A. A., Suyatna I., 2018 The existence of estuarine coral reef at eastern front of Mahakam Delta, East Kalimantan, Indonesia: a first record. AACL Bioflux 11(2):362-378.
Tarigan S. A. R., Aviandhika S., Adiyoga D., Kholilah N., Himawan C., Suniri, 2019 [Monitoring of coral reef ecosystems at Gili Sulat and Gili Lawang TWP, East Lombok Regency]. Technical Report. Lombok Timur: WCS & DKP Kab Lombok Timur.
Todd P. A., 2008 Morphological plasticity in scleractinian corals. Biological Reviews 83(3):315-337.
Todd P. A., Sanderson P. G., Chou L. M., 2001 Morphological variation in the polyps of the scleractinian coral *Favia speciosa* (Dana) around Singapore. Hydrobiologia 444(1):227–235.
Vercelloni J., Liquet B., Kennedy E. V., González-Rivero M., Caley M. J., Peterson E. E., Puotinen M., Hoegh-Guldberg O., Mengersen K., 2020 Forecasting intensifying disturbance effects on coral reefs. Global Change Biology 26(5).
Vieira C., Payri C., Clerck O. D., 2016 A fresh look at macroalgal-coral interactions: are macroalgae a threat to corals?. Perspectives in Phycology 3(3):129–140.

Wijsman-Best M., 1977 Indo-Pacific coral species belonging to the subfamily Montastreinae Vaughan & Wells, 1943 (Scleractinea-Coelenterata) part I. The genera *Montastrea* and *Plesiastrea*. Zoologische Mededelingen 52(7):81-96.

Yusuf S., Jompa J., 2012 First quantitative assessment of coral bleaching on Indonesian Reefs. Proceedings of the 12th International Coral Reef Symposium, Cairns, Vol 1.

Zawada K. J., Madin J. S., Baird A. H., Bridge T. C., Dornelas M., 2019 Morphological traits can track coral reef responses to the Anthropocene. Functional Ecology 33(6):962-975.

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