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# Diversity, Distribution and Abundance of Scleractinian Coral in District-based Marine Protected Area Olele, Bone Bolango, Gorontalo—Indonesia

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## Abstract

Despite its status as District-Based Marine Protected Area, studies pertaining coral reef biodiversity never been conducted in Olele that located in the Gulf of Tomini, biodiversity hotspot in the Coral Triangle. Hence, we aims to investigate diversity, distribution and abundance of scleractinian coral, underpinning the health of reef ecosystems. This study was conducted using Line Intercept Transect on three research stations which were divided into three main zonations, reef flat (3 m depth), upper reef slope (10 m depth) and reef slope (18 m to 20 m depth). Fifty meters long transect were laid in each zonation, thus total transect were nine. The results showed that there were 35 species of scleractinian coral from 12 families. Each zonation has a different pattern of abundance and dominant life form. Based on coral health assessment using Coral Mortality Index (CMI) and the ratio between living and dead coral coverage, coral reef ecosystems in Olele were in healthy condition with the range value 0.29 ± 0.1 and 3.60 ± 1.14. This preliminary study should be used as a basic reference for database and novel direction of conservation management strategy in District-Based Marine Protected Area Olele.

**Keywords:** district-based marine protected area; olele; lit; sclecartinia; life form; zonation

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## 1. Introduction

*Coral Triangle* is the centre of coral diversity in the world with diversity amounts to 76% of the world's total species complement and Indonesia sits firmly at the center of Coral Triangle [1, 2]. According to Veron [3], Indonesian-Philippines archipelago was the real centre of biodiversity not the Great Barrier Reef in Australia. *Coral Triangle* was divided into several specific area called ecoregion and Gulf of Tomini ecoregion in Indonesia is diverse for its small size [4]. Green and Mous [5] confirmed that this ecoregion is localized area of endemism and high species diversity. However, current research mostly conducted in Togean island which is located in the centre area of the gulf.

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Olele, which also located in Gulf of Tomini and has near-pristine area of fringing reef has been designated as a Marine Protected Area (MPA) since 2006 by the government of Bone Bolango regency. Nevertheless, scientific research on coral reef never been conducted, whereas according to Indonesian government regulation, this research is prerequisite for MPA establishment [6, 7], also useful for conservation management [8]. Hence, this research is urgently needed and should be used as a database and conservation management strategy (e.g education tool in elementary school or local people in Olele village as a part of sustainability development program).

## 2. Materials and Methods

### 2.1. Study site and field methods

The study was conducted on April 2013 in District-Based MPA Olele (0°24′23N: 123°09′11E), northern coastline of Tomini Bay in northern Sulawesi, Indonesia. Olele characterized by its pristine fringing reef with narrow reef flat that extends less than 30 m and steep reef slope (Figure 1). Research station was selected by the existence of three main zonations, reef flat (±3 m), upper reef slope (±10 m) and reef slope (±18 m to 20 m) on each. The reefs were initially surveyed using Manta tow techniques. Subsequently, data recorded using Line Intercept Transect (LIT) with SCUBA apparatus [9]. Fifty meter long transect were laid in each zonation at all of the stations and parallels to the shoreline, thus total transect were nine. The substrate component beneath the line was recorded with an underwater slate and the projected length of the coral on the tape was measured to the nearest centimeter [9, 10]. Coral colonies were photographed using underwater camera an < 10 cm coral sample on longest axis were removed from living coral colonies. Living tissue of coral was removed from the specimens using household bleach [11]. The dried specimens identified as far as possible to species level using "*Coral of The World*" volume 1.2 and 3 by Veron [12].

### 2.2. Data analyses

Data was compiled and collated using MS. Excel. Percentage of coral colonies cover was calculated as the ratio of size of coral colonies to transect length [9]. Therefore, the data was summarized in a matrix of percent cover of species in each research station of Olele their respective zonation (reef flat, upper reef slope and reef slope) and grouped using group-average clustering based on Bray-Curtis similarities calculated on abundance of coral species data [13]. Subsequently, a non parametric Kruskal-Wallis was performed using using PAST 2.17 to investigate differences of abundance between zonation. Non parametric test was used since normal distribution assumption can not

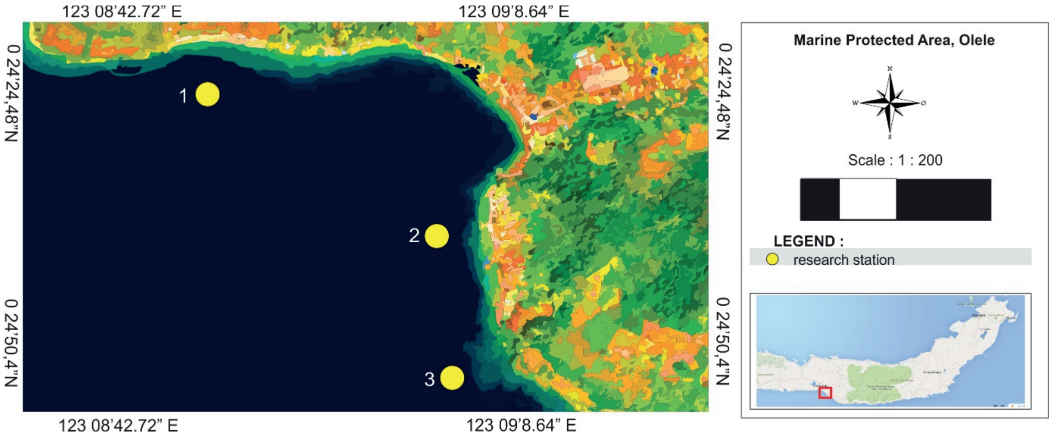



**Figure** 1: Location of study site in District-Based MPA Olele, Gorontalo, North Sulawesi.

be obtained by data transformation. Also, this information was sorted using non-metric multidimensional scaling (NMDS) [14–16].

### 2.3. Diversity index and health assessment

Three indices were used; Shannon-Wiener Diversity Index (*H*), Simpson's Dominance Index (*D*) and Pielou's evenness index (*J*). With a range value 0 to 5 for (*H*), higher value of Shannon Diversity index (*H*) represents higher diversity of communities. For (*D*) value and (*J*) value, with a range value 0 to 1, the higher value, the less variation in communities. For health assessment, Coral Mortality Index (CMI) was calculated as the ratio of dead coral colonies to total cover of both live and dead corals. The index values range between 0 to 1 which is reflected the degree of degradation from live coral (LC) to dead coral (DC). Value 0 (no change) and 1 (significant change) [17, 18]. Furthermore, the ratio of dead coral and living coral cover was calculated with categories (1) Healthy, if percent living to dead coral > 2:1, (2). Fair/moderate, if between 2:1 and 1:2, (3) Unhealthy, if live to dead coral < 1:2) [19].

## 3. Result and Discussion

### 3.1. Diversity

A total of 35 species of Scleractinian coral was listed (Table 1) consisting of 12 families (Acroporidae, Pocilloporidae, Porotidae, Pectiniidae, Agariciidae, Faviidae, Oculinidae, Fungiidae, Merulinidae, Euphyllidae, Dendriphyllidae, Mussidae) distributed in three zones (reef flat, upper reef slope and reef slope).

| | Family | Species | Station 1 | | | Station 2 | | | Station 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | RF | URS | RS | RF | URS | RS | RF | URS | RS |
| 1 | Acroporidae | *Acropora Indonesia* | √ | – | – | √ | – | – | √ | – | – |
| | | *Acropora cerealis* | – | √ | – | – | √ | – | – | √ | – |
| | | *Acropora echinata* | – | – | √ | – | – | √ | – | – | √ |
| | | *Acropora insignis* | √ | – | – | – | – | – | √ | – | – |
| | | *Acropora nasuta* | – | √ | – | – | √ | – | – | √ | – |
| | | *Acropora palifera* | √ | – | – | √ | – | – | √ | – | – |
| | | *Acropora* sp. | – | – | – | – | – | – | – | √ | – |
| | | *Acropora prostrata* | – | – | – | – | √ | – | – | – | – |
| | | *Acropora tenuis* | – | √ | – | – | – | – | – | √ | – |
| | | *Montipora hirsuta* | √ | – | – | √ | – | – | – | – | – |
| 2 | Pocilloporidae | *Pocillopora damicronis* | √ | √ | – | √ | √ | – | √ | √ | – |
| | | *Pocillopora* sp. | – | – | √ | – | – | √ | – | – | √ |
| | | *Seriatopora hystrix* | √ | √ | – | √ | √ | – | – | √ | √ |
| 3 | Poritidae | *Porites tuberculosa* | √ | √ | – | √ | – | – | – | √ | – |
| | | *Porites lutea* | √ | √ | – | √ | – | – | – | √ | – |
| | | *Porites* sp.1 | √ | √ | – | – | – | – | – | √ | – |
| | | *Porites* sp. 2 | – | √ | – | – | – | – | – | √ | – |
| 4 | Pectiniidae | *Oxypora crassispinosa* | – | √ | – | – | √ | – | – | √ | – |
| | | *Pectinia* sp. | – | √ | – | – | √ | – | – | √ | – |
| | | *Mycedium* sp. | – | √ | – | – | √ | – | – | – | – |
| 5 | Agariciidae | *Pavona bipartita* | – | √ | – | – | √ | – | – | √ | – |
| | | *Pavona cactus* | – | √ | – | – | √ | – | – | √ | – |
| | | *Pachyseris gemmae* | – | √ | – | – | – | – | – | √ | – |
| | | *Pachyseris speciosa* | – | – | √ | – | – | √ | – | – | √ |
| 6 | Faviidae | *Echinopora lamellosa* | √ | – | √ | √ | – | √ | √ | – | √ |
| | | *Favites complanata* | √ | – | – | – | – | – | √ | – | – |
| 7 | Oculinidae | *Galaxea cryptoramosa* | – | √ | – | – | √ | – | – | – | – |
| | | *Galaxea fascicularis* | – | √ | – | – | √ | – | – | – | – |
| 8 | Fungidae | *Fungia* sp. | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| | | *Ctenactis echinata* | – | √ | – | – | √ | – | – | √ | – |
| 9 | Merulinidae | *Hydnophora rigida* | – | √ | – | – | √ | – | – | – | – |
| 10 | Euphyllidae | *Plerogyra simplex* | – | – | √ | – | – | – | – | – | √ |
| | | *Plerogyra sinuosa* | – | – | √ | – | – | – | – | – | √ |
| 11 | Dendrophyllidae | *Tubastrea* sp. | – | – | √ | – | – | – | – | – | √ |
| 12 | Mussidae | *Acanthastrea regularis* | – | – | – | – | – | – | – | – | √ |
| | **TOTAL** | | **12** | **20** | **8** | **9** | **15** | **5** | **8** | **19** | **9** |

Table 1: Diversity and distribution of Scleractinian coral in District-Based MPA Olele, Gorontalo.

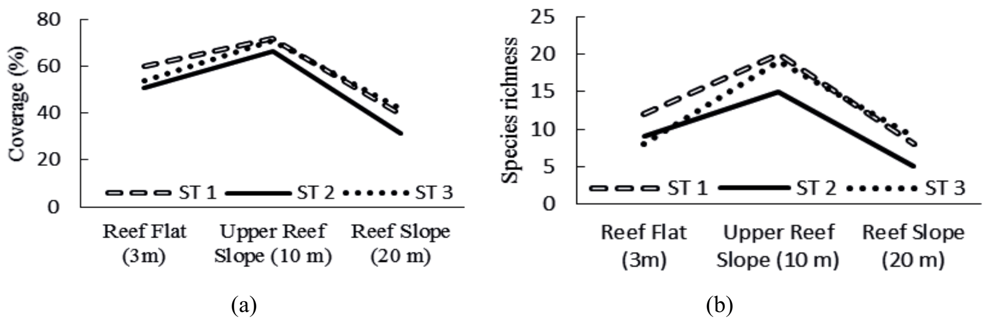



**Figure** 2: Coral abundance each zonation (a) percent living coral cover; (b) species richness.

## 3.2. Abundance

In the present study, the abundance of coral represents the percent of living coral coverage and species richness. Interestingly Figure 2a and Figure 2b showed the same pattern that there was a gradual increase from reef flat and reached a peak at upper reef slope and decrease in reef slope zone, showing the lowest coverage and species richness.

According to [20], coral reef zonation affects environmental conditions and it will be reflected by the degree of taxonomic diversity, species composition, life form or ecomorphs, percentage of coral cover, size and age of the colonies. Zonation related with depth and this factor has been recognized as one of the major parameters controlling and limiting coral species [21–23]. The trend in Figure 2 consistent with previous research Tunnicliffe [24] that stated upper reef slope zone in Indo-Pacific mostly has the highest species richness and percentage of coral cover and gradually decrease until the base of this zone. Ross and Hodson [25] in Philippines found the same pattern with [24] that showed the numbers of species were maximal in upper reef slope zone and according to Death et al. [26], Huston [27] biodiversity of corals often peaks in intermediate depths. This pattern reflecting the trade-off between reduced wave action at the depth with decreased light available for photosynthesis [28]. In the upper reef slope, corals got ideal light with lower energy regimes, oceanic water very low in nutrients and sediments. All of these factors allows the maximum number of coral species to develop [29–31]. A more developed reef with both higher total coral cover and more delicate coral species should be present in lower energy regimes [28].

In the reef, flat corals are struggling against high wave energy. According to Storlazzi et al. [28], high-energy environments the reef should be less well defined, and display both lower coral cover and more wave-resistant species. Even though Olele well known with its low wave action due to its position in Gulf of Tomini and not directly face the ocean, but the wave energy will directly hit the reef flat zone since reef crest not exist in Olele. Furthermore, although light penetration is always high in reef flat, it is not always linear with photosynthesis rate of zooxanthellae inside coral tissue. In corals exposed to extreme levels of solar radiation in general and ultra-violet light in particular, together with high water temperatures (normally associated with shallow ponded water), zooxanthellae produce oxygen 4 to 8 times faster than the coral host can take it up. When this happens, some oxygen ceases to play a normal role in photosynthesis and becomes chemically active as oxygen 'radicals' causing cellular distress. As oxygen radicals become toxic, the zooxanthellae that produce them are expelled by the corals even though this action too puts the corals at risk [32, 33] In the reef slope zone, the light was limiting factor for corals as optimal light intensity decreases. Light controls productivity, physiology, and ecology of corals. Hence, only corals with high photophysiological adaptation will present in this zone [34–36].

## 3.3. Distribution

Corals distribution can be subdivided into three general parts (reef flat, upper reef slope and reef slope) as reef crest not exist. Coral distribution varies in the bathymetric gradient, and coral community structure changes considerably with increasing depth (Figure 3). As mentioned above, term abundance refers to the percent of coral coverage and species richness of every life form. In the reef flat, coral communities dominated by ramose and non-fragile branching coral such as *Pocillopora damicornis*, *Seriatopora hystrix*, and *Acropora palifera*. According to Done [37], branching life form is morphological strategy due to wave action and corals often grow in the same direction of the wave to reduce the energy of wave. However, in the reef flat with very high energy regimes, coral with massive or encrusting colonies which would be more likely to survive. As mentioned above, Olele located in Gulf of Tomini with low energy regimes. Hence, branching corals can struggle against wave action and relatively abundant in the reef flat. Moreover, all of those dominant corals in reef flat were opportunistic coral (r-strategist) which well withstand with the surf and according to [20], in the wavestressed area, dominating corals belong mostly to opportunistic, ramose, fast growing species.

In the upper reef slope, substrate dominated by different life form compared to reef flat. In general, this was the part of reef where there was luxurious coral growth and show the greatest range of forms. There was no single life form become the most abundant since there were four dominant lifeforms namely massive, branching, ramose and foliate coral consisting 8 abundant species such as *Galaxea fascicularis*, *Pavona cactus*, *Porites lutea*, *Acropora cerealis*, *A. tenuis*, *A. nasuta*, *Pocillopora damicornis* and *Seriatopora hystrix*. Massive coral *G. fascicularis* has the highest percent cover even though there was no big discrepancy compared to another species (Figure 5). As previously described, in the upper reef slope corals obtained ideal light with lower energy

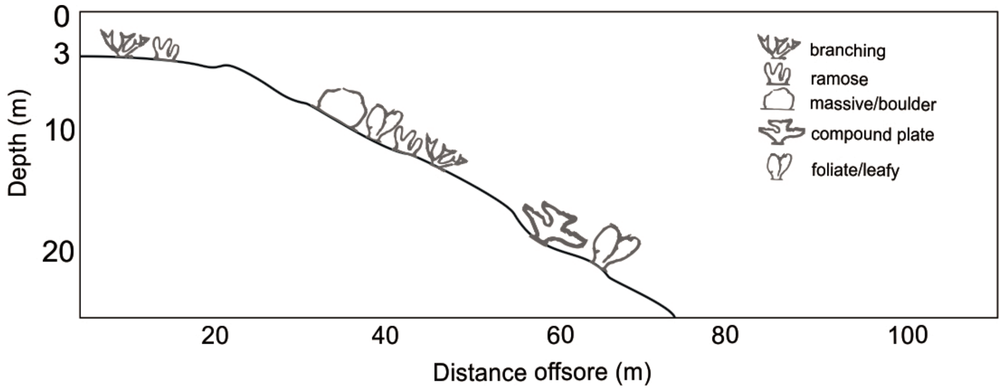
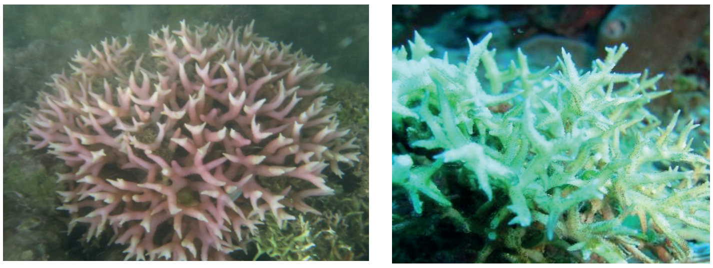



**Figure** 3: Cross-sectional profiles of the fringing reef off Olele from reef flat (3 m) to reef slope (20 m) life form symbol adapted from Chappel [38].



(a) (b)

**Figure** 4: Different form of *Seriatopora hystrix* colony, (a) reef flat; (b) upper reef slope.

regimes, oceanic water very low in nutrients and sediments. All of those condition supports corals thrive in this zone. According to Holling et al. [39] in Moberg and Folke [40], reef zonation can be categorized as balance ecosystem if single dominant life form does not exist even though interspecific competition always occurs.

Interestingly there were two species have relatively high percent cover both in upper reef slope and reef flat zone, they were *P. damicornis* and *S. hystrix* (Figure 4). This might occur due to their life strategies as r-strategist with intensive breeding and increase their chances in competition for the substrate and adapt with different environmental condition [20]. Even though those species exist in upper reef slope, but the colony form was quite different.

In the reef flat, *P. damicornis* branches were highly compact and *S. hystrix*, they form short and thick branches in reef flat. In the upper reef slope, *P. damicornis* form thin and open branches and *S. hystrix* form thin and needle-like branches. This morphological compression corresponds with combined input of environmental parameters in particular wave action in reef flat and upper reef slope zone. Their sensing capabilities of the coral organism result in a phenotype that is epigenetically controlled and thus expressed as various morphotypes (growth form, color patterns) even within same species [41].

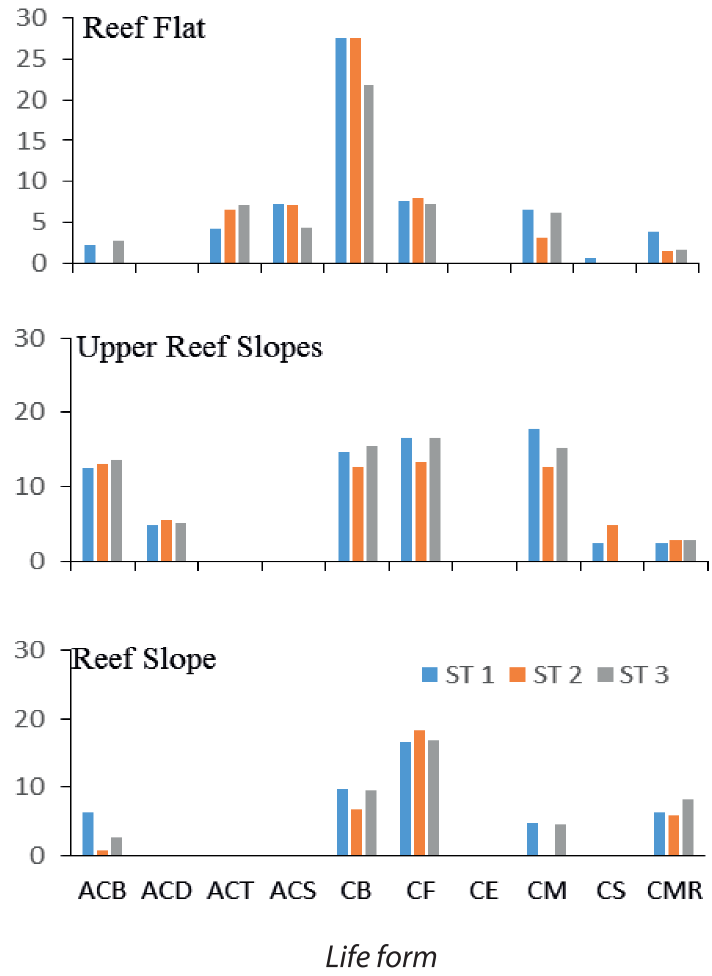
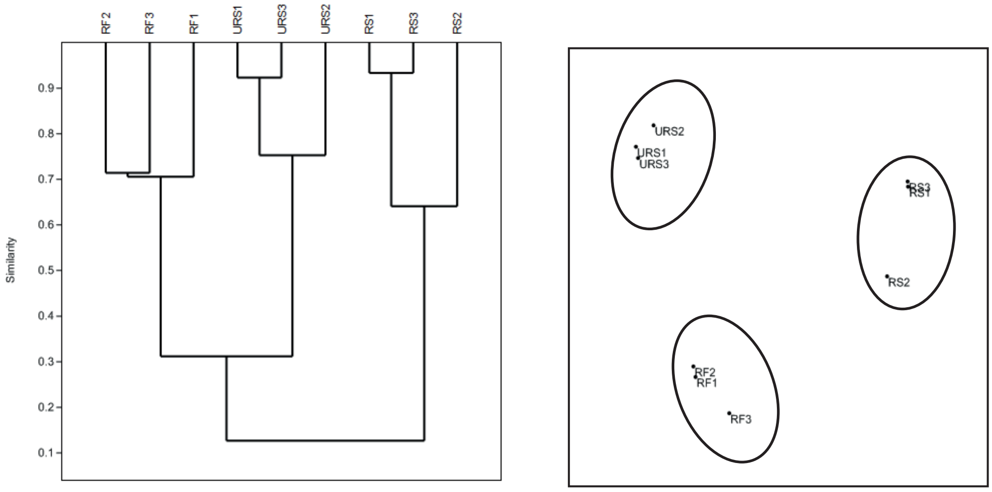



**Figure** 5: Percent of living coral cover each life form among zonation. ACB: Acropora Branching, ACD: Acropora Digitate, ACT: Acropora Tabulate, ACS: Acropora Submassive, CB: Coral Branching, CF: Coral Foliose, CE: Coral Encrusting, CM: Coral Massive, CS: Coral Submassive, CMR: Coral Mushroom (ST 1: station 1, ST 2: station 2, ST 3: Station 3).

In the reef slope which poorly illuminated, foliose and plate/laminar coral were the most abundant life form compared to others consist of two abundant species, *Pachyseris speciose* and *Echinopora lamellosa*. This adaptation highly corresponded with light availability as main source for their endosymbiont (zooxanthellae) to photosynthesis and corals need energy that produce from photosynthesis [42]. Therefore, corals adapt with very fine, thin and flat form to intercepting weak light and needing less calcareous material for their construction [43, 44]. In addition, in this zone there was several branching corals but form flattened colonies, in which most branches grow laterally, being perpendicular to the direction of light stream [44].

Each zonation in Olele has its own pattern in term of coverage and composition of corals life form (Figure 5). This pattern of coral distribution and abundance with depth suggests that each coral species may have an optimal depth [45, 46]. Additionally, certain photosynthetic taxa may be differentially adapted to deep water where ambient light levels are too low to support their shallow-water counterparts [47].




(a) (b)

**Figure** 6: (a) Bray-Curtis similarity analysis for the Olele Reef based on abundance of coral at all of zonation; (b) MDS analysis based on abundance of coral at all of zonation. Codes for zonation were RF for Reef Flat, URS for Upper Reef Slope, and RS for Reef Slope and number belongs to research station.

| **Index** | **Reef Flat** | **Upper Reef Slope** | **Reef Slope** |
|---|---|---|---|
| Shannon-Weiner Diversity Index (*H*) | 2.23 | 2.77 | 1.91 |
| Simpson's Dominance Index (*D*) | 0.12 | 0.07 | 0.17 |
| Pielou's Evenness Index (*J*) | 0.90 | 0.89 | 0.92 |

Table 2: Calculation of diversity, dominance and evenness index between zonation.

Furthermore, we use similarity profile and ordination analyses to provide a more unbiased interpretation of the distributional patterns and the results clustered coral communities into three main groups: (i) corals in the reef flat (RF 1,2,3), (ii) corals in the upper reef slope (URS 1,2,3), and (iii) corals in the reef slope (RS1,2,3) (Figure 6a). These three major groups were also observed in the NMDS analysis (Figure 6b). Furthermore, Kruskal-Wallis that performed in this research corroborate previous results and showed was a significant difference of abundance among zonation ($p = 0.048$). Even though the result showed a significance, but the $p$ value obtained just under significance level (0.05). This result might be correlated with the relatively low number of sample in this research and may had lowered the statistical power to detect finer scale patterns [48].

## 3.4. Diversity index

There are two important factors when measuring biological diversity, richness and evenness. Species richness is very important, but evenness is crucial to determine diversity since evenness explain the variation in communities between species [49]. In order to understand diversity in all of zonation, we measured it using three different

| Research Station | Zonation | %LC/%DC | Status | CMI |
|---|---|---|---|---|
| 1 | RF | 3.52 | Health | 0.28 |
| 1 | URS | 5.55 | Health | 0.18 |
| 1 | RS | 4.21 | Health | 0.23 |
| 2 | RF | 2.56 | Health | 0.39 |
| 2 | URS | 4.48 | Health | 0.22 |
| 2 | RS | 2.23 | Health | 0.44 |
| 3 | RF | 2.07 | Health | 0.48 |
| 3 | URS | 4.85 | Health | 0.21 |
| 3 | RS | 3.73 | Health | 0.26 |

Table 3: Health condition of coral communities in coral reef ecosystem District-based MPA Olele.

indices, such as Shannon Diversity Index (*H*), Simpson Index (*D*), and Pielou's Evenness Index (*J*) (Table 2).

In general, the higher value of Shannon Diversity Index (H) so the higher diversity of communities. However, in Simpson's index (*D*) and Pielou's evenness index (*J*), the higher value, the less variation in communities and dominance by single taxa frequently occur. Based on measurement by this index, upper reef slope has the highest *H* value and lowest *D* and *J* value compared to another reef zonation (Table 2). These results strengthen previous results in Figure 2 and Figure 5 that upper reef slope was the most diverse zonation in Olele in term of species richness and evenness compared to reef flat and reef slope. Furthermore, Table 2. showed that reef slope has the lowest *H* value, and higher *D* and *J* value, it explains that reef slope has the lowest diversity. Hence, if we rank all zonation in term of diversity (species richness and evenness) from the highest to the lowest based on results from Figure 2, Figure 5, and Table 2. they were upper reef slope, reef flat and reef slope, respectively.

## 3.5. Health assessment

We used comparison between living coral cover and dead coral cover and coral mortality index (CMI) to assess health condition of coral reef ecosystem (Table 3). All of the ratio of living corals and dead corals have value more than 2 with a range of values from 2.07 to 5.55. Moreover, the results from CMI shown there was no value more than 1 at all of research station. In addition, from the value of each zonation at all research station, upper reef slope consistently has the highest value of ratio between living and dead coral cover and lowest CMI value. Thus, based on these methods, all of coral reef ecosystem in Olele can be categorized in healthy condition and upper reef slope was the healthiest among the others zonation.

## 4. Conclusion

The results showed that there were 35 species of Scleractinian coral from 12 families and distributed in three zonations (reef flat, upper reef slope and reef slope). Each zonation has different pattern of abundance and dominant lifeform. Upper reef slope zone had the highest value of species richness, percent living coral coverage and evenness thus can be categorized as the most diverse and balance ecosystem. Based on coral health assessment, coral reef ecosystems in Olele were in healthy condition. This preliminary study should be used as a basic reference for database and conservation management strategy in District-Based Marine Conservation Area Olele as regulated by government regulations.

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