Diversity of reef fish on Lembeh Island as an indicator of the coral reef health condition

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Abstract. Lembeh Strait in North Sulawesi is one of the areas included in the world's coral triangle. Coral reef structures provide a habitat for reef fish. Herbivorous and invertivorous fish were essential to determine the direction of coral reef succession. This study aims to examine the health of coral reefs based on the presence of reef fish. Observations were conducted on January 16-19, 2019, with a total of 22 observation points. Observation of reef fish communities using the underwater visual census (UVCs) and belt transect method. At the observation site, it was found that there were 260 species of reef fish. The resilience of coral reefs based on the presence of reef fish has a high value on the parameters of the abundance of herbivorous fish, taxonomic diversity, and abundance of coral reef fish.

Keywords: coral reef health; Lembeh strait; reef fish; resilience

1. Introduction

Indonesia's coral reefs are ecosystems with the highest biodiversity in the world. There are more than 2000 fish species and 650 coral species; Indonesia is declared the center of the world's marine biodiversity [1][2]. Coral reefs play an important role both in ecological and socio-economic aspects. Unfortunately, these reefs are being degraded very fast by climate change and human activities in the last decade, such as destructive fishing, unsustainable fisheries, land base pollutants, and impact of harbour construction, which are the most severe threat to coral reefs [3]. The relationship of fish function in coral reefs is fish manure can to add nutrients to the waters, move the fish will also clean the polip coral.

Lembeh Island shows habitat heterogeneity and is rich in many different species, including endemic, rare, and most vulnerable species. The biota and reefs in this area contribute to the province's economy through tourism and fishery activities. A total of 193 species of scleractinian corals belonging to 68 genera has been recorded, including seven species of non-scleractinian coral such as Tubipora, Heliopora, Millepora, Distichopora, and Stylaster. The high diversity of species in the Lembeh Strait, not matched by comprehensive management, makes coral communities vulnerable to declining conditions[4],[5]. As a result, coral reefs were damaged, and fish cannot live properly. Pressure on reef fish also occurs due to destructive fishing (for example, cyanide and blast fishing) for ornamental and consumption fish [6].

The distribution of reef fish is closely related to the spatial distribution and condition of coral reef ecosystems. Juvenile reef fish that will settle in coral reef ecosystems. Reef fish distribution is limited due to specific habitat conditions. Reef fish depend on coral reef ecosystems to survive, especially reef fish in the juvenile stage. Reef fish need a good and healthy coral reef as a nourishment, shelter, and breeding area. However, coral reefs also need reef fish to control their competitors’ biota, so that coral reef fish are currently used as an indicator of the resilience and health of coral reefs.

Assessment of coral reef health has been done a lot by considering the local condition and a wide variety of environmental parameters. The parameter that is used to analyze starts from slight to comprehensive. We believe that using a comprehensive parameter does not necessarily guarantee a good...
result based on those studies. In assessment condition coral reefs, that formula can be delivered comprehensive information based on a national standard. So, the objective of this study is to examine the health of coral reefs based on the presence of reef fish on Lembeh Island. The information is essential for the local government when management action should be made.

2. Material and method

2.1. Study site
Observations were made for three days from 16-19 January 2019 around the waters of Lembeh Island from north to south. Observations depth were carried out at a depth of meter to a depth of 12 meters on the reef flat of Lembeh Island. Observation locations are depicted on the map (figure 1).

2.2. Data collection technique for coral reef habitat

2.2.1. Coral reef fish community structure. For reef fish communities, data collection was carried out using underwater visual census (UVCs) using belt transects 50 meters long and 5 meters wide [7]. For observation, the reef fish are target fish with an economic value, hoping that many fish will describe the excellent condition of the coral reef ecosystem. Data recorded includes individual abundance, species diversity, and the estimated total length of each individual [8].

2.2.2. Coral reef health index. The coral reef health index was measured using a method developed by the Indonesian Institute of Sciences (LIPI). LIPI’s method was determined based on two main components: percentage cover of benthic biota and biomass of coral reef fishes. The coral reef health index value from reef fish was calculated based on the biomass values of herbivorous fish (Scaridae, Siganidae, and Acanthuridae) and carnivorous fish (Serranidae, Lutjanidae, Lethrinidae, and Haemulidae). Furthermore, it will be combined with assessing the resilience index of coral reefs based on the abundance of herbivorous fish [9].

2.3. Data analysis

2.3.1. Community structure of coral reef fish. The community structure is analyzed using the following equations 1, 2, 3 and 4. Diversity is known using the Shannon-Wiener index, which considers species richness and evenness [10].

\[ H_i = \sum P_i \ln P_i \]  

Pl is the proportion of abundance of species i.
The equation calculates evenness:

\[ E_i = \frac{H_i}{H'max} \]  

(2)

H' is the diversity index, H'max = H' / Ln S, and S is the species richness.

The equation calculates dominance:

\[ C = \Sigma P_i^2 \]  

(3)

Pi is the proportion of abundance of species i.

Fishes biomass was calculated using the length-weight relationship approach for each type of fish [11].

\[ W = a \cdot L^b \]  

(4)

W = weight (g);  
L = fork length (cm);  
a dan b = constant

2.3.2. Coral reef health index. The coral reef health index is analyzed using table 1,2 and 3.

3. Result and discussion

3.1. Reef fish community structure

The index of diversity and abundance of reef fish is influenced by the number of individuals and types of fish found in coral reefs. The high fish population is influenced by good environmental conditions, sufficient food, shelter, and a low level of predation [13]. The fish diversity index is in the low to the high category, indicating that the fish community is under pressure to stable conditions. The dominance index shows the dominance of certain species from low to moderate levels. The higher dominance value will affect the stability of fish in the community and their diversity [14]. Based on observations, the coral reef fish community was quite varied, with 260 reef fish species. It's also stated by Campbell that around 342 species of reef fish from 48 families have been found in Lembeh Island. Based on the
analysis of the coral reef fish diversity index, a value of 3.77 was obtained. It means the diversity of coral reef fish was high, with the highest value at the Angel Window location (4.82) and the lowest at the Dorbolaang (2.14). The evenness index was used to see the distribution of individuals in the community and obtained a value of 0.91 which means that the reef fish community was in stable condition, with the highest index at Tugu Trikora (1.13) and the lowest at Dorbolaang (0.59). The dominance index value of 0.06 means no dominant species in the community, where the highest is in Dorbolaang (table 4).

The reef fish abundance is quite varied, with a range of 100-2700 individuals/ha, with a total of about 3,572,360 individuals/ha. *Pomacentrus coelestis* was the most abundant reef fish, then *Pomacentrus alexanderae*, *Amblyglyphidodon curacao*, and *Amblygliphidodon aureus* as the list of 10 species with the highest abundance are shown in figure 2b. Biomass is quite varied from 0.01 to 7,073.67 kg/ha, with a total of 83,701.13 kg/ha. The highest biomass is shown by *Ctenochaetus striatus*, then *Odonus niger*, *Zebrasoma scopas*, and *Amblyglyphidodon curacao* (figure 2a). Based on the family, the dominant one is Pomacentridae which is associated with corals, especially the life form of branched corals. Campbell et al. 2009 stated that in the Lembeh Strait, the family Pomacentridae (damselfishes) having the highest number of species. Pomacentridae is closely related to the life form of branching corals because the Pomacentridae group often inhabits crevices in the branches of hard corals. Even some Pomacentridae species have a preference for certain types of branching. This family is also vulnerable to habitat damage on coral reefs [16].

### Table 4. Indeks H' (diversity), E (evenness), C (dominance) and species richness (S).

| No | Research Location   | H'  | E   | C  | S  |
|----|---------------------|-----|-----|----|----|
| 1  | Angel Window        | 4,82| 1,06| 0,01| 96 |
| 2  | Batu Lubang Kecil   | 4,51| 0,99| 0,01| 63 |
| 3  | Batu Sandar         | 3,17| 0,87| 0,06| 38 |
| 4  | Dorbolaang          | 2,14| 0,59| 0,25| 38 |
| 5  | California Dreaming | 3,29| 0,85| 0,07| 48 |
| 6  | Honey Bay           | 2,76| 0,77| 0,12| 36 |
| 7  | Karang Napokering   | 4,56| 1,06| 0,01| 75 |
| 8  | Kelapa satu         | 4,64| 1,03| 0,01| 89 |
| 9  | Pante nusu          | 4,51| 1,02| 0,02| 82 |
| 10 | Pasir Panjang       | 4,8 | 1,03| 0,01| 107|
| 11 | Pasir Parigi        | 4,69| 1,03| 0,01| 97 |
| 12 | Pintu Kota          | 3,01| 0,75| 0,1 | 55 |
| 13 | Pulau Dua           | 4,49| 1,05| 0,02| 71 |
| 14 | Tanjung Dula        | 3,38| 0,91| 0,05| 42 |
| 15 | Tanjung Kubui       | 2,79| 0,84| 0,1 | 28 |
| 16 | Tanjung Kuning      | 4,66| 1,04| 0,01| 90 |
| 17 | Tanjung Limango     | 3,39| 0,79| 0,06| 73 |
| 18 | Tanjung Mandolang   | 3,55| 0,88| 0,05| 56 |
| 19 | Tanjung Pancuran    | 4,36| 1,04| 0,02| 66 |
| 20 | Tanjung Paudean     | 2,6 | 0,72| 0,15| 38 |
| 21 | Timur Pasir Panjang | 2,29| 0,69| 0,17| 28 |
| 22 | Tugu Trikora        | 4,62| 1,13| 0,01| 59 |
An ecosystem can have high species diversity, but if there is missing one important functional group, then the function of the ecosystem will be disrupted. Herbivorous fish in coral reefs consist of four families were Acanthuridae, Scaridae, Siganidae, and Kyphosidae. The first three families were the main herbivorous fish. Based on their trophic level, the results of the analysis of coral reef fish on Lembeh Island show that the composition and proportion are based on biomass (figure 3b). The dominant fish were omnivorous (45%), followed by herbivorous (24%), carnivorous (20%), planktivorous (9%) and corallivorous (2%). Based on the composition of the abundance proportion (figure 3a), it can be seen that omnivores (64%), followed by carnivores (16%), herbivores (11%), planktivores (7%), and Corallivores (2%). The omnivores, herbivorous, carnivorous, and planktivorous reef fish were dominant based on abundance and biomass. It is mean these groups are large-bodied reef fish that dominate the coral reef ecosystems on Lembeh Island. On the other hand, only planktivorous fish are in small size.

The abundance and biomass of target fish on Lembeh Island show a higher omnivorous composition than the herbivorous reef fish. It indicates that the condition of the target fish community is experiencing disturbances, where the regular composition should be around 60% of herbivorous fish in a healthy coral reef ecosystem. However, variations can be different in other locations [17]. Low herbivore intensity will cause macroalgae dominance over coral communities stated that low abundance herbivores would

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**Figure 2.** The ten highest abundance and biomass of coral reef fish at the observation site. (a) biomass (kg/ha) and (b) abundance (individual/ha).

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increase the abundance of macroalgae communities or algal turf [18][19]. Biomass of herbivorous fish will increase the ability of coral reefs to recover because it increases post-settlement survival, and the loss of these fish groups will increase macroalgae cover [20][21]. Previous studies on Sangiang Island and Belitung in Indonesia showed the vital role of herbivorous fish in controlling the abundance of macroalgae [22][23]. Then another study exhibits that the critical function of turtles and dugongs in Jamaica does not cause a phase shift because herbivorous fish could replace their functions. In general, sustainable fisheries will choose carnivorous fish as a fishing target. However, if there is a derivation of the carnivorous fish catchment, herbivorous fish will be the next catchment [24]. The low abundance and biomass of herbivorous fish in Lembeh Island usually indicate that fisheries in the area are no longer sustainable and impact the decrease of coral reef conditions.

3.2. Coral reef health index
Coral Reef Health Index is expected to be a tool in measuring management with specific standards in measuring whether the ecosystem is in good condition or not. Reef fish can be grouped into three based on utilization status in capture fisheries, namely major, target, and indicator fish. The target fish obtained varies between 0.1 to 3,777.6 kg/ha with a total of 20,798.3 kg/ha (figure 4b), and the abundance ranged from 40 to 85,500 ind/ha with a total of 447,720 ind/ha (figure 4a). Where the highest abundance and biomass is at Pasir Panjang and the lowest at Tugu Trikora station. Uniquely, Pintu Kota contains all family groups of target fish. In other locations such as Angel Window, Karang Napokering, Kelapa Satu, Pasir Panjang, Pasir Parigi, Tanjung Kuning, Tanjung Limango, and Tanjung Pancuran only found four to six family, while at Batu Lubang Kecil, Batu Sandar, Borbolaang, California Dreaming, Honey Bay, Pante Nusu, Pintu Kota, Pulau Dua, Tanjung Dula, Tanjung Kubui, Tanjung Mandolang, Tanjung Paudean, Timur Pasir Panjang and Tugu Trikora only found one to three family of target fish. biomass is at Pasir Panjang and the lowest at Tugu Trikora station. Uniquely, Pintu Kota contains all family groups of target fish. In other locations such as Angel Window, Karang Napokering, Kelapa Satu, Pasir Panjang, Pasir Parigi, Tanjung Kuning, Tanjung Limango, and Tanjung Pancuran only found four to six family, while at Batu Lubang Kecil, Batu Sandar, Borbolaang, California Dreaming, Honey Bay, Pante Nusu, Pintu Kota, Pulau Dua, Tanjung Dula, Tanjung Kubui, Tanjung Mandolang, Tanjung Paudean, Timur Pasir Panjang and Tugu Trikora only found one to three family of target fish.

Acanthuridae family dominated the abundance (86%) and biomass (88%) of target fish in Lembeh Island, while the lowest was Lethrinidae (0.01%). The Acanthuridae family was dominant on Lembeh Island because these fish were found in almost all observation locations except Honey Bay and Trikora Monument. The fish species of the Acanthuridae family found on Lembeh Island were abundantly dominated by Zebrasoma scopas, but in terms of biomass, it was dominated by Ctenochaetus striatus. Predatory fish groups such as snapper (Lutjaniidae), grouper (Serranidae), emperor fish (Lethrinidae), sweetlips (Haemulidae) each have a biomass of 77.82 kg/ha (0.37%); 381.74 kg/ha (1.84%); 1.65 kg/ha (0.01%); 278.54 kg/ha (1.34%); and 563.92 kg/ha (2.71%). Furthermore, their abundance was found to
be 600 species/ha (0.13%); 49,080 species/ha (10.96%); 40 species/ha (0.01%); 1,800 species/ha (0.40%); and 440 species/ha (0.10%). Based on these results, Lethrinidae is the fish with the least abundance and biomass because, in 22 observation sites, the fish were only found in one location (Pitu Kota). The most abundant predatory fish family is Serranidae (11 species), with *Pseudanthias dispar* being the most commonly found species. Next are the Lutjanidae and Haemulidae families, with three species each, with the dominant species being *Lutjanus decussatus* and *Plectorhinchus albovittatus*. In comparison, the Lethrinidae are only contained by *Gnathodentex aureolineatus*.

**Figure 4.** Abundance (a) and biomass (b) of target fish at the observation site.
The presence of reef fish in quality and quantity can be used as bioindicators of the condition of coral reef ecosystems. Mainly, massive coral colonies provide habitat for large-bodied Seranididae and Lutjanidae [25]. The reef fish community structures could monitor overall coral reef health due to their strong affinity for corals, such as the association of Chaetodontidae tribe as obligate corals and indicators of coral reef health [26][16].

The predatory fish that are the target catches, such as Lutjanidae, Serranidae, Lethrinidae, Siganidae, and Haemulidae, are generally classified as high economic fish [27]. Controlling these groups will affect the herbivores group's composition and, in general, will change the structure fish community. Thus the corallivorous, herbivorous, and carnivorous can be determined as an indicator to monitor coral reefs conditions [28][29].

A general abundance of herbivorous fish was poor, the biomass of reef fish was dominant in the low category, and the diversity of indicator fish was dominant in the low category. Based on table 5, there are five locations (Angel Window, Nusu Beach, Pasir Panjang, Pulau Dua, and Tanjung Kuning) with high target fish biomass but very few herbivorous fish abundances. In contrast, the diversity of indicator Fish was moderate to high. There were four locations with moderate target fish biomass, but the abundance of herbivorous fish was low, while the diversity of indicator fish and abundance of corallivores fishes on live coral were moderate to very high. Furthermore, there were 13 locations with low target fish biomass, but the abundance of herbivorous fish and the diversity of indicator fish was very low.

### Table 5. Coral reef health index in observation site.

| No  | Observation site  | Biomassa of Reef Fish | Abundance of Herbivorous Fish | Diversity of Indicator Fish |
|-----|-------------------|-----------------------|-------------------------------|-----------------------------|
| 1   | Angel Window      | High                  | Very Low                      | High                        |
| 2   | Batu Lubang Kecil | Low                   | Very Low                      | Low                         |
| 3   | Batu Sandar       | Low                   | Very Low                      | Low                         |
| 4   | Dorbolaang        | Low                   | Very Low                      | Low                         |
| 5   | California Dreaming | Low                | Very Low                      | Low                         |
| 6   | Honey Bay         | Low                   | Very Low                      | Low                         |
| 7   | Karang Napokering | Moderate             | Very Low                      | Moderate                    |
| 8   | Kelapa satu       | Moderate             | Very Low                      | High                        |
| 9   | Pante nusu        | High                  | Low                            | Moderate                    |
| 10  | Pasir Panjang     | High                  | Low                            | High                        |
| 11  | Pasir Parigi      | Moderate             | Very Low                      | High                        |
| 12  | Pintu Kota        | Low                   | Very Low                      | Low                         |
| 13  | Pulau Dua         | High                  | Low                            | Moderate                    |
| 14  | Tanjung Dula      | Low                   | Very Low                      | Low                         |
| 15  | Tanjung Kubui     | Low                   | Very Low                      | Low                         |
| 16  | Tanjung Kuning    | High                  | Low                            | Moderate                    |
| 17  | Tanjung Limango   | Low                   | Very Low                      | Low                         |
| 18  | Tanjung Mandolang | Low                   | Very Low                      | Low                         |
| 19  | Tanjung Pancuran  | Moderate             | Very Low                      | Moderate                    |
| 20  | Tanjung Paudean   | Low                   | Very Low                      | Low                         |
| 21  | Timur Pasir Panjang | Low            | Very Low                      | Low                         |
| 22  | Tugu Trikora      | Low                   | Very Low                      | Low                         |
The locations of Angel Window, Nusu Beach, Pasir Panjang, Pulau Dua, Karang Napokering, Kelapa Satu, Pasir Parigi, Tanjung Pancuran, and Tanjung Kuning are areas with healthy coral reef ecosystem conditions due to the condition of target fish biomass from moderate to high and diversity of indicator fish were moderate to high. In contrast, the abundance of herbivorous fish is very low. Furthermore, the locations of Batu Lubang Kecil, Batu Sandar, Dorbolaang, California Dreaming, Pintu Kota, Tanjung Dula, Tanjung Kubui, Tanjung Limango, Tanjung Mandolang, Tanjung Paudean, East Pasir Panjang, and Tugu Trikora are included as poor coral reef condition, because of the lack of target fish biomass, abundance of herbivorous fish and also the lack of abundance of indicator fish.

In general, it can be said that the condition of the coral reef ecosystem on Lembeh Island is poor based on the target fish biomass, diversity of indicator fish, and abundance of herbivorous fish. Several studies show that the abundance of indicator fish groups such as the Chaetodontidae family correlates with the live coral cover. Chaetodontidae made coral polyps as food items, so if the coral reefs in an area are healthy, Chaetodontidae will be visited this habitat. Chaetodontidae are valued as a relative measure to determine coral reef health in general [30][31][32][33]. Furthermore, the abundance and biomass of herbivorous fish also strengthen the analysis results. The low abundance and biomass of herbivorous fish in these nine locations is due to the lack of algae as food. Some researchers state that herbivorous fish will control the growth of algae that inhibit the recruitment of new corals and coral growth by providing an open substrate as a place for recent coral individuals/colonies to attach [35][37][9][36][37][22][23]. In contrast, overexploitation of herbivorous fish will cause high algae growth [19][38]. Low herbivorous abundance could lead to a decreasing percentage of coral cover and increase the mortality of recent corals colonies [39]. Furthermore, Mumby et al. [40] stated that The abundance of herbivorous fish was negatively correlated with the percentage of macroalages cover but positively correlated with the addition of individuals/coral colonies.

4. Conclusion
Some conclusions that can be drawn from the results of this study are:
1. Angel Window, Nusu Beach, Pasir Panjang, Pulau Dua, Karang Napokering, Kelapa satu, Pasir Parigi, Tanjung Pancuran and Tanjung Kuning were areas with healthy coral reef ecosystem conditions on Lembeh Island, based on the structure of the coral reef fish community.
2. Batu Lubang Kecil, Batu Sandar, Dorbolaang, California Dreaming, Pintu Kota, Tanjung Dula, Tanjung Kubui, Tanjung Limango, Tanjung Mandolang, Tanjung Paudean, Timur Pasir Panjang, dan Tugu Trikora are locations where the condition of coral reef ecosystems is not healthy based on the structure of the coral reef fish community.
3. The condition of the coral reef ecosystem on Lembeh Island is not healthy based on the target fish biomass, diversity of indicator fish, and Abundance of herbivorous fish.

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References
[1] Allen G R and T B Werner 2002 Coral Reef Fish Assessment in the 'Coral Triangle' of Southeastern Asia *Environmental Biology of Fishes* 65 209–214.
[2] Allen G R and M Adrim 2003 Review article; Coral reef fishes of Indonesia *Zoological Studies* 42 1-72.
[3] Pandolfi J M, R C Sean, J M Dustin, L C Anne 2011 Projecting coral reef futures under global warming and ocean acidification *Science* 333 418-422.
[4] Wallace C C, Z Richard and Suharsono 2001 Regional distribution patterns of Acropora and their use in the conservation of coral reefs in Indonesia Indonesian Journal of Coastal and Marine Resources 4 40 – 58.

[5] Hoeksema B W 2007 Delineation of Indo-Malayan Center of maximum marine biodiversity: The coral triangle Biogeography, Time, and Place: Distributions, Barriers, and Islands. Topics In Geobiology, vol 29 ed W Renema (Dordrecht:Springer) 117–178

[6] Idris, E Setiawan and A Mardesyawati 2013 Status penangkapan ikan hias di kepulauan seribu tahun 2007-2009 Marine Fisheries Journal of Marine Fisheries Technology and Management 2 155.

[7] Hill J and C Wilkinson 2004 Methods for ecological monitoring of coral reefs: A resource for managers (Australia: Australian Institute of Marine Science and Reef Check)

[8] Suharti S R, K Wibowo, I N Edrus, Fahmi and M Y Iswari 2017 Indeks Kesehatan Terumbu Karang Indonesia (Jakarta: Puslit Oseanografi-LIPI) p 99

[9] Obura D O and G Grimsdith 2009 Resilience Assessment of coral reefs – Assessment protocol for coral reefs, focusing on coral bleaching and thermal stress IUCN working group on Climate Change and Coral Reefs (Gland, Switzerland:IUCN) p. 70.

[10] Magurran A E 1998 Ecological Diversity and It’s Measurement (New Jersey:Princeton University Press)

[11] Kulbicki M and Guillemot N 2005 A general approach to length-weight relationship for new Caledonian Lagoon fishes Cybium 29 235-252.

[12] Giyanto P, N Mumby, M Dhowani, Abrar and M Y Iswari 2017 Indeks Kesehatan Terumbu Karang Indonesia (Jakarta: Puslit Oseanografi-LIPI) p 99

[13] Jones G P, M I McCormick, M Srinivasan and J V Eagle 2004 Coral decline threatens fish biodiversity in marine reserves Proceeding of National Academy of Science USA 101 8251–8253.

[14] Odum E P 1998 Dasar-dasar Ekologi Diterjemahkan dari Fundamental of Ecology oleh T. Samingan (Yogyakarta:Gadjah Mada University Press)

[15] Campbell S T, R L Ardiwijaya, Y Herdiana, T Kartawijaya, S T Paredfe, F Setiawan, R Prasetya, I Yulianto 2009 A Preliminary Study: Coral Reef and Fish Survey in Lembeh Strait, North Sulawesi Indonesia (Bogor:Wildlife Conservation Society – Indonesia)

[16] Pratchett M S, Hoey A S, Wilson S K, Messmer V and Graham N A J 2011 Changes in biodiversity and functioning of reef fish assemblages following coral bleaching and coral loss Diversity 3 342–452.

[17] Bellwood D R, Hoey A S and Choat J H 2003 Limited functional redundancy in high diversity systems: resilience and ecosystem function on coral reefs Ecology Letters 6 281–285.

[18] Littler M M, Littler D S and Brooks B L 2006 Harmful algae on tropical coral reefs: Bottom-up eutrophication and top-down herbivory Harmful Algae 5 565–585.

[19] Hughes T P, Bellwood D R, Folke C S, McCook, Laurence J and Pandolfi J M 2006 No-take areas, herbivory and coral reef resilience Trends in Ecology & Evolution 22 1–3.

[20] Jompa J and McCook L J 2003a Contrasting effects of turf algae on corals: massive Porites spp. are unaffected by mixed-species turfs, but killed by the red alga Anotrichium tenue Marine Ecology Progress Series 258 79-86.

[21] Graham N A J, Jennings S, Wilson S K, Mouillot D and Mcneil A 2015. Predicting climate-driven regime shifts versus rebound potential in coral reefs Nature 518 136-142.

[22] Idris, Putri A R, Aidiwijaya C, Gilang M, Santoso P, Prabowo B, Muhammad F, Lestaringhish W A, Lestari D F, Setyaninggis W A and Zamani N P 2020 Assessment of coral reefs health in Nature Recreation Park (TWA=Taman Wisata Alam) Sangiang Island, Banten. IOP Conference Series Earth and Environmental Science 429 012020.

[23] Idris, Fakhrurozi and Aidiwijaya C 2021 Assessment of coral reef health conditions in Juru Seberang Village, Tanjung Pandan District, Belitung Regency-Bangka-Belitung Province IOP Conference Series Earth and Environmental Science 744 012030.
Bacthiar I, Suharsono, Damar A and Zamani N P 2019 Practical resilience index for coral reef assessment Ocean Science Journal

Campbell S J and Pardele S T 2006 Reef fish structure and cascading effect in response to artisanal fishing pressure Fisheries Research 79 75-83.

Komyakova V, Munday P L and Jones G P 2013 Relative importance of coral cover, habitat complexity and diversity in determining the structure of reef fish communities PLoS ONE 8 e83178.

Badrudin, Aisyah and Wiadnyana N N 2010 Indeks Kelimpahan Stok dan Tingkat Pemanfaatan Sumberdaya Ikan Demersal di WPP Laut Jawa Laporan Akhir untuk Program Insentif PKPP Ristek (Jaktab: Balai PenelitianPerikanan Laut) p 71

Bruno J 2008 Grazer composition an important factor in controlling macroalgae http://www.climateshifts.org/?p=597. Accessed On October 20, 2008

Setiawan F, G Santoso, E W Handoyo, T Setiyawati and Y S Uyun 2013 Kajian Keefektifan Zonasi Berdasarkan Komunitas Ikan Karang di Taman Nasional Bunaken, Sulawesi Utara (Manado:Balai Taman Nasional Bunaken) p12

Allen G R 2000 Marine Fishes of South East Asia (Perth: Kaleidoscope Pront and Prepress Periplus Edition)

Shokri M R, Fatemi S M R and Crosby M P 2005 The status of butterflyfishes (Chaetodontidae) in the northern Persian Gulf Aquatic Conserv: Marine and Freshwater Ecosystem 15 91–99.

Bouchon-Navaroa Y, Bouchon C, Louis M and Legendre P 2005 Biogeographic patterns of coastal fish assemblages in the West Indies Journal Experiment Marine Biology Ecology 315 31–47.

Pratchett M S, Wilson S K and Baird A H 2006 Declines in the abundance of Chaetodon butterflyfishes following extensive coral depletion Journal of Fish Biology 69 1269–1280.

Manuputty A E W and Winardi 2007 Monitoring Ekologi Biak (Jakarta: Coremap II-LIPI)

Green A L and Bellwood D R 2009 Monitoring functional groups of herbivora reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region IUCN working group on Climate Change and Coral Reefs (Gland : IUCN) 70 pp.

Mumby P J 2006b The impact of exploiting grazers (Scaridae) on the dynamics of Caribbean Coral Reefs Ecological Applications 16 747–769.

Mumby P J, Bejarano S, Golbun Y, Steneck R S, Arnold S N, van Woesik R and Frienlander A M 2013 Empirirical relationship among resilience indicators on Micronesian Reefs Coral Reef 32 213–223.

Kopp D, Bouchon-Navaro Y, Louis M, Mouillot D and Bouchon C 2010 Herbivorous fishes and the potential of Caribbean marine reserves to preserve coral reef ecosystems Aquatic Conservation: Marine and Freshwater Ecosystems 20 516–524.

Mumby P J 2006a Connectivity of reef fishes between mangroves and coral reefs: Algorithms for the design of marine reserves at seascape scales Biology Conservation 128 215–222.

Mumby P J, Dahlgren C P, Harborne A R, Kappel C V, Micheli F, Brumbaugh D R and Buch K 2006 Fishing, trophic cascades, and the process of grazing on coral reefs Science 311 98–101.