

Assessing functional diversity and biomass of herbivorous fish as resilience indicators of coral reef ecosystems in Doreri Bay, Manokwari Regency, Indonesia

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Abstract. The issue of coral reef resilience is important in this era of climate change and herbivorous fish is one of the key resilience indicators of coral reef ecosystems. This study is a baseline study that aims to assess functional diversity and biomass of herbivorous fish as indicators of resilience potential of coral reef ecosystems in Doreri Bay, Manokwari Regency. Belt transect method was applied in collecting fish species data, number, and length of fish. The functional diversity of herbivorous fish groups was calculated as the number of functional groups present at each observation site. The average length of the fish size class was applied to calculate biomass using the length-weight relationship formula (L-W), which is $W = a \times L^b$, where a and b are the parameter values for each species obtained from FishBase. Biomass was calculated as an estimate of the total weight of herbivorous fishes, divided by the area covered by transects, then converted to units of grams per square meter (g m^{-2}). To obtain a composite value from both indicators at each site, the normalization process of the values of each indicator was carried out, then the values of both were averaged. The results showed that herbivorous fish in Doreri Bay consisted of 3 functional groups, namely grazers/detritivores, small excavators/scrapers, and browsers. The grazer/detritivore group was found at 29 sites, scraper/small excavator at 20 sites and browsers at only 12 sites out of a total of 30 observation sites. Biomass values are generally relatively low, ranging from 0.85 to 494.12 g m^{-2} and the average biomass ranging from 0.42 to 54.90 g m^{-2} . The highest biomass values are found in the southwest of Lemon Island, in the southern reef flat, and south of Lemon Island. In contrast, the lowest biomass was found in the east and northeast of Lemon Island, as well as the northern reef flat. The results of this study suggest that long-term monitoring programs need to be designed to provide long-term trend information from herbivorous fish populations and other important factors in maintaining coral reef resilience.

Key Words: detritivores, coastal management, climate change, coral reef management.

Introduction. Assessing the resilience of coral reefs is an important part of resilience-based management (RBM), which can support the determination of priorities and action plans for coral reef management. The development of the concept of assessing the potential for the resilience of coral reefs was initially initiated by Salm et al (2001) and then continued by West & Salm (2003). This concept was built in response to the serious coral bleaching event in 1998. This was based on the idea that coral reefs have physical and ecological characteristics that enable some coral reefs to survive or recover from disturbances.

The status of coral reef ecosystems is usually measured and monitored using indicators of coral abundance or cover from important taxonomic groups. Whereas coral abundance or cover is not the right measure to describe resilience, because healthy reefs that are in the process of recovery lead to a coral-dominated equilibrium condition may have fewer corals compared to reefs which are heading towards conditions dominated by macroalgae. The coral cover can only be a phase shift indicator if one same location is monitored regularly within a few years (Hughes et al 2010).

One example of a shift in status has ever happened to coral reefs in the Caribbean. Although some aspects of the ecosystem are increasingly understood, none of the researchers suspect the sudden dramatic shift from large reefs to algae-dominated status. Increased sediment load as a result of land use has spurred algal growth, but this is not apparent because herbivorous fish suppress the development of algae. Over time the intensive fishing activities reduce the number of herbivorous fish. In response to starfish density the *Diadema antillarum* increases and takes the role of herbivorous fish. But finally, when the disease attacks the *D. antillarum*, algae are released from their eating control so that algae eventually developed very rapidly and dominated the reef area in a short time (Scheffer & Carpenter 2003; Mumby et al 2007; Roff & Mumby 2012).

Learning from the case examples in the Caribbean, one of the important things in supporting sustainable management of coral reef ecosystems is a clear understanding of the role played by certain herbivores in limiting the development of harmful algae and supporting corals under a range of certain environmental conditions. Herbivores are a key role that supports the continuity of reefs by inhibiting the development of macroalgae which can have an impact on the habitat, growth, and survival of corals (Heenan & Williams 2013; Adam et al 2015a). The increase in herbivorous fish has the opportunity to reduce algal competition against corals (Bonaldo & Hay 2014; Stender et al 2014; Pawlik et al 2016).

Pattiasina et al (2018a) in their study concerning the potential of the coral reef regime in Doreri Bay found that although the percentage of live coral cover is still relatively good, there is potential for the development of alternative reef regimes such as the abiotic regime and algae regime. While the results of other studies on the potential resilience of coral reef ecosystems carried out in Doreri Bay by Pattiasina et al (2018b) shows that around 53% of sites surveyed in Doreri Bay belong to the class of potential for low coral resilience. Among all indicators used to assess the potential for resilience, herbivorous biomass is an indicator that has the lowest average value. Referring to the results of these studies, further research is needed regarding the condition of herbivorous fish in Doreri Bay, taking into account the importance of the herbivorous role in maintaining the resilience of coral reef ecosystems. This study aims to assess the functional diversity and biomass of herbivorous fish as an indicator of potential resilience of coral reefs in the Doreri Bay region, Manokwari Regency.

Material and Method

Description of the study sites. This research was conducted in Doreri Bay, Manokwari Regency, West Papua Province, Indonesia. Doreri Bay is part of Manokwari Regency, West Papua Province, and is also part of the Papua Bird's Head Seascape (Bird's Head Seascape - BHS). BHS is the biggest contributor to coral diversity and reef fish in the tropics (Allen & Erdman 2009). The Doreri Bay waters are also known as ecotone between Cenderawasih Bay and the Pacific Ocean waters. This can be seen from the uniqueness of the kepe-kepe (Chaetodontidae) fish pattern in Doreri Bay (Allen & Erdman 2008). Until now the Doreri Bay coral reef fisheries have become the main source of food and income for local communities. However, with the increase in population and increasing development activities in Manokwari, the coral reef ecosystem in Doreri Bay is currently under pressure both from the development impacts and from the effects of climate change.

Doreri Bay is located in a geographical position 0° 52' 43" S - 1° 0' 29" S and 134° 08' 06" E - 134° 04' 03" E, covering the administrative area of 3 districts in Manokwari Regency, namely East Manokwari District, West Manokwari and South Manokwari (Figure 1). In these three districts concentrated various development activities since Manokwari was established as the capital of West Papua Province in 1999. Based on the analysis of Landsat satellite images, Doreri Bay's waters area is around 131.83 km² and is a unity of five small bays, namely Pasirputih Bay, Sawaibu Bay, Wosi Bay, Sowi Bay, and Andai Bay. These five bays are estuaries of rivers and large and small waterways. The use of space in the upper land has an impact on the aquatic environment in the Doreri Bay

region in the form of increasing frequency and intensity of floods, erosion, increasing sedimentation in river estuaries and decreasing the quality of the waters of Doreri Bay. Besides that, fishing with methods that can damage coral reef ecosystems is still carried out even though there have been awareness efforts from the government and universities.

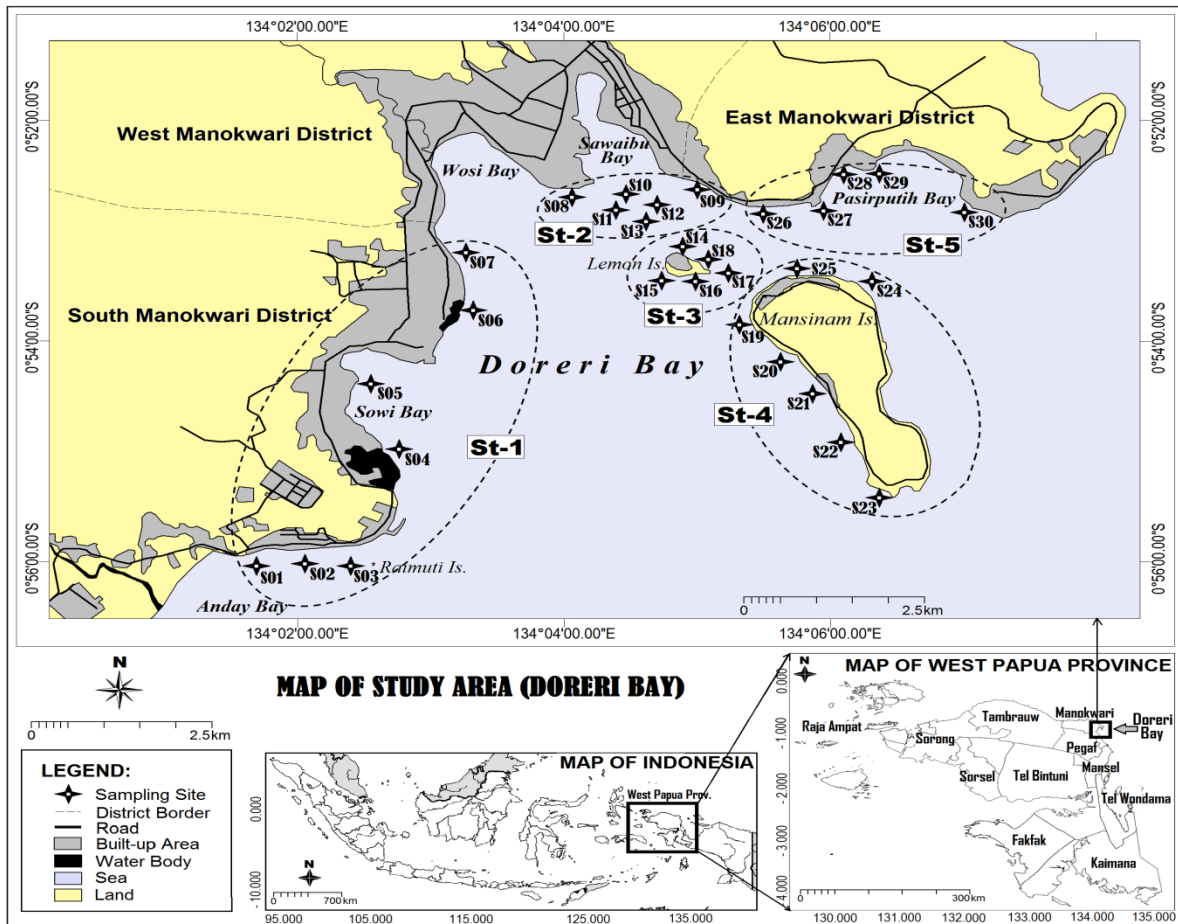


Figure 1. Map of the study area showing the location of Doreri Bay and the location of sampling sites. Dot circle showing the group of sites at each observation station.

Data collection. Determination of stations and data collection points was carried out based on a preliminary analysis of Landsat 8 OLI images, 2016 recordings, and preliminary survey results. Data collection on herbivorous fish was carried out at 5 observation stations that could represent and describe the overall condition of the coral reefs at the study site. A total of 30 points were determined for data collection (Table 1), which are spread from the west side of the bay to the bay side and included three small islands inside the bay (Figure 1). Data on functional diversity indicators of herbivorous fish and biomass indicators of herbivorous fish were collected by the belt transect method. At each sampling point, three belt transects measuring 5×50 m were used to collect fish community data. For each transect, the number and total length (TL) of the fish was observed for each species, using a 5 cm long class (Jupiter & Egli 2011). The geographical position of the data collection point was recorded with a Garmin 64 CSx receiver.

In order to calculate the functional diversity of herbivorous fish, fish species were classified into herbivorous fish and others. Herbivorous fish were then divided into four functional groups: large excavators, browsers, grazers/detritivores and small excavators/scrapers (Green & Bellwood 2009). For each point, the functional wealth of the group of herbivorous fish "herbivore functional group richness" was calculated as the number of functional groups present. To calculate the biomass of each fish, the average

length of the fish size class was applied, in the long-weight relationship formula (LW), namely $W = a \times L^b$, with a and b parameter values for each selected species selected from the points closest observations to Manokwari in FishBase (Froese & Pauly 2009). The L-W conversion requires a fork length - FL parameter. For this purpose conversion factors from total length to fork length (TL-FL) were also obtained from FishBase (Froese & Pauly 2009), and were applied before the calculation of body weight. For each point, "herbivorous biomass" is calculated as an estimate of the total weight of all herbivorous fish, divided by the area covered by the transect, then converted to units of grams per square meter ($g\ m^{-2}$).

The base map of the research location was made by digitizing the screen with the background of satellite images from the provider Bing using the OpenLayers Plugin on the QuantumGIS (QGIS) 3.2 open source software. Measurement points and sampling were marked with a GPS receiver, and then imported into QGIS software in the form of a point map of field data. Then a geometric correction process was carried out which includes the georeferencing process and sample. This is intended to equalize the spatial reference of the sample point map with the base map of the research location so that it can be overlapped.

Table 1

The sampling stations and sites in the study area with geographic coordinates, each station consists of 5 – 7 observation sites

<i>Station</i>	<i>Site code</i>	<i>Location</i>	<i>Latitude</i>	<i>Longitude</i>
Station 1 (7 sites) West of Doreri Bay	S01	Arfai	134.02844	-0.93302
	S02	Arfai-Raimuti	134.03289	-0.93235
	S03	Raimuti	134.03970	-0.93282
	S04	Telaga Wasti	134.04510	-0.91637
	S05	Marampa Port	134.04058	-0.90538
	S06	Telaga Rendani	134.05218	-0.89735
	S07	Rendani Settlement	134.05353	-0.88852
Station 2 (6 sites) Sawaibu Reef Flat	S08	Sanggeng BLK	134.06944	-0.87672
	S09	Kwawi	134.08360	-0.87591
	S10	North Reef Flat	134.07611	-0.87713
	S11	West Reef Flat	134.07504	-0.87868
	S12	South Reef Flat	134.07800	-0.87901
	S13	East Reef Flat	134.07713	-0.88050
Station 3 (5 sites) Lemon Island	S14	North Lemon	134.08158	-0.88562
	S15	South West Lemon	134.07915	-0.88960
	S16	South Lemon	134.08245	-0.88946
	S17	East Lemon	134.08562	-0.88906
	S18	North East Lemon	134.08454	-0.88724
Station 4 (7 sites) Mansinam Island	S19	Mansinam Cemetery	134.08852	-0.89540
	S20	Mansinam Bunker	134.09196	-0.89978
	S21	Mansinam Mariculture	134.09857	-0.90727
	S22	South West Mansinam	134.10241	-0.91650
	S23	Mangewa Cape	134.10648	-0.92286
	S24	North East Mansinam	134.10101	-0.88884
	S25	North Mansinam	134.09583	-0.88869
Station 5 (5 sites) East of Doreri Bay	S26	Inggandi Beach	134.09272	-0.87937
	S27	Inggandi Cape	134.09716	-0.87922
	S28	Pasirputih Cemetery	134.09997	-0.87449
	S29	Pasirputih Cape	134.10456	-0.87478
	S30	Pasirido	134.11832	-0.88041

Data analysis. Descriptive statistics (mean±SE) were applied to compare the total biomass of herbivorous fish between stations and biomass for each functional group of herbivorous fish. To compare the potential resilience of coral reefs based on functional

group indicators and herbivorous fish biomass between sites and between observation stations methods were applied according to Maynard et al (2015), through the following stages:

- 1) Compilation of indicator variable data: Data on functional diversity indicator variables and herbivorous fish biomass for all sampling points (site) are compiled in one ms-excel table.
- 2) Normalization of indicator variable data: The normalization process is done by dividing the value of each indicator from each site with the maximum value of the indicator among all sites.
- 3) Merging the values of indicators: The average value of the indicator of functional diversity and the indicator value of the biomass of herbivorous fish is calculated for each site.
- 4) Calculation of relative resilience values: At this stage, an assessment of the resilience of each site is carried out relative to other sites, specifically for sites with the highest combined average indicator value (the result in the "c" point above). For this purpose, anchoring the average value of the combined indicator of the entire site against the maximum combined indicator value.
- 5) Grouping sites based on value categories: Grouping site-sites based on the following criteria:
 - High (High Resilience): the value of resilience is relatively more than the average plus one standard deviation ($\text{Value} > \text{Average} + 1 \text{ STDEV}$);
 - Medium-High (Medium-High Resilience): the value of resilience is relatively more than the average, and less than the average plus one standard deviation ($\text{Value} > \text{Average}$ and $< \text{Average} + 1 \text{ STDEV}$);
 - Medium-Low (Medium-Low Resilience): the value of resilience is relatively less than the average, and more than the average of less than one standard deviation ($\text{Value} < \text{Average}$ and $> \text{Average} - 1 \text{ STDEV}$);
 - Low (Low Resilience): the value of resilience is relatively less than the average of less than one standard deviation ($\text{Value} < \text{Average} - 1 \text{ STDEV}$).

Results

Functional diversity of herbivorous fish. Herbivorous fish in Doreri Bay were classified into 3 functional groups, namely grazers/detritivores, small excavators/scrapers, and browsers. The large excavators group was not found during the survey period. The grazers/detritivores group was found in almost all sites (29 sites), except site S29. Scrapers/small excavators group were found at 20 observation sites. Meanwhile, browsers group was only found at 12 sites (Table 2). The grazers/detritivores group consisted of the families of Acanthuridae, Pomacanthidae, and Siganidae. The browsers group consisted of the fishes of Acanthuridae and Ehippidae families, while the group of scrapers/small excavators consisted of only one family, namely the Scaridae family. Among the families of herbivorous fish, Pomacanthidae was the family with the most genus, namely a number of 7 genera. In contrast, the family found with the lowest number of genera was Siganidae family, with only one genus. Among all genus that existed, there were three genera with the largest number of species, namely with 6 species. These genera were the genus *Acanthurus* from the family Acanthuridae, the genus *Scarus* from the family Scaridae, and the genus *Naso* which is also from the family Acanthuridae.

The highest number of herbivorous species were 10 species found on Site S11, Site S12 and Site S13 (Station 2), and Site S16 (Station 3). Conversely, only one species was found on Site S10 (Station 2). In the 9 observation sites of a total of 30 sites were found 3 functional groups, namely grazers, scraper/small excavators and browsers, in 13 sites were found only two functional groups, and in the other 8 sites was found only one functional group (Figure 2).

Table 2
Functional groups of herbivorous fish with family, genus, and number of species

Functional group	Family	Genus	Number of species
Grazer/Detritivore (29 sites)	Acanthuridae	Acanthurus	6
		Ctenochaetus	2
		Zebrasoma	1
		Amblyglyphidodon	1
		Amphiprion	1
	Pomacanthidae	Chrysiptera	3
		Dascyllus	4
		Dischistodus	1
		Pomacanthus	1
		Pomacentrus	3
Small excavator/Scraper (20 sites)	Siganidae	Siganus	3
	Scaridae	Scarus Chlorurus	6 1
Browser (12 sites)	Acanthuridae	Naso	6
	Ephippidae	Platax	1
Total	5	15	40

In all sites, no large excavator functional group was found. In all the observation sites in the western part of Doreri Bay and several sites on the Sawaibu reef average (Site S01 - Site S10) only functional groups of grazers and scraper/small excavators were found, and no browser group. A new browser group was found on some sites in Sawaibu reef flat, some sites on Lemon Island, Mansinam Island to the east of Doreri Bay. Even so, the largest number of types of browser groups was found around Sawaibu reef flat and Lemon Island averages.

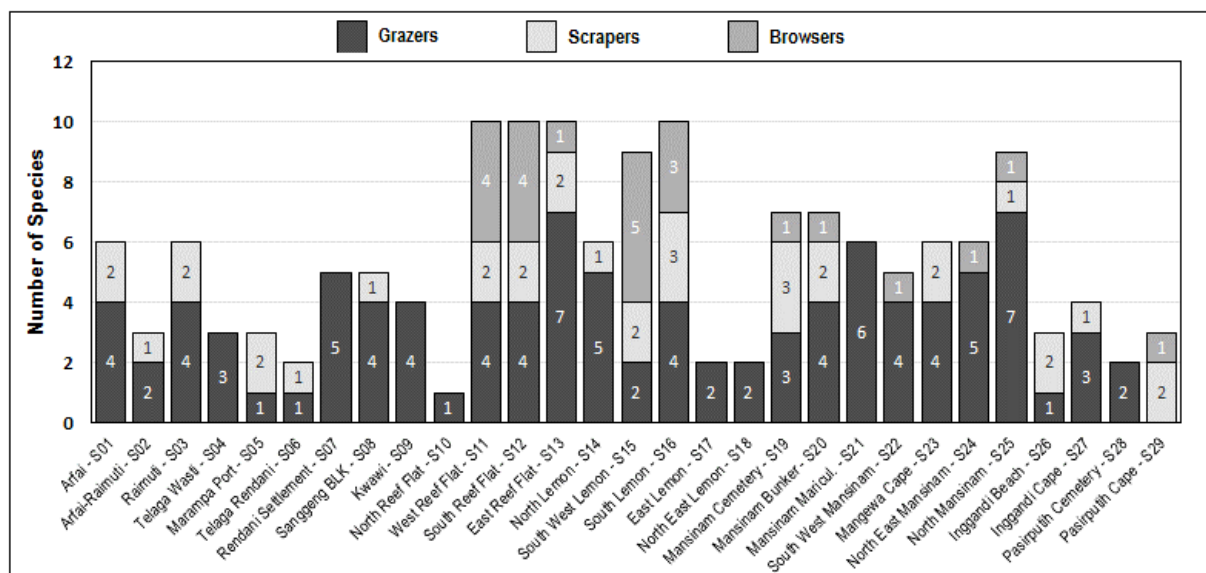


Figure 2. Number of species of each functional group based on the observation site.

Comparison between observation stations, showed the highest number of herbivorous fish species at Station 2 (Sawaibu reef average), with 25 species (Figure 3). Whereas Station 5 (eastern part of Doreri Bay) was the station with the lowest number of herbivorous fish species, namely with 11 species. Besides Station 5, the number of species of herbivorous fish at Station 4 (Pulau Mansinam) was also relatively high, namely with 22 species. In general, the grazer/detritivore group was represented by a higher number of species than other functional groups. At Station 2 and Station 4, 16

species of this group were found. Meanwhile, small excavator/scrapper groups and browsers were found in a small number of species at all stations. Even specifically at Station 1 (western part of Doreri Bay), the browser functional group was not found throughout the observation period.

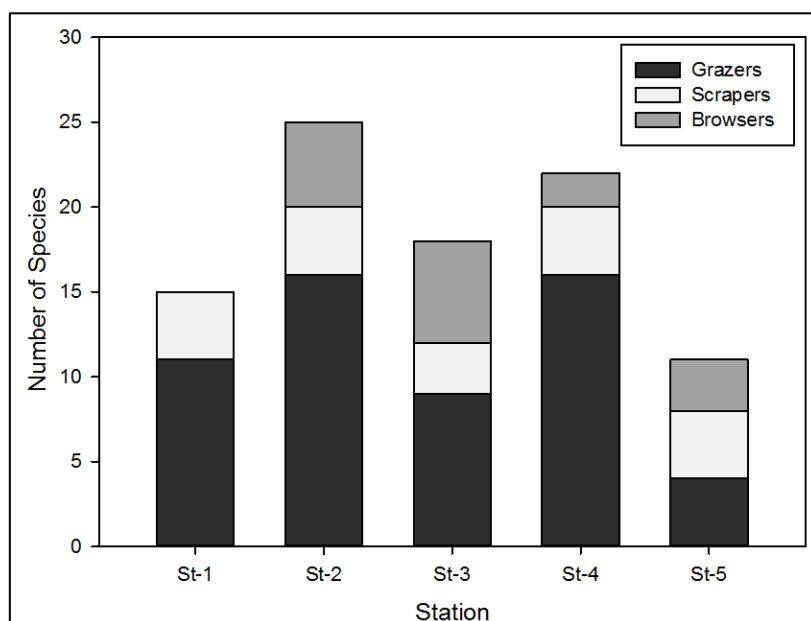


Figure 3. Number of species of functional groups by station.

One of the important aspects of the results was the absence of a large excavator functional group during the observation period (Table 3). Although to ensure this absence, regular monitoring activities are required, but this result can be basic information about the existence of herbivorous fish functional groups. The group of large excavators generally consists of bumphead parrotfish (*Bolbometopon muricatum*), fish from the genus *Cetoscarus* and genus *Chlorurus* (Green & Bellwood 2009; Obura & Grimsditch 2009). Browser groups were also not found in Station 1, even though this functional group plays an important role in controlling the development of macroalgae.

Table 3
Functions of each herbivorous fish functional group and presence at the research stations

Functional group	Function related to coral reef resilience	Presence in stations
Large excavator	<ul style="list-style-type: none"> Limit the development of macroalgae <ul style="list-style-type: none"> Intensively consume turf algae Remove the substrate when eating (Main Bioeroders) Provide an area for CCA & coral recruitment 	Not available in all stations
Small excavator/ Scrapper	<ul style="list-style-type: none"> Limit the development of macroalgae <ul style="list-style-type: none"> Intensively consume turf algae Lift the substrate when eating (Bioeroders) Provide an area for CCA & coral recruitment 	Available in all stations
Browsers	<ul style="list-style-type: none"> Consistent in consuming macroalgae Reducing macroalgae as a coral competitor Acting in preventing phase changes between corals to algae 	Not available in Station 1
Grazer/Detritivore	<ul style="list-style-type: none"> Limit the development of turf algae intensely Able to limit macroalgae development as well 	Available in all stations

Source: Green & Bellwood (2009), Obura & Grimsditch (2009).

Herbivorous fish biomass. In general, the biomass of herbivorous fish in the research location was relatively low. Based on the calculation results, the total biomass of herbivorous fish at the site-site sampling ranged from 0.85 to 494.12 g m⁻² and the average biomass ranged from 0.42 to 54.90 g m⁻². The maximum total biomass value was 494.12 g m⁻² with an average of 54.90 g m⁻² recorded on Site S15 (southwest of Lemon Island). Compared to other sites of the study locations, site S15 does have relatively higher herbivorous fish biomass (Figure 4). In addition to Site S15, another site that has a high total biomass value is Site S12 (southern reef average) of 341.75 g m⁻² with an average of 34.18 g m⁻², and Site S16 (south of Lemon Island) of 305.85 g m⁻² with an average of 30.59 g m⁻². On the other hand, the total minimum biomass value was 0.85 g m⁻² with an average of 0.42 g m⁻² recorded on Site S17 (east of Lemon Island). In addition to Site S17, other sites that have a total value of low herbivorous biomass are Site S10 (north reef average) which is 1.28 g m⁻² with an average of 1.28 g m⁻², Site S18 (northeast of Lemon Island) amounting to 1.58 g m⁻² with an average of 0.79 g m⁻², and Site S28 (TPU Pasirputih) of 1.90 g m⁻² with an average of 0.95 g m⁻².

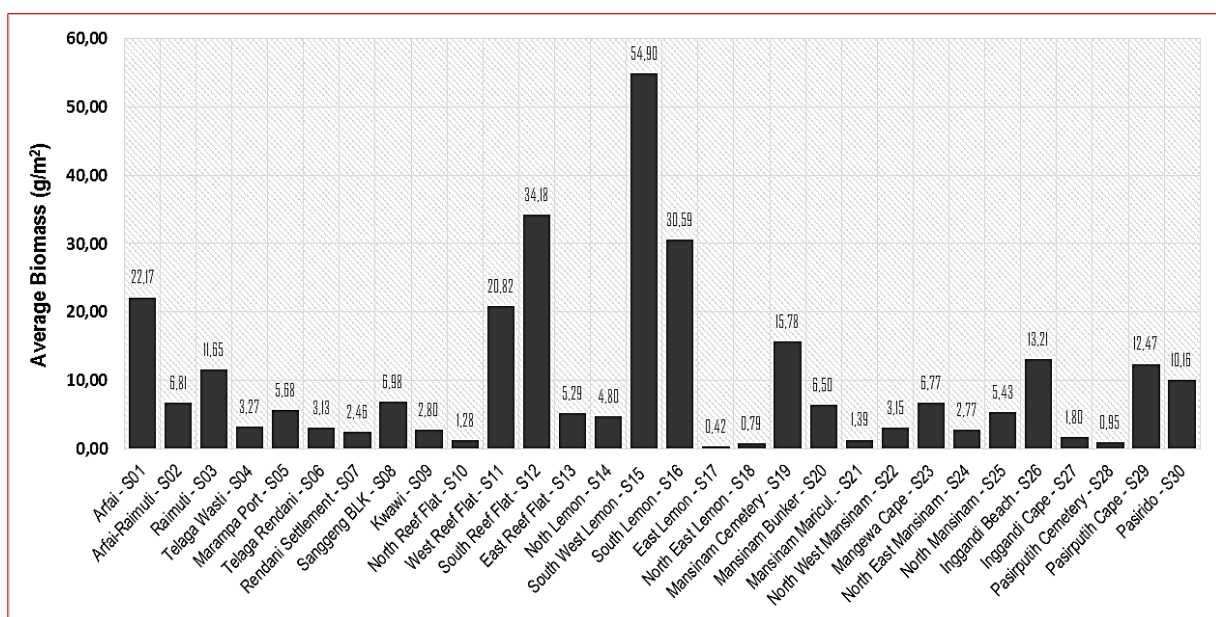


Figure 4. Average herbivorous fish biomass in each observation site.

If the average biomass of herbivorous fish is compared based on the observation station (Figure 5), then Station 3 (Lemon Island) is the station with the highest herbivorous fish biomass compared to other stations. The average herbivorous fish biomass at the station was recorded at 28.66±7.16 g m⁻². In contrast, Station 4 (Mansinam Island) is the station with the lowest herbivorous fish biomass. At this station herbivorous fish biomass was recorded at 6.22±1.19 g m⁻². In addition to Station 4, other stations that have relatively low herbivorous fish biomass are Station 5 (eastern part of Doreri Bay). The number of herbivorous fish in Station 3 (Lemon Island) was indeed less than in Station 2 and Station 4. However, the presence and abundance of herbivorous fish at Station 3 was higher compared to other stations.

The average biomass of the scraper/small excavator group was higher than the other functional groups in almost all observation stations (Figure 6). The highest scraper/small excavator biomass was recorded at Station 3 (Lemon Island), which is 57.56 g m⁻², while the lowest biomass of the lowest scraper/small excavator group recorded at Station 1 (west of Doreri Bay). Meanwhile, although the average biomass is still lower than the scraper/small excavator group, the browser group is noted to have the highest biomass average at Station 2 compared to other groups. Although the grazer/detritivore group was found in a higher number of species at all stations, the average biomass of this group was much lower than of the other two groups.

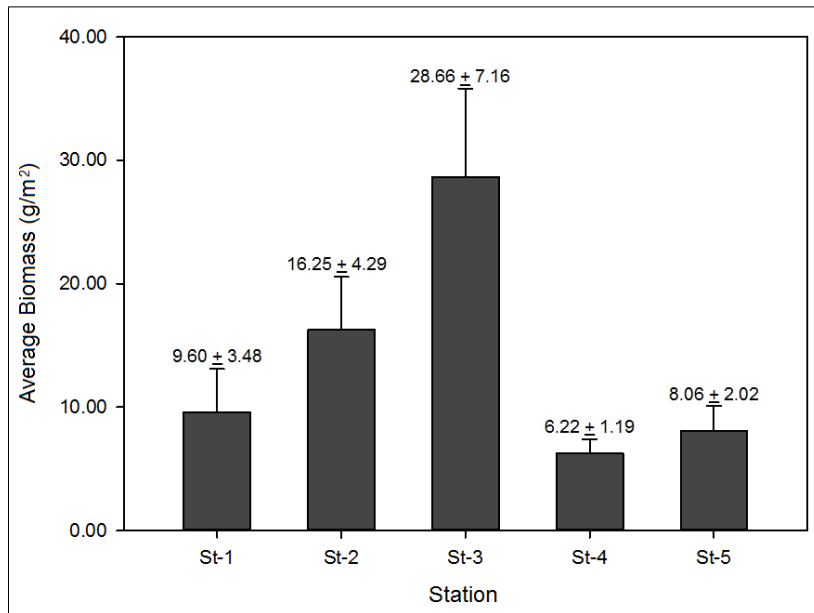


Figure 5. Average herbivorous biomass based on observation station.

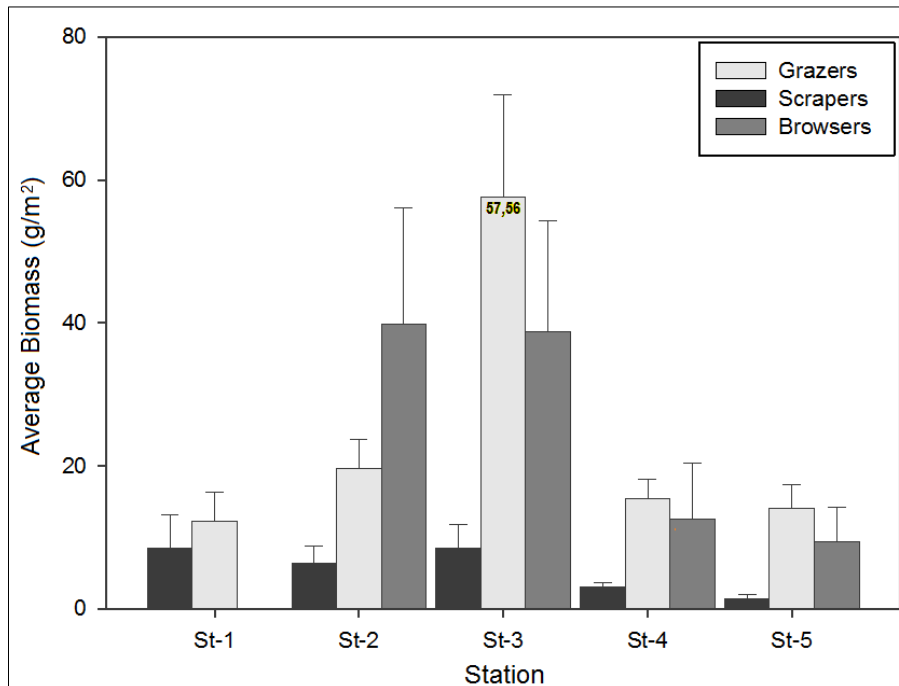


Figure 6. Average biomass of each functional group of herbivorous fish by station.

Based on the relative classification of combined values of functional diversity indicators and biomass of herbivorous fish normalized from 30 site surveys, as many as 4 sites (13.3%) belongs to the relatively high class, 7 sites (23.3%) belongs to the Medium - High class, 11 sites (36.7%) belongs to the Medium-Low class, and 8 sites (26.7%) belongs to the Low class (Table 4).

Sites belonging to the Relatively High class were located on reef flats in Sawaibu Bay, as well as the southern and southwestern part of Lemon Island. Meanwhile, two sites belong to the relative Moderate-High class, namely one site in Arfai and one other site in the Mansinam Island Tomb. On the other hand, the sites classified as the Medium-Low relative class are the most and are spread in all parts of Doreri Bay (Figure 7).

Table 4

Observation site categories based on herbivorous fish biomass indicators

Resilience category	Number of sites	Percentage (%)
High	0	0.0
Medium-High	9	30.0
Medium-Low	13	43.3
Low	8	26.7
Total	30	100.0

Source: Results of primary data processing.

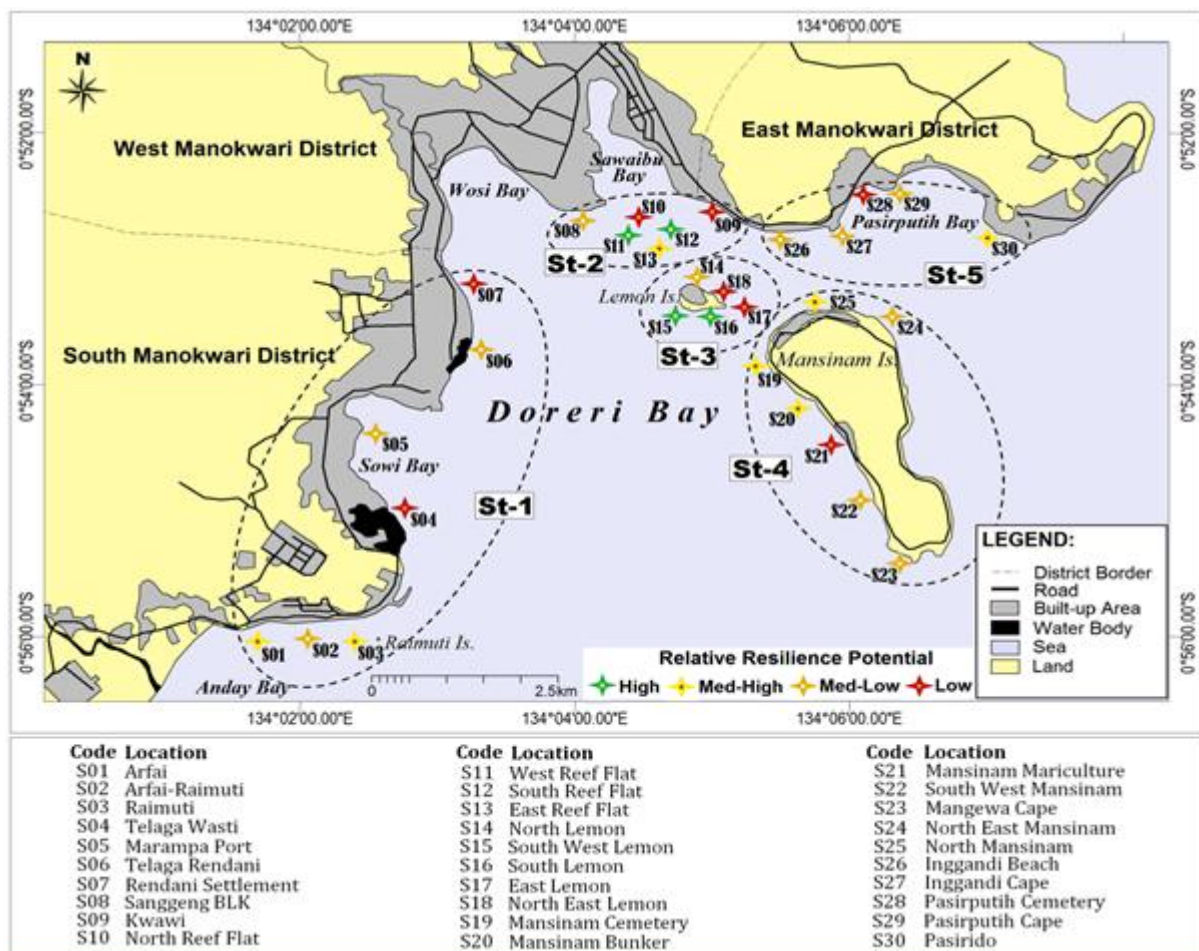


Figure 7. Relative classification of 30 sites based on normalization of value of functional diversity and herbivorous fish biomass.

Discussion. Adam et al (2015b) suggested that the combination of herbivorous species is needed to inhibit the development of dangerous algae and facilitate coral recruitment and growth. Each herbivorous group has its own choice of eating and food types, but the combination of certain species will be effective in controlling the development of algae.

The presence and abundance of herbivorous fish are often related to the characteristics of their habitat. Herbivorous fish exhibit variability in terms of functional roles, feeding activities and abundance along diverse reef environments in their habitat composition (Heenan & Williams 2013; Mellin et al 2010). Based on the results of his research in American Samoa, Heenan & Williams (2013) found that herbivorous fish biomass is an important variable in predicting benthic cover, and not so with the combined biomass of all fish. In addition, variations in benthic cover can also be explained very well by the biomass of herbivorous fish, compared to the overall biomass of fish. The results of their research more specifically illustrate that: 1) an increase in biomass in the grazers and detritivores group will cause a decrease in algal macroalgae

and turf cover; 2) an increase in biomass group of fish grazers, detritivores and browsers will cause an increase in encrusting algal cover; 3) increase in biomass groups of large fish excavators or bio-eroders in line with the increase in hard coral cover.

The increase in biomass of herbivorous fish does have a positive impact on increasing live coral cover, but the reality in many places, including in Doreri Bay shows that the biomass of herbivorous fish has decreased. According to Adam et al (2015a) in many cases, key herbivore populations have experienced a sharp decline due to overfishing and diseases. This results in increased algae breeding and a barrier to recovery of corals after serious disturbances. However, the extent of the role of herbivores in supporting the resilience of coral reefs also depends on the limiting factors of coral and algal populations which can have an impact on the mediating role of their interactions by herbivores.

A model developed by Mumby (2006) on the case of coral reefs in the Caribbean shows that the decline in parrotfish's ability to graze from 10 to 30% of reefs can cause fundamentally different reef communities. Under high grazing, coral cover increased from the initial level of 30% to around 65%. Conversely, coral cover decreases to around 7% when herbivorous fish are much depleted. The different responses of reefs to grazer depletion are maintained for all variable ranges such that coral cover always increases under high grazing and always decrease under low grazing by herbivorous fish. Based on the model it is concluded that the depletion of grazing is a fundamental and comprehensive impact on the dynamics of Caribbean coral reefs.

The absence of a large excavator group at all stations is a big disadvantage because this group performs an important function in maintaining the resilience of the coral reef system.

In addition to its role in controlling the development of algal macroalgae and turf, the large excavator group plays an important role in the coral recruitment process by providing media for the development of Crustose Coraline Algae (CCA) and coral recruitment. This is possible because large excavators function as bioeroders, wherein they move/shift the substrate, especially dead corals so that they can be a good growing medium for CCA and coral recruitment (Green & Bellwood 2009; Obura & Grimsditch 2009). Crustose Coraline Algae (CCA) is an alga that functions as a medium for growing coral or young coral recruitment (Green & Bellwood 2009; Shlesinger & Loya 2016).

Browser groups were also not found in Station 1, even though this functional group plays an important role in controlling the development of macroalgae. According to Green & Bellwood (2009) browser groups consume macroalgae consistently, so the absence of this group provides a great opportunity for rapid macroalgae development. The development of macroalgae will be faster, especially if nutrient conditions in the waters support it. It was also stated that browser group roles might be run by other functional groups, however.

Conclusions

- 1) Herbivorous fish in Doreri Bay only consisted of three functional groups, Small Excavators/Scrapers, Browsers, and Grazers/Detritivores.
- 2) Groups of Grazers/Detritivores were found in a higher number of species at all stations compared to other groups.
- 3) The highest biomass was found in the waters of Lemon Island (Station 3), and generally, the biomass of the Small Excavator/Scrapers group was higher than of other groups.
- 4) *Pomacentrus moluccensis* was a common species, but *Scarus chameleon* was the type with the highest biomass value.
- 5) Based on the indicators of functional diversity and biomass of herbivorous fish, around 64% of sites are classified as medium-low and low resilience potential classes, while only 36% of sites are classified as medium-high and high resilience potential classes.

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