Conditions and characteristics of coral reefs in Gusung Batu Lampe, Muara Badak, Kutai Kartanegara, Indonesia

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Abstract. Gusung Batu Lampe is one of the coral reef spots in Muara Badak. It consists of two patch reefs, namely Gusung Lampe Besar and Gusung Lampe Kecil. This study was conducted to determine the conditions and characteristics of coral reefs in Gusung Batu Lampe. Data regarding the total area of coral reefs were obtained by the snorkeling technique and marked using GPS. In addition, data regarding the conditions of coral reefs were taken from 10 stations using the LIT method. Results showed that Gusung Batu Lampe consisted of 2 clusters, namely Lampe Besar with an area of 6.2 ha and Lampe Kecil with an area of 0.4 ha. Coral reefs in all the research stations represented conditional status that varied from poor/damaged to very good category. On average, their conditional status was in the moderate category. The most common hard coral lifeforms are non-*Acropora* massive coral (CM) and non-*Acropora* encrusting coral (CE). The stations located in the northern part of Lampe Besar have a better percentage of coral reef coverage than those in the southern part. The live coral community in Batu Lampe is mostly supported by the presence of hard coral (HC) colonies. Overall, from all observation stations, there were 43 genera found of HC groups that belong to 14 families. In addition, the three types of coral with the highest number of colonies are *Montipora*, *Porites*, and *Acropora*. Furthermore, an increase in the number of colonies is not always followed by an increase in the number of genera.

Key Words: hard coral, LIT, percent cover, *Montipora*, *Porites*, *Acropora*.

Introduction. The Coral Triangle of Indonesia is spread from East Kalimantan to Papua (Burke et al 2011). The presence of coral reefs in East Kalimantan is identified in Berau, Pandan Bay, Tanjung Santan, Balikpapan Bay, northern part of the Mahakam Delta (Muara Badak), southern part of the Mahakam Delta (Samboja), and eastern part of the Mahakam Delta (Anggana) (Tomascik et al 1997; Efendi et al 2014; Syahrir et al 2015; Suyatna 2017; Syahrir et al 2018). The existence of coral reefs in the northern part of the Mahakam Delta (Muara Badak) is spotted in six points with a total area of 41.84 ha. One of the coral reef spots in Muara Badak is Gusung Batu Lampe with an area of 19.33 ha and having a good condition. Although the coral reefs are in the good condition, they are under constant pressure from the Mahakam Delta, in the form of turbidity and soft bottom sediments (Suyatna et al 2017). Turbidity and soft bottom sediments are natural threats because they are not suitable for coral reef life (Rogers 1990; Tomascik et al 1997; Fabricius & De’ath 2001; Philipp & Fabricius 2003; Fabricius 2005; Golbuu et al 2008; Jokiel et al 2014; Santodomingo et al 2015; Bessell-Browne et al 2017). In addition to the natural influence of the Mahakam Delta, coral reef ecosystems are also used for various activities, such as fishing by fishermen, which can cause coral reef degradation, especially by catching fish using explosives (Tomascik et al 1997; Fox & Caldwell 2006; England 2014). Records on the practice of catching fish using explosives in Gusung Batu Lampe, in particular, and in general in the Muara Badak waters are also mentioned in a study conducted by Suyatna et al (2017) and news from several newspaper media agencies, such as Koran Kaltim and Tribun Kaltim on August 28th 2019 (Fahlevi 2019; Taufik 2019), Linimasa on November 25th 2020 (Audric 2020), Liputan 6 on February 24th 2021 (Jalil 2021), and 96.8 kpfm on April 5th 2021 (Fajar 2021).

Based on the phenomena aforementioned, further study is needed to obtain more detailed data to complement the study conducted by Suyatna et al (2017). Therefore, the current study attempted to determine the characteristics and distribution of coral reef conditions in the waters of Muara Badak, especially in the Gusung Batu Lampe.

Material and Method

Research locations and data collection. This study was conducted in the waters of Gusung Batu Lampe, Muara Badak, Kutai Kartanegara from March to September 2017 to collect the latest data which was not recorded in previous studies. Data regarding the total area of coral reefs were collected by the snorkeling technique which was carried out along the edge of the reef (researchers were able to see up to a depth of about 7 m). In addition, researchers also carried out marking using GPS. Data concerning the condition of coral reefs was obtained by doing scuba diving at a depth of 3-5 m to collect data from 10 stations using the LIT (Line Intercept Transect) method. Since Gusung Batu Lampe consists of two clusters with different areas (i.e., Lampe Besar and Lampe Kecil), 9 LITs were placed in Lampe Besar (Stations LB1 to LB9) and 1 LIT was put in Lampe Kecil (Station LK1). All the coordinates of the research stations are presented in Table 2. A 50 m long measuring tape was installed underwater above the coral reef profile. The length of each lifeform category was measured at coral colony passed by measurement tape (English et al 1994). The categories of life forms and codes referred as shown in Table 1.

Table 1

Coral lifeform categories and their coding

Categories/Lifeform	*Code*
Dead coral	DC
Dead coral with algae	DCA
Hard coral	
Acropora branching coral	ACB
Acropora tabulate coral	ACT
Acropora encrusting coral	ACE
Acropora submassive coral	ACS
Acropora digitate coral	ACD
Non-*Acropora* branching coral	CB
Non-*Acropora* encrusting coral	CE
Non-*Acropora* foliose coral	CF
Non-*Acropora* massive coral	CM
Non-*Acropora* submassive coral	CS
Non-*Acropora* mushroom coral	CMR
Non-*Acropora* millepora coral	CME
Non-*Acropora* heliopora coral	CHL
Other fauna	
Soft coral	SC
Sponge	SP
Zoanthids	ZO
Others	OT
Algae: Algal assemblage	AA
Coralline algae	CA
Halimeda	HA

Categories/Lifeform	*Code*
Macroalgae	MA
Turf algae	TA
Abiotic	
Sand	S
Rubble	R
Rock	RCK
Silt	SI
Water	WA
Missing data	DDD

Table 2

Coordinates of research stations

No.	*Station ID*	*Coordinates*	
		Latitude	*Longitude*
1	LB 1	0°12'59.50" S	117°29'45.10" E
2	LB 2	0°13'01.16" S	117°29'45.14" E
3	LB 3	0°13'02.96" S	117°29'42.60" E
4	LB 4	0°13'04.08" S	117°29'39.44" E
5	LB 5	0°13'07.15" S	117°29'35.20" E
6	LB 6	0°13'07.50" S	117°29'31.00" E
7	LB 7	0°13'04.53" S	117°29'32.57" E
8	LB 8	0°13'01.58" S	117°29'37.23" E
9	LB 9	0°13'00.22" S	117°29'42.63" E
10	LK 1	0°13'09.41" S	117°29'27.00" E

Data analysis. GPS data from snorkeling tracks were analyzed to obtain data concerning the total area of coral reefs. The results were presented in a map made using ArcGIS 10.1 software (ESRI 2012). The percentage of coral cover was calculated using the following formula (Gomez & Yap 1988; English et al 1997; Gomez et al 1994).

$$Percent\ Cover\ \alpha = \frac{total\ length\ of\ lifeform\ \alpha}{length\ of\ transect}\ x\ 100$$

Where:
ɑ - a category of lifeform.

The total coverage of both *Acropora* and non-*Acropora* lifeforms was the percentage of HC coverage. Furthermore, live coral coverage (LC) was the sum of the total HC and soft coral (SC) coverage (LC=HC+SC). Coral condition was indicated by the percentage of live coral, classified into the following categories: LC<25% (poor/bad), 25≤LC≤50% (fair/moderate), 50≤LC≤75% (good), and LC>75% (excellent) (Gomez & Yap 1998; Gomez et al 1994; Hill & Wilkinson 2004). Hard coral colonies were identified to the genus level in-situ (Kelley 2009) and/or ex-situ (Veron & Stafford-Smith 2002).

Results and Discussion. Batu Lampe is about 6 km to the east from Pangempang Bay and about 12 km to the north from the Mahakam Delta. Batu Lampe consists of two coral clusters, namely "Lampe Besar" and "Lampe Kecil". Lampe Kecil is located southwest of Lampe Besar and the two are only about 60 m apart but are separated by a gap with a depth of up to ±20 m. Based on the results of the analysis, Lampe Besar has a coral reef area of ±6.2 ha, while Lampe Kecil has an area of ±0.4 ha. The result of the calculation of this coral reef area is different from the results of a study by Suyatna et al (2017) which stated that the total area of coral reefs of Batu Lampe is 19.33 ha. This is most likely due to the different approaches to data collection and analysis employed. In their study, data collection was conducted using the method of basic characteristic reading with the assistance of a marine acoustic instrument, namely an echosounder. It was different from what was used in this study, in which the researchers only defined the area based on coral reef communities that were clearly visible as stretches (including clean substratum or not covered by thick mud) through the visual survey technique. Acoustic tools, through the process of analyzing the results of sound reflections from the bottom of the water, are known to be able to identify the hard-soft characteristics, density, and type of bottom substrate of the waters (Allen et al 1976; Lawrence & Bates 2001; Kgesten 2008; D'Elia et al 2009). The interpretation of the results in the form of maps of Batu Lampe Besar and Batu Lampe Kecil, distribution of research stations, percentage of lifeform cover, and coral reef conditions are shown in Figure 1 and 2, and in Table 3.

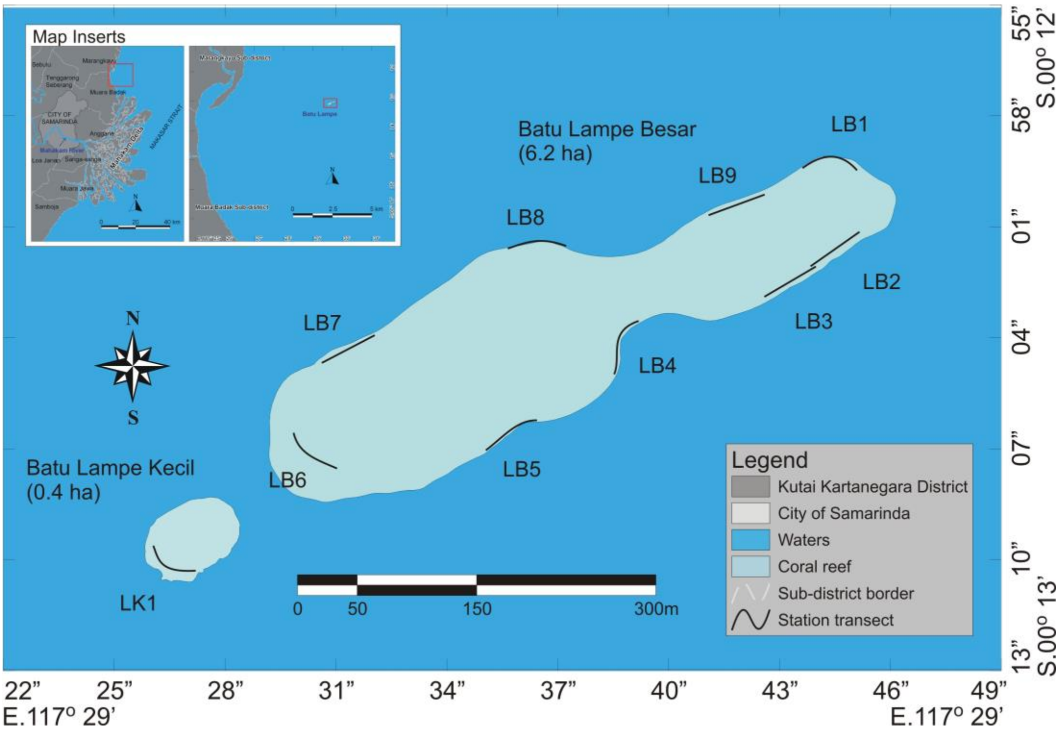


Figure 1. Map of Batu Lampe Besar & Batu Lampe Kecil and distribution of research stations.

Table 3

Percentage of lifeform coverage at each research station and the average of all research stations

Lifeform	*Code*	*LB1*	*LB2*	*LB3*	*LB4*	*LB5*	*LB6*	*LB7*	*LB8*	*LB9*	*LK1*	*Average*
Dead coral	DC	0.8	0.5	1.0		1.1	0.2	0.6	0.9	0.7	0.6	0.6
	DCA	7.2	6.7	2.1	9.9	14.8	0.2	5.1	3.3	6.6	10.7	6.7
Acropora	ACB	1.4		0.2		3.3	0.3	28.3		2.7		3.6
	ACT	5.4	3.5	1.8		0.6		3.2		10.5	2.1	2.7
	ACE											
	ACS											
	ACD			0.4						0.6		0.1
Non *Acropora*	CB	0.9		0.4		1.3	1.2	19.3	0.6	4.5	12.4	4.1
	CE	14.0	22.0	24.5	1.8	11.3		10.9	4.8	15.0	5.5	11.0
	CF	12.5	2.9	7.0	6.0	6.9		10.3	1.1	3.2	16.8	6.7
	CM	18.9	19.6	12.4	4.2	18.0	0.1	6.6	41.5	25.5	10.4	15.7
	CS	1.5	0.4	1.9	0.4	2.9		0.4	1.2	0.5	1.4	1.1
	CMR	0.5		0.4	1.6			0.8		0.2	4.5	0.8
	CME			0.1						2.8		0.3
	CHL											
Other fauna	SC				0.8		0.6			1.2	1.8	0.4

Lifeform	*Code*	*LB1*	*LB2*	*LB3*	*LB4*	*LB5*	*LB6*	*LB7*	*LB8*	*LB9*	*LK1*	*Average*
	SP	2.1	0.1	4.3	2.8	0.4	0.2	0.7	0.5	0.6	1.3	1.3
	AA	12.6	5.1	6.0	3.2	1.3	0.4	0.1	9.9	3.4	4.7	4.7
	CA										0.4	0.0
	HA											
	MA	0.1						3.4		0.5	0.8	0.5
	TA				0.3		1.7					0.2
	ZO		0.2									0.0
	OT	2.1	1.9	1.2	1.4			0.1	0.5	1.6	1.5	1.0
	S	2.5	6.7	2.7	7.3	8.3	5.6	0.7	3.0	5.4	0.7	4.3
	R	13.0	22.1	28.5	58.7	18.1	88.3	8.4	25.2	12.2	23.3	29.8
Abiotic	RCK	2.6	8.3	5.1	0.7	5.3		1.1	6.8	1.4		3.1
	SI	1.9			0.9	6.4	1.2		0.7	0.9	1.1	1.3
	WA											
	DDD											
Total		100	100	100	100	100	100	100	100	100	100	100

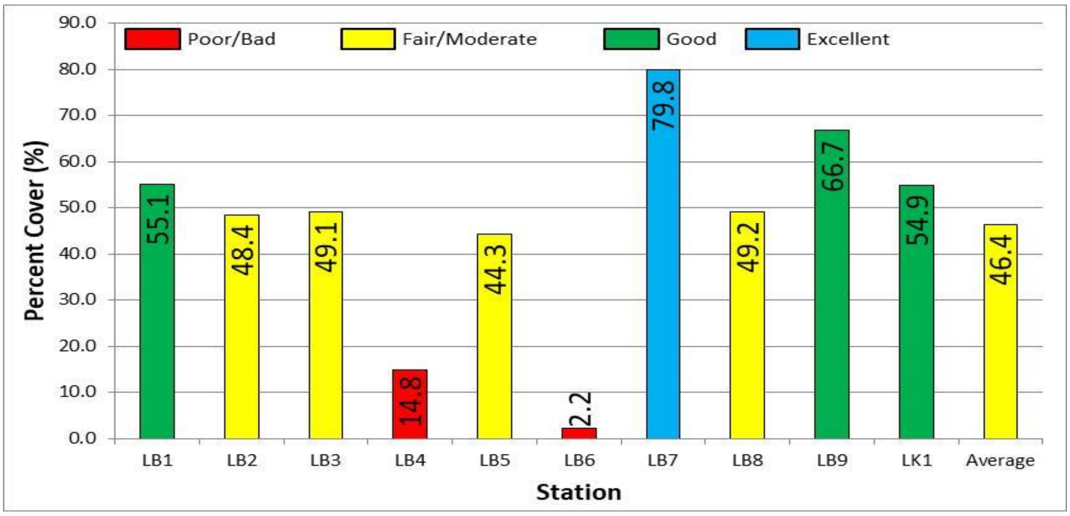


Figure 2. The percentage of live coral (LC) coverage at each research station, the average of all research stations, and the category of their coral reef condition (indicated by the color of the bar graph).

In general, the coral reef community at the research stations can be considered to be able to develop well. The percentage of LC coverage at the research stations ranges from 2.2 to 79.8% with an overall average of 46.4%. The lowest value was obtained at station LB6, while the highest was at station LB7. These values indicate that the coral reefs at the research stations represent the conditional status that varies from the poor/bad to the excellent category with an average of being in the category of moderate condition. There are two stations with poor/bad status, namely stations LB4 and LB6 with LC percentages of 14.8 and 2.2%, respectively. In addition, there are four stations with moderate conditions, namely stations LB2, LB3, LB5, and LB8 with LC percentages of 48.4, 49.1, 44.3 and 49.2%, respectively. Moreover, there are three stations with good condition status, namely LB1 (LC=55.1%), LB9 (LC=66.7%), and LK1 (LC=54.9%). Furthermore, only one station is recorded as having a coral reef status in excellent condition, namely station LB7 with an LC percentage reaching 79.8%. The percentage of LC coverage shows that the live coral community in Batu Lampe is mostly supported by the presence of HC colonies because the percentage of HC coverage is much higher than that of SC. The ratio of percentage cover show that SC colonies are only recorded at four of the ten observation stations and in a very small percentage, namely the stations LB4 (HC=14.0% and SC=0.8%), LB6 (HC=1.6% and SC=0.6%), LB9 (HC=65.5% and SC=1.2%), and LK1 (HC=53.1% and SC=1.8%). Thus, at the other six stations (stations LB1, LB2, LB3, LB5, LB7, and LB8), the coral community can be considered to be fully supported by the HC group. On the overall average, the percentage of HC coverage represents a proportion of 46.0%, while SC coverage is only 0.4%.

The distribution of coral reef also shows a trend: stations in the northern part of Lampe Besar are better than those in the southern part. The four northern stations (LB1, LB9, LB8, and LB7) reach an average LC percentage of 62.7%, while the southern stations (LB2, LB3, LB4, LB5, and LB6) have an average LC percentage of only 31.7%. Even if station LK1, which is located in Lampe Kecil, has a "good" status, in its southern part, the average LC percentage is only 35.6%, suggesting that the coral groups that develop in the northern part of Batu Lampe have two times better conditions than those in the southern part. This is presumed to be closely related to the characteristic conditions of the Mahakam Delta and Makassar Strait currents. The northern part of Batu Lampe receives direct flushing through the thrust current coming from the north so that the waters tend to be clearer than in the southern part. Meanwhile, in the southern part, the turbid water flow that comes from the south (Delta Mahakam) is not completely washed out because the strength of the current coming from the north is blocked or damped by the mound of Batu Lampe itself. Therefore, the waters (including their coral reef community) in the southern part of Batu Lampe will be more affected by the turbidity. According to Stroms et al (2005) and Nursigit et al (2013), the Mahakam Delta has two branches of an active flow system, namely one to the northeast (Muara Berau which is in the northern part of the delta) and the other to the southeast (Muara Jawa which is in the southern part of the delta). The two flow branch systems constantly carry the load of solid particles and turbidity from the Mahakam River flowing to the delta area. However, the load is more dominant towards the south than towards the north (Husein 2008; Mandang et al 2009) with a plume that can reach 400 km to the southeast of the delta area (Eisma et al 1989). The main flow of the Makassar Strait which flows towards the south throughout the year (Eisma et al 1989; Tomascik et al 1997) helps to prevent coral reef communities in Batu Lampe from being exposed to heavy sedimentation from the Mahakam Delta.

The distribution of the percentage of Rubble (R) coverage between stations shows a data distribution pattern similar to that of LC, with an inverse correlation. The percentage of R at stations in the north tends to be lower than those in the south. The coverage percentage ranges from 8.4 to 88.3% with an average of 29.8%. The lowest percentage was obtained by station LB7, while the highest was at station LB6. Eight out of ten observation stations show a percentage of R less than 30%, while two stations (LB4 and LB6) show quite a significant difference with percentages of 58.7 and 88.3%, respectively. At stations in the southern part, the data concerning the percentage of R is mainly influenced by the large values obtained by stations LB4 and LB6. The condition of low LC coverage with high R illustrates the severe coral damage at both stations. Compared with the observation stations that are adjacent to stations LB4 and LB6, the damage that occurred does not have a uniform or comprehensive impact on coral reefs in Batu Lampe. Station LB3 which is east of station LB4 has a much better LC percentage, which is 49.1%. Then, station LB5 which is between stations LB4 and LB6 also show the same thing, with the LC percentage of 44.3%. In addition, station LB7, which is adjacent to station LB6, shows very different conditions, with the LC percentage reaching 79.8%. The pattern of differences can also be clearly seen through the data of the percentage of R which are 28.5, 58.7, 18.1, 88.3 and 8.4% from stations LB3 to LB7, consecutively. This reduces the possibility that the cause of the large amount of coral destruction or damage to coral reefs at stations LB4 and LB6, in particular, and Batu Lampe, in general, is hydrodynamic pressure of the waters, which is a natural factor. The cause of damage to coral reefs at Batu Lampe (stations LB4 and LB6) is specifically presumed to be a result of destructive fishing practices, especially the use of explosives (blast fishing). Based on information from the local community and fishermen, Batu Lampe was once a target for fishing using this destructive method. The existence of such fishing practices both in Batu Lampe, in particular, and the waters of Muara Badak, in general, are also mentioned in the study conducted by Suyatna et al (2017). Signs of coral damage caused by the explosives are identified by small fragments of destruction. Furthermore, the researchers found the edges of the coral cliffs that have collapsed on the mound of Batu Lampe (Figure 3). Jameson et al (1999), Fox & Caldwell (2006), England (2014) stated that explosive fishing harms reef fish and coral reef communities, which directly damages the physical structure of corals, resulting in crumbling and scattered coral skeletons.

Figure 3. Negative impact on reef fish and coral reef collapses due to explosive fishing at the research location (indicated by arrows).

Although the initial presumptions of coral damage at certain stations are more dominant by the practice of the usage of explosives based on the quantity and form of coral debris, the overall cause of coral death in Batu Lampe is still very likely caused by various factors, both natural and anthropogenic. In addition to the value of R, an indication of coral damage can also be seen from the percentage of dead coral (DC) and coral that has been dead for a long time and overgrown with algae (DCA or dead coral with algae) (Mahmudin et al 2020). As with R coverage, dead coral forms, both DC and DCA, were found in all research stations. Overall, the percentage of DC is 0.6%, while DCA is 6.7%. The data regarding the distribution of DC and DCA between stations shown in table 2 do not present a certain trend. The percentage of DCA is found higher than DC in almost all stations (except station LB6 which has the same value), indicating that the death of coral colonies in this location mostly occurred in the past. The coral colonies that died and became DC and DCA are mostly found in the form of solid lumps which are assumed to be from the non-*Acropora* massive coral (CM) lifeform.

Natural factors and characteristics of the waters of the Mahakam delta (e.g., turbidity, sedimentation, and fluctuations in salinity & temperature) can affect the death of coral polyps but tend not to directly damage the skeletal structure. Turbidity which is dissolved solid particles in the water column will hinder the penetration of sunlight into the water, thereby reducing the intensity of light received by coral organisms. Sunlight is an important factor in the existence of coral reefs in connection with the process of photosynthesis in the coral body carried out by zooxanthellae symbionts. When these solid particles begin to settle and fall on the coral body, they can cover the polyp to bury the coral structure (Rogers 1990; Fabricius 2005; Erfttemeijer et al 2012). Then, changes in salinity and water temperature that are outside the tolerance limit can directly cause the death of coral polyps. One of the events that cause coral death on a large scale is the occurrence of the El Niño-Southern Oscillation (ENSO) phenomenon or better known as El Niño. This phenomenon is an increase in water temperature and an extension of summer. Therefore, coastal and marine ecosystems will be exposed to temperature anomalies for a longer period. One of the worst El Niño phenomena throughout the last decade occurred in 2015-2017 which was followed by weak-to-moderate-scale El Niño in 2018-2019 (Hughes et al 2017,2018; Klingaman & Keat 2018; Bollati et al 2020).

When the zooxanthellae symbionts, contained in the coral's body, experience stress to the point of being released or dying, the coral animal that is the host also dies. Coral animals and their symbionts that have died will leave a limestone skeleton structure which is generally white to yellowish in color. Then, over time it will become dirty and dark in color until it is covered by algae. However, the effects of these factors generally do not directly cause damage to the physical structure of the coral skeleton. The affected coral colonies are generally still observable in their original skeletal form. The frame structure is generally damaged after receiving hydrodynamic pressure in the form of currents and waves. This occurs mostly in brittle structural forms, such as *Acropora* branching coral (ACB), *Acropora* tabulate coral (ACT), non-*Acropora* branching coral (CB), non-*Acropora* foliose coral (CF), non-*Acropora* millepora coral (CME), and non-*Acropora heliopora* coral (CHL). Meanwhile, denser structural forms, (e.g., non-*Acropora* massive coral (CM), non-*Acropora* encrusting coral (CE), and non-*Acropora* submassive coral (CS)), generally require greater strength, such as storms and tsunamis, to cause direct damage to the skeletal structures. This physical pressure will result in rubble, especially for fragile skeletal structures. However, the size of the resulting debris is generally still larger than the result of explosives, which produce much smaller coral debris. The shock effect of a blast on a coral bed or colony may vary depending on the distance from the object in question. Coral destruction is a direct effect of explosives which generally occurs on coral colonies that have fragile skeletal structures, such as branching, tabulating, and foliose forms. However, in coral colonies with denser skeletal structures (i.e., massive and sub-massive forms), the effects of explosive pressure can be (1) direct physical damage resulting in coral fragments which are generally still in the form of chunks or (2) tissue death on a partial to total scale if the solid structure of the associated colony is not damaged. This illegal and destructive fishing practice has been widely reported to occur on various coral reefs and is one of the main threats even in Indonesia. It has caused damage to around 80-85% of reefs in the world and the threat continues to increase over time (McManus et al 1997; Riegl & Luke 1998; Pet-soede et al 1999; Erdmann 2000; Riegl 2001; Burke et al 2002; Kunzmann 2002; Burke et al 2011, 2012). The condition of coral reefs that have been damaged will continue and be further degraded as long as these activities continue (Pratchett et al 2014). Therefore, the coral reef recovery process requires the absence of these destructive factors. In other words, the source of the damage must first be removed from the related location. In this case, it is human activities (Edinger & Risk 2000; Burke et al 2012).

Although coral reefs in Batu Lampe are estimated to have suffered a lot of damage in the past, the intensity of disturbance from explosive fishing activities must be less frequent as a result of marine surveillance efforts in Muara Badak, which may provide a better opportunity for the coral community to carry out recovery. The comparison of the data presented by Suyatna et al (2017) with previous scientific data indicates a recovery process. Station A2 in a study conducted by Suyatna et al (2017) is an observation point located adjacently to station LB7 in this study. The data was taken in 2013 and shows a percentage of LC coverage of 61.8%. When compared to 2017 data (LC=79.8%), it shows that, over a period of about five years, coral reefs at this location have experienced an improvement in the LC coverage, reaching 18.0%. At this point of observation, the composition of hard coral (HC) lifeforms tended to be similar between 2013 and 2017 data, namely CM lifeforms were recorded in a small percentage (<10%), while CB, CE, and CF appeared in the percentages of >10%. Furthermore, the types of HC lifeforms observed were *Acropora* branching coral (ACB) and ACT from the *Acropora* group in the absence of *Acropora* encrusting coral (ACE), *Acropora* submassive coral (ACS), and *Acropora* digitate coral (ACD) and (2) CB, CE, non-*Acropora* foliose coral (CF), CM, CS, and non-*Acropora* mushroom coral (CMR) from the non-*Acropora* group in the absence of CME and CHL. In this case, the data from both years show the same thing. Specifically, for the HC group, there is a dominant change in lifeforms between 2013 and 2017 data, namely from foliose (CF) to branching form (mainly ACB). *Acropora* coral colonies, especially the branched form (lifeform ACB), are known to be a type of coral that can develop rapidly, with high growth rates (Licuanan & Capili 2004). The growth rate of branching *Acropora* corals is reported to be > 10 cm per year (Onaka et al 2013; Xin et al 2013, 2016; Anderson et al 2017; Muzaki et al 2019). This type of coral in favorable water conditions will be able to spread more quickly, forming large colonies, and to cover other types of colonies. Therefore, branching *Acropora* and other fast-growing species are often found to dominate the space or form monospecific communities. For this reason, the percentage of LC coverage can reach the category of very good condition (Roberts & Ormond 1987; Tomascik et al 1997; Edinger & Risk 2000; Syms & Kingsford 2008).

In general, in Batu Lampe, CM was the lifeform of the HC group with the highest percentage of coverage. CM along with encrusting coral (CE) with cover percentages of 15.7 and 11.0%, respectively, are the two most common lifeforms observed throughout Batu Lampe, especially at the top of the mound as response or adaptation to water conditions with estuarine characteristics, fluctuating salinity, and turbid waters (Figure 4). Many works of literature have stated that these two lifeforms are generally found in turbid coastal waters with high sedimentation and fluctuating salinity & temperature. In addition, they have long periods of air exposure (Tomascik et al 1997; Edwards et al 2001; Torres & Morelock 2002; Hennige et al 2010; Chou et al 2012; Sutthacheep et al 2013; Ferns 2016).


Figure 4. The expanse of coral with non-*Acropora* massive coral (CM), non-*Acropora* encrusting coral (CE), and *Acropora* branching coral (ACB) lifeforms.

Although the CM lifeforms, in general, have the highest percentage in Batu Lampe, if viewed individually from each station, there will be different lifeforms that dominate. CM is recorded as a lifeform with the highest percentage of coverage at four stations, namely stations LB1, LB5, LB8, and LB9 with the coverage percentages of 18.9, 18.0, 41.5 and 25.5%, respectively. The encrusting coral (CE) lifeform, which generally has the highest percentage after CM, is recorded as dominant at two stations, namely stations LB2 (CE=22.0%) and LB3 (CE=24.5%). Then, at other stations, the lifeforms that appeared with the highest percentage of coverage are CF at station LB4 (6.0%), CB at station LB6 (1.2%), ACB at station LB7 (28.3%), and CF at station LK1 (16.8%).

The CM lifeform, although having a slow growth rate, has a hard skeletal structure compared to other lifeforms, thereby having better resistance to hydrodynamic pressure. The CE lifeform also has a strategy of environmental adaptation through encrusting growth. The shape of the CE lifeform which tends to be flat following the surface profile of the substratum will reduce and/or prevent it from being subjected to hydrodynamic forces. Due to the effect of turbidity in the waters, both CM and CE lifeforms have a wide body surface/structure, adapted for maximizing sunlight reception (Rogers 1990; Edinger & Risk 2000; Todd et al 2004). In contrast to CM and CE which adapt through 'survival', lifeforms that have a more fragile structure (e.g., ACB and CF) may adapt through high growth rates. Coral species that have a fast growth will be accompanied by a faster self-recovery ability at the level of tissue damage. Moreover, fragments of fractured structures have a higher survival rate (Meesters et al 1994; Hall 1997; Jones 2008). Although coral species ACB and CF are easily damaged or broken, they will also experience faster recovery, even covering the empty area after damage, as indicated by the coverage of ACB at station LB7. Number of colonies per type of hard coral group found at each research station and the total at all research stations show in Table 4.

Referring to the data presented in Table 4, through the results of the analysis of 1,061 colonies of hard coral groups at all research stations, there were 43 genera of HC groups belonging to 14 families found. Figure 6 shows that station LK1 in Lampe Kecil is recorded as having the highest number of colonies and genera, namely 194 colonies with 26 genera, while station LB6 in Lampe Besar has both the lowest number of colonies and genera, namely only 11 colonies with 4 genera. The small number of colonies and genera at station LB6 is closely related to the condition of coral reefs classified as poor/bad, so that the observed substratum coverage is only dominated by coral debris. The number of colonies, genera and types of hard coral groups recorded at each research station in the reef of Batu Lampe are shown in the following figures below (Figures 6 and 7).

Table 4

Number of colonies per type of hard coral group found at each research station and the total at all research stations

Families	Genus	*Stations*										
		LB1	*LB2*	*LB3*	*LB4*	*LB5*	*LB6*	*LB7*	*LB8*	*LB9*	*LK1*	*Total*
Mussidae	*Acanthastrea*	1										1
Acroporidae	*Acropora*	10	1	3		9	2	39	1	18	2	85
Poritidae	*Alveopora*			1							23	24
Acroporidae	*Astreopora*		2								1	3
Faviidae	*Barabattoia*						1					1
Fungiidae	*Ctenactis*				1			1			5	7
Fungiidae	*Cycloseris*	2		1	2						7	12
Faviidae	*Cyphastrea*							1		1		2
Faviidae	*Diploastrea*				1							1
Faviidae	*Echinopora*				8			1			9	18
Euphylliidae	*Euphyllia*		1									1
Faviidae	*Favia*	4	5	5	1	2		2	4	2	3	28
Faviidae	*Favites*	4	2	11	2	3		3	7	1	5	38
Fungiidae	*Fungia*	1		1	2					1	5	10
Oculinidae	*Galaxea*			2	1	1					2	6
Faviidae	*Goniastrea*	1	2		1	2			5		1	12
Poritidae	*Goniopora*				2						1	3
Fungiidae	*Halomitra*				1							1
Fungiidae	*Heliofungia*										2	2
Fungiidae	*Herpolitha*				1						1	2
Merulinidae	*Hydnophora*	1	1			1	1	1	5	1	24	35
Faviidae	*Leptastrea*								1	1	1	3
Faviidae	*Leptoria*					1						1
Agariciidae	*Leptoseris*				2							2
Mussidae	*Lobophyllia*					1						1
Merulinidae	*Merulina*				4						11	15
Milleporidae	*Millepora*			1						8		9
Faviidae	*Montastraea*	1								1		2
Acroporidae	*Montipora*	60	44	49	3	36		58	7	40	49	346
Pectiniidae	*Oxypora*				1							1
Agariciidae	*Pachyseris*										1	1
Agariciidae	*Pavona*			1							6	7
Pectiniidae	*Pectinia*				1							1
Faviidae	*Platygyra*	1	3	1						4	5	14
Euphylliidae	*Plerogyra*			1	1						1	3
Pocilloporidae	*Pocillopora*	2	1	2				2				7
Fungiidae	*Podabacia*										1	1
Fungiidae	*Polyphyllia*				2							2
Poritidae	*Porites*	30	30	23	2	17	7	65	66	70	26	336
Siderastreiidae	*Pseudosiderastrea*	2						1	1	1		5
Fungiidae	*Sandalolitha*							1			1	2
Pocilloporidae	*Stylophora*	2				3		1				6
Dendrophylliidae	*Turbinaria*					3					1	4

Figure 7 shows that, in general, the three coral species with the highest number of colonies are *Montipora* representing 32.6% of the total recorded colonies, *Porites* representing 31.7%, and *Acropora* representing 8.0%. Here, *Montipora* colonies are generally found in the form of encrusting corals (CE) and foliose corals (CF). observation results show that most *Porites* colonies develop in a massive lifeform (CM), except at station LB7 where colonies with a branching form (CB) dominate. Apart from that, *Acropora* colonies are mostly observed to have branching (ACB) and tabulating (ACT) forms.

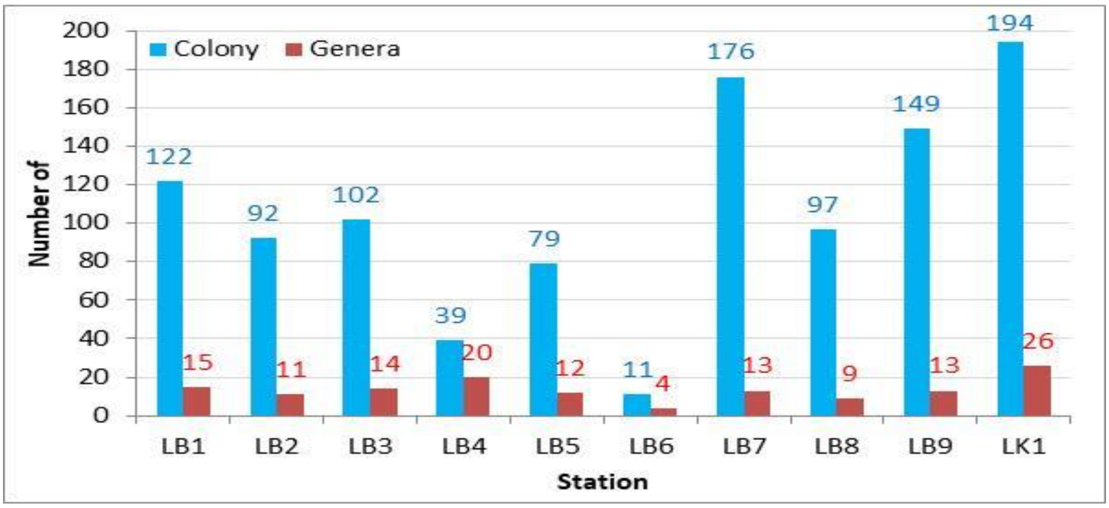


Figure 6. The number of colonies and genera of hard coral groups recorded at each research station.

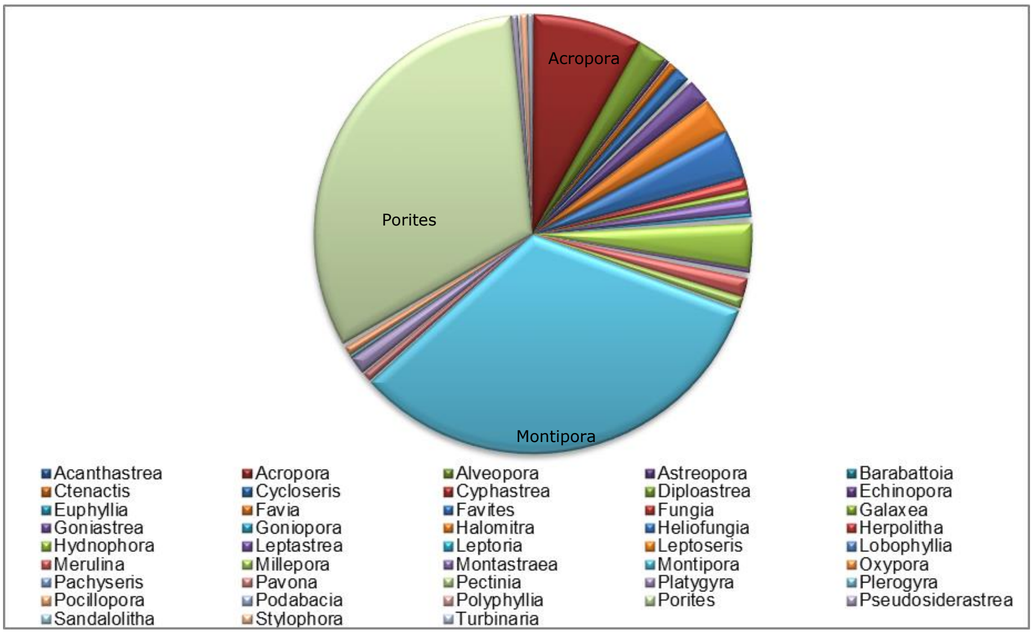
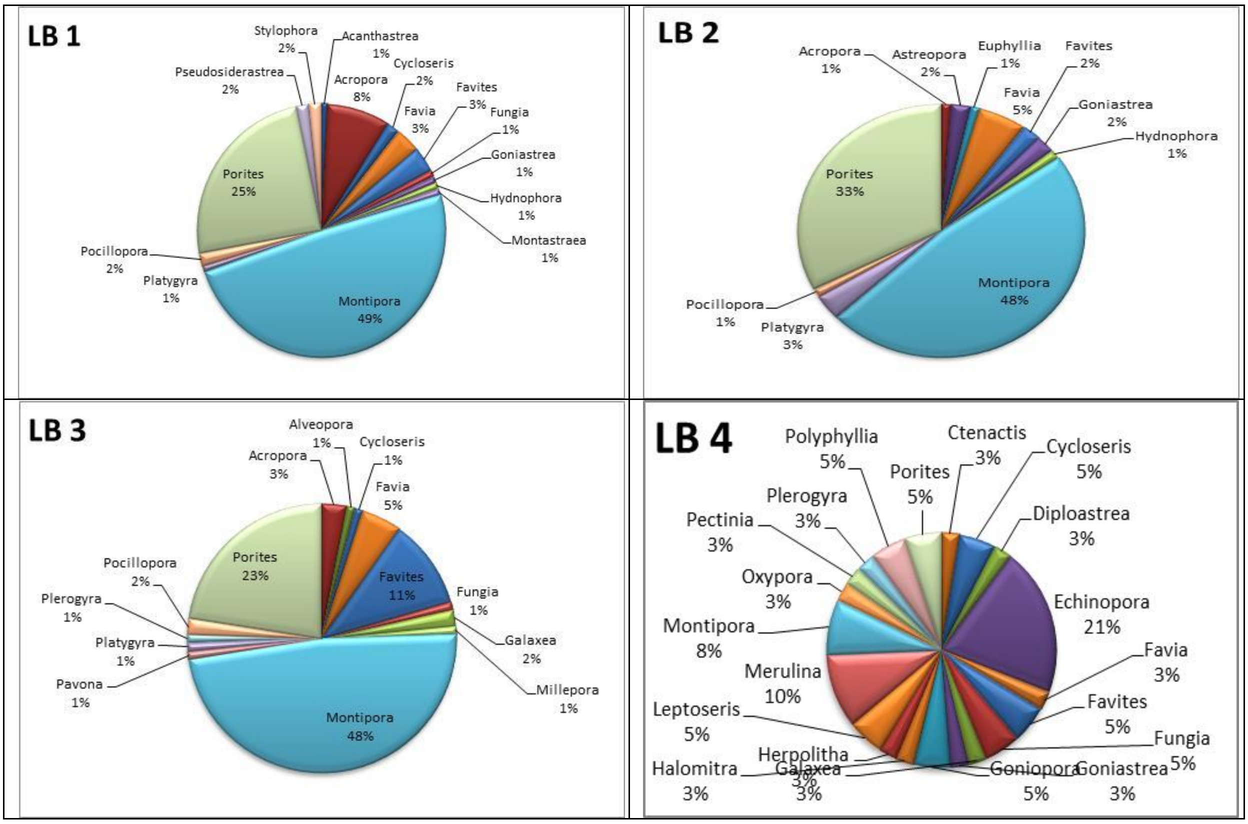


Figure 7. The reef composition by type of hard coral group in Batu Lampe.

Although the overall number of colonies of *Montipora* is similar to that of *Porites*, *Montipora* is present in greater number than *Porites* at six stations (LB1, LB2, LB3, LB4, LB5, and LK1). However, *Porites*, in terms of the number of colonies, are dominant, compared to *Montipora*, at four stations (LB6, LB7, LB8, and LB9). *Porites* are the only species recorded and found at all observation stations. *Porites* colonies in Batu Lampe are mostly observed in CM form. Apart from these lifeforms, *Porites* species are also observed in CB, CE, and CS lifeforms. *Porites* coral colonies generally have a very slow growth rate. In many studies, its average annual growth is stated to be around 1 cm or even only several millimeters (Klein & Loya 1991; Supriharyono 2004; Zamani & Lubis 2016; Groves et al 2018; Luthfi & Sondodipoero 2019). However, *Porites* coral colonies with CM form have a solid or sturdy skeletal structure so that their presence on the reef is more stable and more able to withstand various disturbances. This species is a group that is classified as a stress-tolerator that has a high tolerance for sedimentation and/or eutrophication. Furthermore, it may even survive from high pressure of hydrodynamic (Rogers 1990; Edinger & Risk, 2000; Storlazzi et al 2002; Huda et al 2013; Quataert et al 2015; Erftemeijer et al 2012; Guest et al 2016; Reza & Sancayaningsih 2017).

Acropora is one of the most important coral species in coral reef communities in shallow waters. Moreover, in Indo-Pacific waters, this species is referred to as the main building block of reefs (Heeger & Sotto 2000; Edwards 2010; Aeby et al 2011; Young et al 2012). Most of the colonies of *Acropora* species have both branching (ACB) and tabulate (ACT) forms. In addition, colonies of both lifeforms can grow to a width of about 3 m (Wallace 1999). All species belonging to the genus *Acropora* in their data collection according to English et al (1997) are grouped separately. The hard coral groups are classified in "*Acropora*", while the others are classified as "Non-*Acropora*". The distinction between these groups is based on the presence of axial corallites, in which *Acropora* corals have axial and radial corallites, while non-*Acropora* corals do not have axial corallites (Suharsono 2010). Station LB7, as seen in Figure 6, is the station with the best reef conditions, in which the hard coral stretch is greatly dominated by the three types of aforementioned coral species. However, this large dominance causes an imbalance in the composition of coral species that make up the reef at station LB7. As shown in Figure 8, coral species other than *Porites*, *Montipora*, and *Acropora* are rare. In addition, the result of the dominance in the number of colonies and the use of space on the reef by these three species will reduce the opportunity for other coral species to occupy the related area. As shown in Figure 6 and 8, although these other coral species have the highest number of colonies (176 colonies), the number of genera found does not show the same pattern (13 genera). Moreover, a stark contrast is found in station LB4, a station with a closure condition that is categorized as poor/bad, with a much lower number of colonies (39 colonies), but consist of higher number of genera (20 genera). Therefore, it can be concluded that an increase in the number of colonies is not always followed by an increase in the number of genera. The reef composition of hard coral species, in number of colonies, at each research station is shown in Figure 8 below.



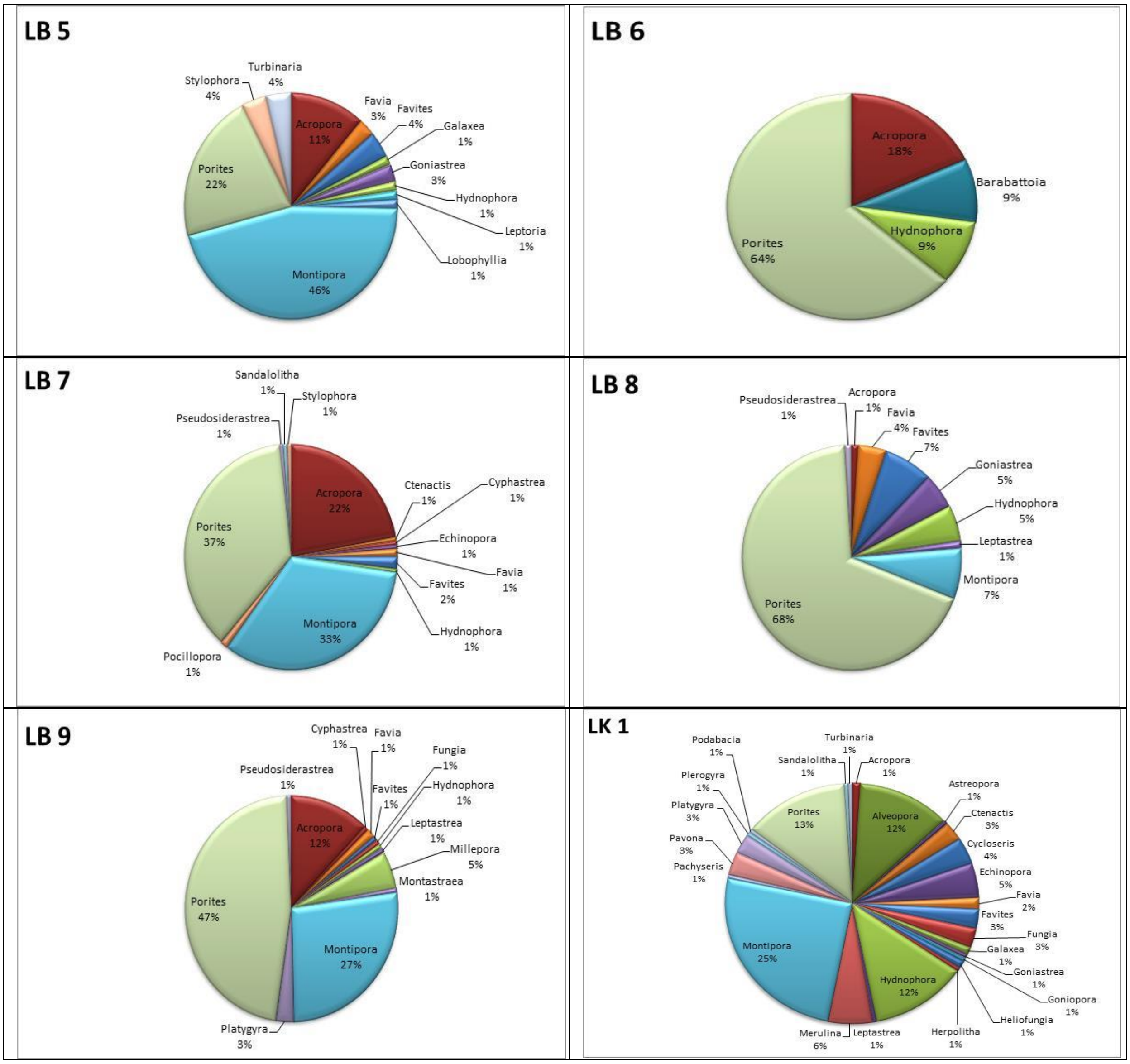


Figure 8. The reef composition of hard coral species, in number of colonies, at each research station.

Conclusions. Gusung Batu Lampe consists of 2 clusters, namely Lampe Besar covering an area of 6.2 ha and Lampe Kecil covering an area of 0.4 ha. Coral reefs in all research stations represented conditional status that varied from poor/damaged to very good category. On average, their conditional status was in the moderate category. The most common hard coral lifeforms are CM and CE. Stations located in the northern part of Lampe Besar have a better percentage of coral reef coverage than those in the southern part. The live coral community in Batu Lampe is mostly supported by the presence of HC colonies. Overall, from all observation stations, we found 43 genera of HC groups that belong to 14 families. In addition, the three types of coral with the highest number of colonies are *Montipora*, *Porites*, and *Acropora*. Furthermore, an increase in the number of colonies is not always followed by an increase in the number of genera.

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