Community structure of estuarine reef fish in Muara Ilu, Mahakam Delta, Indonesia

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Abstract. The Mahakam Delta represents one of the largest tropical deltas in Indonesia located at Kutai Kartanegara, Kalimantan Island and it is heavily affected by sedimentation processes that impact the coral reef habitats. The reef-building corals and reef-inhabiting fish have a mutually symbiotic relationship, with corals providing food and habitat while depending on the grazing by certain fish for reproductive success. This research aims to investigate the coral reef condition and also the community structure of the reef fish in the Mahakam Delta. This study was conducted in July 2018, in Muara Ilu, Mahakam Delta. We observed the coral reef area and reef fish at 6 sites throughout the Mahakam River mouth. The condition of coral reefs and reef fish is assessed through scuba diving activities, using the video belt transect method, while reef fish surveys were done by the operated video transect diver method. The results showed that the coral reefs in the Muara Ilu waters of Tani Baru Village, Anggana District, Kutai Kartanegara Regency, have an area of 36.36 Ha, consisting of two stretches, "Batu Laut Muara Ilu", covering an area of 35.11 Ha and "Batu Darat Muara Ilu", covering 1.25 Ha. The percentage of live coral cover ranges from 2% to 46.4%, with an overall average of 28.5%, which is classified in moderate/moderate coral reef conditions. The reef fish community data from twelve transects showed high diversity and stable fish communities in the coral reef ecosystem from the study sites. The index values obtained are: H'=2.60; E=0.65; C=0.13. In conclusion, the diversity of reef fish was in the medium category, even distribution of species was present and no dominance by certain types was observed.
Key Words: coral, diversity index, Muara Ilu, reef fish.

Introduction. The Mahakam Delta, the largest tropical delta in Indonesia, is located at Kutai Kartanegara, Kalimantan Island. Sedimentation processes at the Mahakam River have created the delta with a covered area of approximately 1800 km^2 and 42 islands (Allen & Chambers 1998; Persoon & Simarmata 2014). The Mahakam River presents 1000–1500 m^{3}sec^{-1} riverine discharge to the ocean, generating up to 8×106 m^3 soil sediments per year, 70% muddy sediments and 30% sand. As a result, the tropical Mahakam Delta is heavily affected in terms of sedimentation, salinity, pH and turbidity. Mahakam Delta might be an unsuitable environment for coral reef development, since water conditions with high turbidity levels can prevent *Symbiodinium* spp. (Zooxanthellae) to carry out photosynthesis (Rogers 1990; Tomascik et al 1997; Fabricius 2005; Golbuu et al 2008; Santodomingo et al 2015) and the light reduction associated with turbidity poses a proportionally greater risk to the coral.

The genus *Symbiodinium* is a mutualistic symbiont within coral that lives in the polyps of most reef building corals in tropical reefs (Stat et al 2009; Trench 1979). Coral can acquire energy heterotrophically and catch zooplankton using tentacles and nematocyst release (Houlbrèque & Ferrier-Pagès 2009). Corals can also swallow and digest suspended particles (Anthony 1999; Anthony 2000; Anthony & Fabricius 2000; Goreau et al 1971), or particles attached to their polyps (Mills et al 2004, Mills & Sebens 2004). Corals have also been shown to be able to ingest and consume macrozooplankton and even benthic gastropod taxa

(Alamaru et al 2009; Mehrotra et al 2016; Mehrotra et al 2019). Corals can also obtain energy autotrophically and endosymbiotic algae can produce food sources for coral hosts (Muscatine et al 1981; Falkowski et al 1984; Muscatine 1990). Some corals have flexibility in their feeding strategies and may preserve a positive energy equilibrium by alternation from autotrophy to heterotrophy depending on depth (Palardy et al 2006), bleaching condition (Bessell-Browne et al 2014; Grottoli et al 2006), and turbidity (Anthony & Fabricius 2000). However, the ability of corals to feed in these modes makes them vulnerable to high sedimentation and turbidity.

Interestingly, even though Muara Ilu has high turbidity, a probably unsuitable habitat for coral, Suyatna et al (2017) and Syahrir et al (2018) have found the presence of coral reefs in the Mahakam Delta. Nevertheless, the Mahakam Delta denotes the spreading boundary of several sponges, scleractinian corals and shallow water fish, among other groups of coastal and reef-associated organisms (Suyatna et al 2017; Syahrir et al 2018). Yet, the study on coral reef ecosystem including the total reef area and the reef fish community in this area is still limited.

Here, we present a comprehensive study on coral reef condition, the ecological health of coral reefs and also the structure of the reef fish community in the Mahakam Delta. The results will provide more insight regarding coral reef condition and its fish community in an unusual environment, Muara Ilu. Coral reef condition and community structure of fish will become a management target because this ecosystem is one of the most important ecosystems in Mahakam Delta.

Material and Method

Study site. This study was conducted during July 2018 in Muara Ilu, Mahakam Delta. The Mahakam Delta is located in the east coast of Kalimantan Island and encompasses approximately 1800 km^2, at the mouth of the Mahakam River, of one of the largest rivers in Indonesia (Figure 1).

Data collection. The coral reef area was investigated at 6 sites throughout the Mahakam River mouth, with 2 transects for each site (Figure 1; Table 1). The sampling sites followed previous study sites that found the existence of coral reef in the Mahakam Delta (Syahrir et al 2018). The total coral reef area was determined by (a) marked coordinates in Citra data that showed coral reefs and (b) ground-check, using an acoustic technique with an Echosounder (Garmin 420i). This tool is known to detect the differences in underwater substrate (Lawrence & Bates 2001; Kagesten 2008; D'Elia et al 2009). The coordinates of each location that indicated the presence of a hard substrate were marked. These coordinates were the initial benchmark for the size and distribution of coral reefs, as well as the coral condition.

Table 1 Locations of sample collections

No	*GPS (UTM)*		*Sample ID*
1	S 00°30'18.9"	E 117°41'26.6"	ST1
2	S 00°30'10.6"	E 117°41'28.5"	ST2
3	S 00°30'01.9"	E 117°41'23.8"	ST3
4	S 00°30'10.1"	E 117°41'18.2"	ST4
5	S 00°30'05.4"	E 117°41'18.0"	ST5
6	S 00°29'58.8"	E 117°40'40.0"	ST6

The condition of coral reefs and reef fish was carried out through scuba diving activities, using the video belt transect method (Hill & Wilkinson 2004; PERSGA/GEF 2004; Lam et al 2006). Surveys were done by SCUBA diving with a belt transects of 50 m length with the diameter of 2.5 m, both to the left and right sides and 5 m upright. Video documentation was taken along the transect. Reef fish surveys were carried out using the operated video transect diver method (Langlois et al 2010; Watson et al 2010; Holmes et al 2013; Tessier et al 2013;

Wartenberg & Booth 2014). This method is similar to the fish belt transect method (Hill & Wilkinson 2004) or rapid visual count (PERSGA/GEF 2004), with the observation being done by video. The survey was carried out by conducting a set of video recordings as far as 50 m following the same stretch of transect on the video belt transect for coral reef condition.

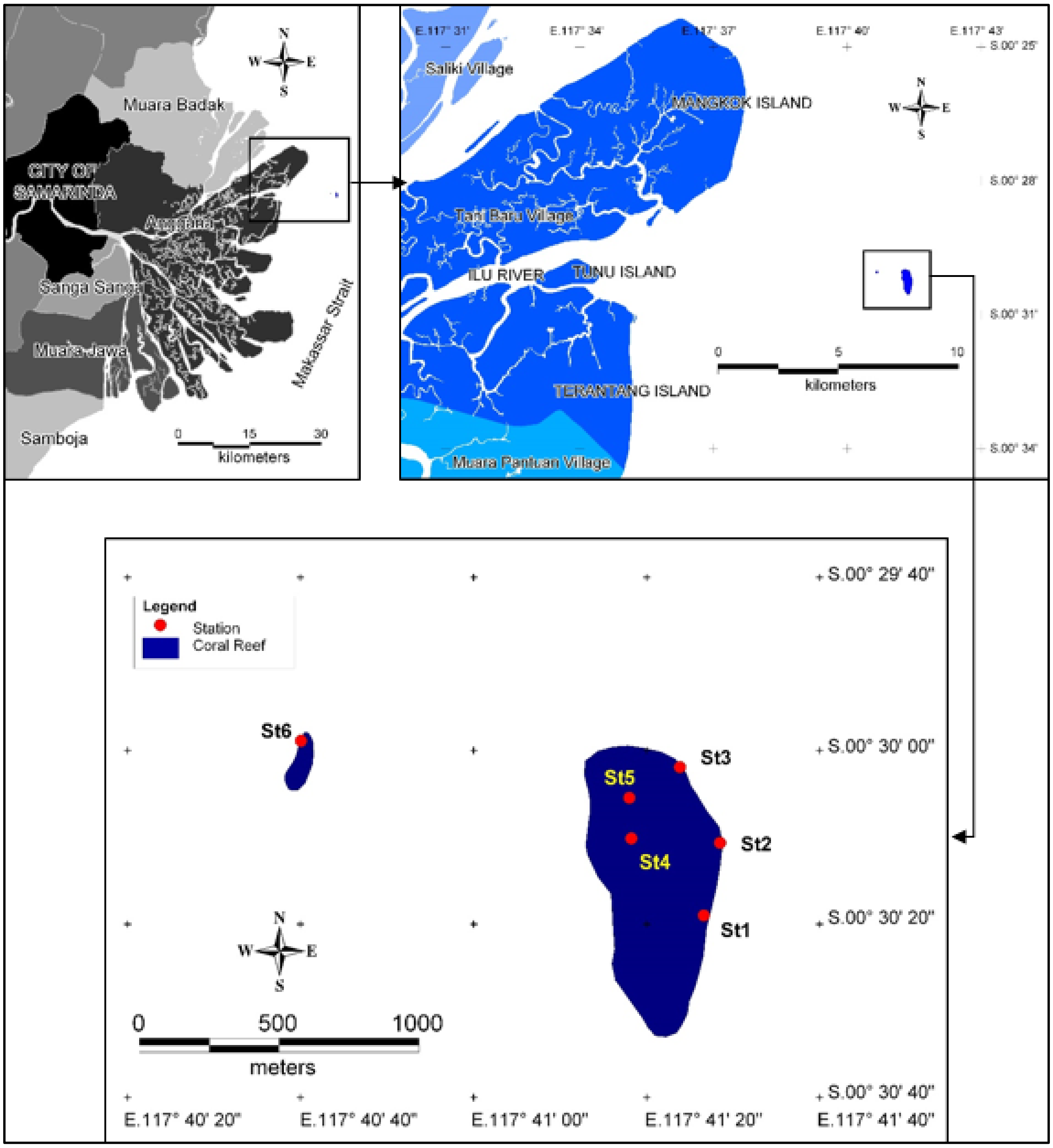


Figure 1. Sample collection sites and distribution of coral reefs in Muara Ilu, Tani Baru Village, Mahakam Delta.

Data analysis. The data analysis of the echosounder and underwater CCTV results was performed with Arcgis 10.1 (ESRI 2012). The coordinates of the coral reef area were connected to the mapping distribution and the total reef area in Muara Ilu, Mahakam Delta was estimated. The presence of coral reefs was determined by qualitative description from the video belt transect results. The cover percentage of live hard coral (HC) was based on the lifeform categories (English et al 1994). The cover percentage of coral life is the total percentage of hard and soft coral (LC=HC+SC). HC is the sum of all the coral cover percentage in the *Acropora* and non-*Acropora* groups (Gomez & Yap 1988; Gomez et al 1994; Jompa & Pet-Soede 2002; Hill & Wilkinson 2004). The coral reef condition category is based on Kepmenneg LH No. 4/2001, about the Coral Damage Standard Criteria and studies by Jompa & Pet-Soede (2002) and Hill & Wilkinson (2004).

The analysis of reef fish videos was carried out using the CountN technique by determining each individual fish recorded in the digital transect video (Wartenberg & Booth 2014). The genus of the reef fish was identified based on scientific literature (Allen & Steene 1994; Randal et al 1997; Allen 2000; Bergbauer & Kirschner 2014) and the validation of genus and family names was performed with the help of WoRMS Editorial Board (2018). For each of the 12 transects, we calculated the following community parameters: the diversity index (Shannon's diversity index), evenness index (E) uniformity, and dominance. Shannon's diversity index (H') is calculated as:

$$H' = -\sum_{i=1}^{s} \mathrm{pi} \ln \mathrm{pi}$$

Where: S is the number of species in the sample and pi is the proportion of S in the species (Shannon & Weaver 1949; Odum 1971).

Community balance was calculated by evenness index (E) ranging from 0 to 1 with the following formula:

E=H'/ Hmax

Where: H' is Shannon's diversity index, Hmax is the maximum value of diversity and S is the number of species in the sample (Odum 1971; Bengen 2000).

Simpson index of dominance (C) represent dominancy rate of one area and the value ranging from 0 to 1 is calculated as:

$$C = \sum \left(\frac{ni}{N}\right)^2$$

Where: ni is importance value for each species and N is the total of importance value (Odum 1971).

Results and Discussion

The coral reef area. The coral reefs in the Muara Ilu waters, Tani Baru Village, Anggana District are a part of the coastal ecosystem in the Mahakam Delta. There were no data, from what we know, of the existence of these ecosystems before our previous study (Syahrir et al 2018). This up-to-date research continued the previous research. The coral reef ecosystem of the Muara Ilu waters, Tani Baru Village, Anggana District is divided in two parts. The farthest part to the sea was about 12.5 km to the east of Tunu Island with an estimated area of 35.11 ha, called the "Batu Laut Muara Ilu". The other part is about 11.5 km from Tunu Island with an estimated area of 1.25 ha, "Batu Darat Muara Ilu" (Figure 1). There are 6 research stations, ST1 to ST5 were located in Batu Laut Muara Ilu and ST6 was located in Batu Darat Muara Ilu (Table 1).

Coral coverage. The coral coverage averaged at 28.59%, with the highest value in ST4 (35.8%) and the lowest value in ST6 (15.3%) (Figure 2). HC coverage was 15.4% and soft coral (SC) was 13.1%, with ST2, ST3, ST4 and ST5 in the category of moderate/moderate coral conditions, and ST1 and ST6 in the category of bad/damaged conditions. The study sites were dominated by muddy or silt (SI) substrate with an average percentage of coverage of up to 48.1% (Figure 3). The high percentage of sludge cover was related to the high concentration of suspended solids, which were transported by the Mahakam River to the delta (Creocean 2000).

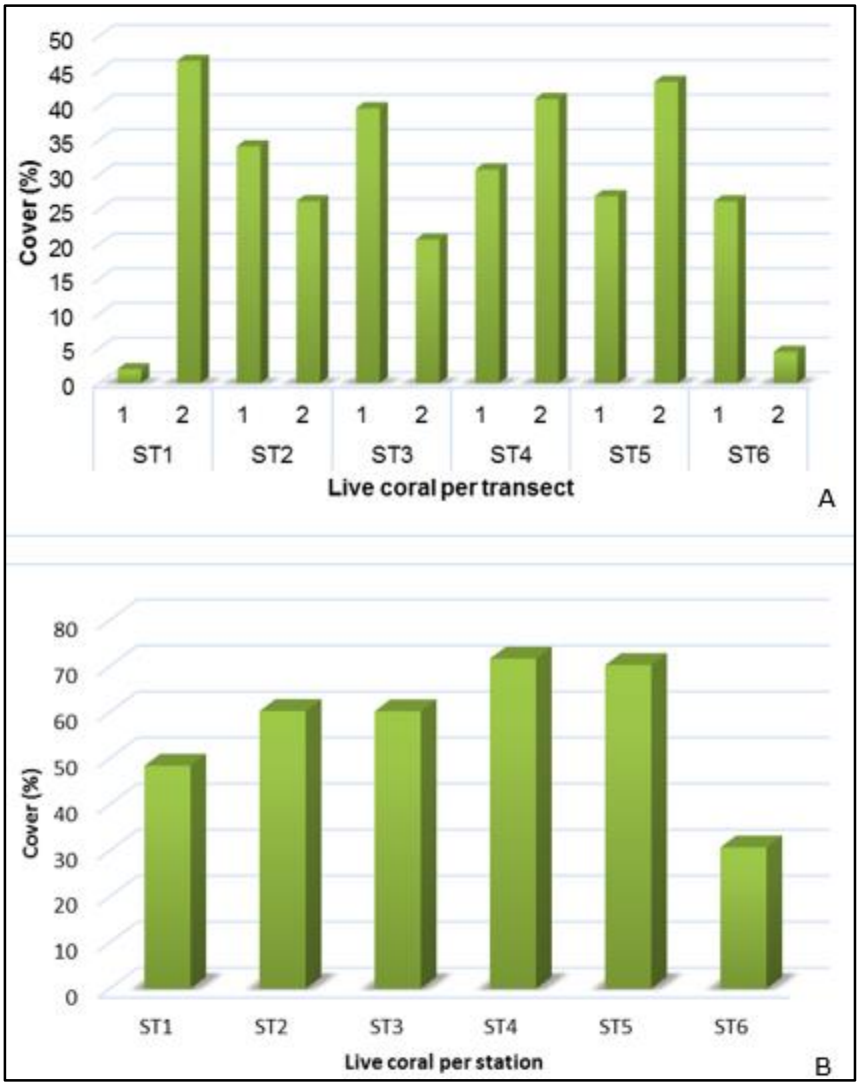


Figure 2. Percentage of live coral. A - average per transect; B - average per station.

The HC groups were mainly composed of sub-massive corals (CS), massive corals (CM) and encrusting corals (CE) (Figure 3). Based on visual observations along the transect, the coral reefs are dominated by the monospecific HC *Galaxea* and the SC *Sinularia* (Figures 4 and 5).

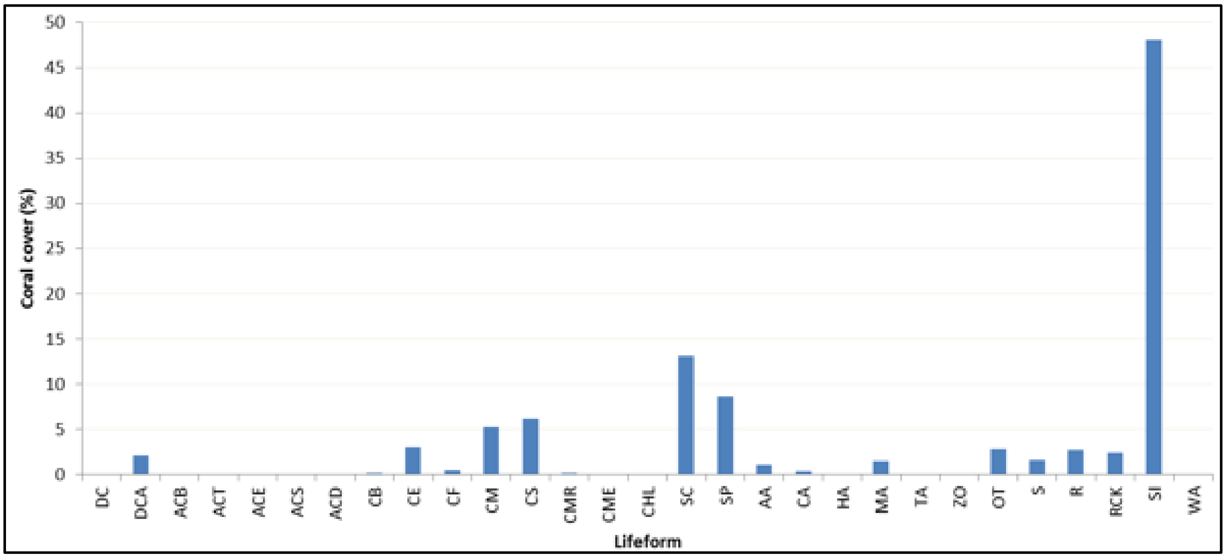


Figure 3. Percentage of average covering per lifeform.

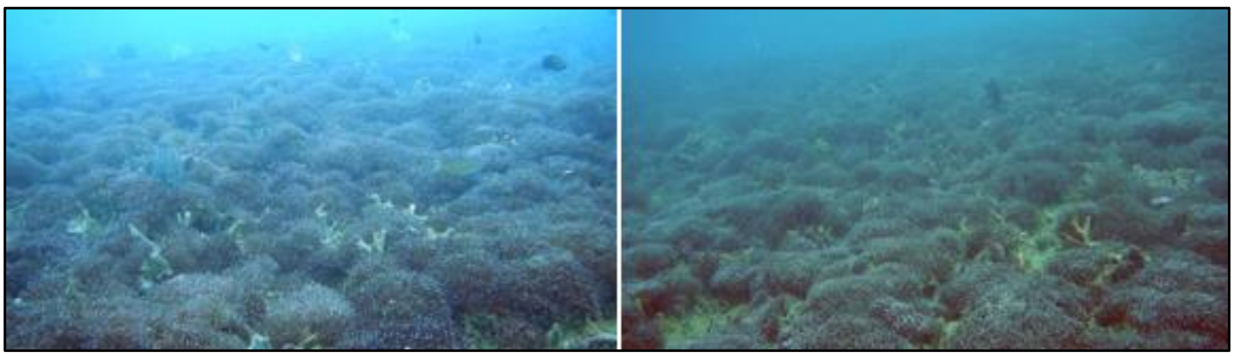


Figure 4. Expanse of hard coral dominated by monospecific genus of *Galaxea*.

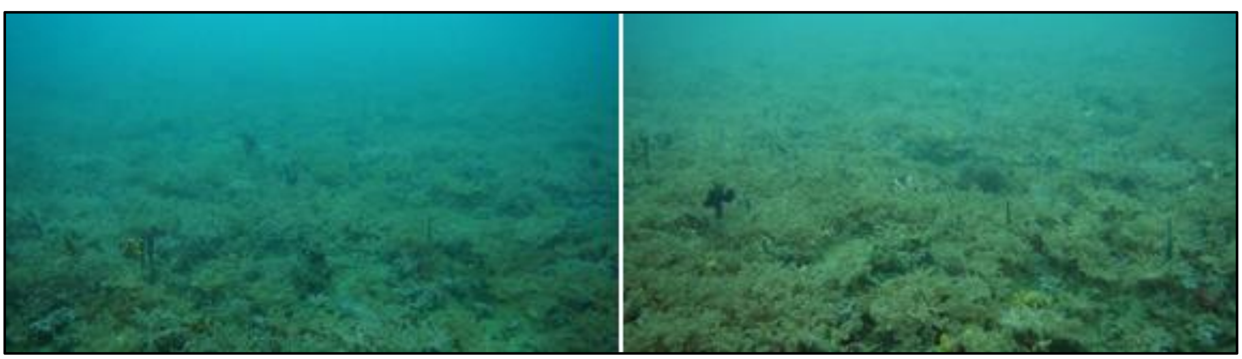


Figure 5. Soft coral overlays dominated by monospecific *Sinularia*.

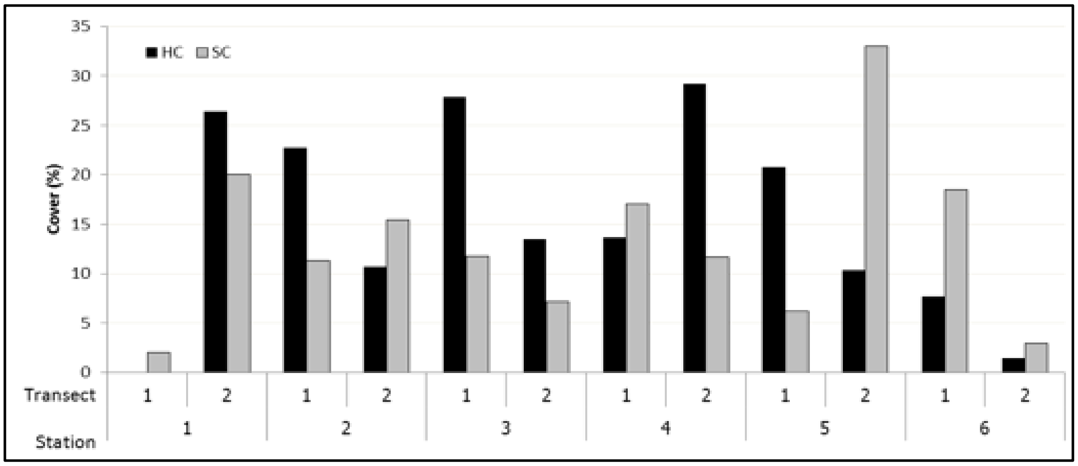


Figure 6. Percentage of hard coral (HC) and soft coral (SC).

Fish abundance and habitat characteristics. The Muara Ilu waters and its fishing activities showed a large fishing potential. However, there are no specific data on reef fish communities and associated fish at the site. Data collection or direct observations through scuba diving revealed some information about the reef fish type and number, and the association with the reef location. The fish communities of the two stretches of coral reefs of Muara Ilu totaled 3855 individuals, from 56 genera and 28 families.

The largest fish community was the genus *Lutjanus* of the family Lutjanidae, with approximately 1000 individuals (29%), followed by the genus *Apogon* the family Apogonidae at 22%, with 768 individuals. The dominance of these fish is almost evenly distributed at all stations (Figure 7). This result was different from previous observations of Suyatna et al (2011), who found the dominance of the family Leiognathidae, with 3 genera, *Leiognathus*, *Gazza* and *Secutor*.

The number of fish counted from all stations and observation transects varied from the lowest of ST4 transect 1 with a number of 5 fish to the highest at ST5 transect 2 with 1085 individuals. There are two points/transects that quite different compared to the other transects, ST5 transect 2 and ST6 transect 1. ST5 transect 2 contained 1085 individuals, most of which consisted of the genus *Apogon*, family Apogonidae, with 695 individuals, while ST6 transect 1 contained 888 individuals, most of which were from the genus *Lutjanus*, family Lutjanidae with 373 individuals. ST5 had the highest number of fish 1523 individuals and ST4 had the least number of fish, 56 individuals (Figure 8; Table 2).

The results showed similar numbers of individual fish. ST5 presented the highest number of genera (37 genera), while ST1, ST2, ST3 and ST6 showed similar numbers of genera, 20, 21, 22 and 21 genera, respectively. ST4 had the lowest number of genera (13 genera). ST4 transect 1 has the lowest number of genera (2 genera). The highest number of genera was found in ST5 transect 1. The results of the genera of reef fish per transect and per observation station are presented in Figure 10.

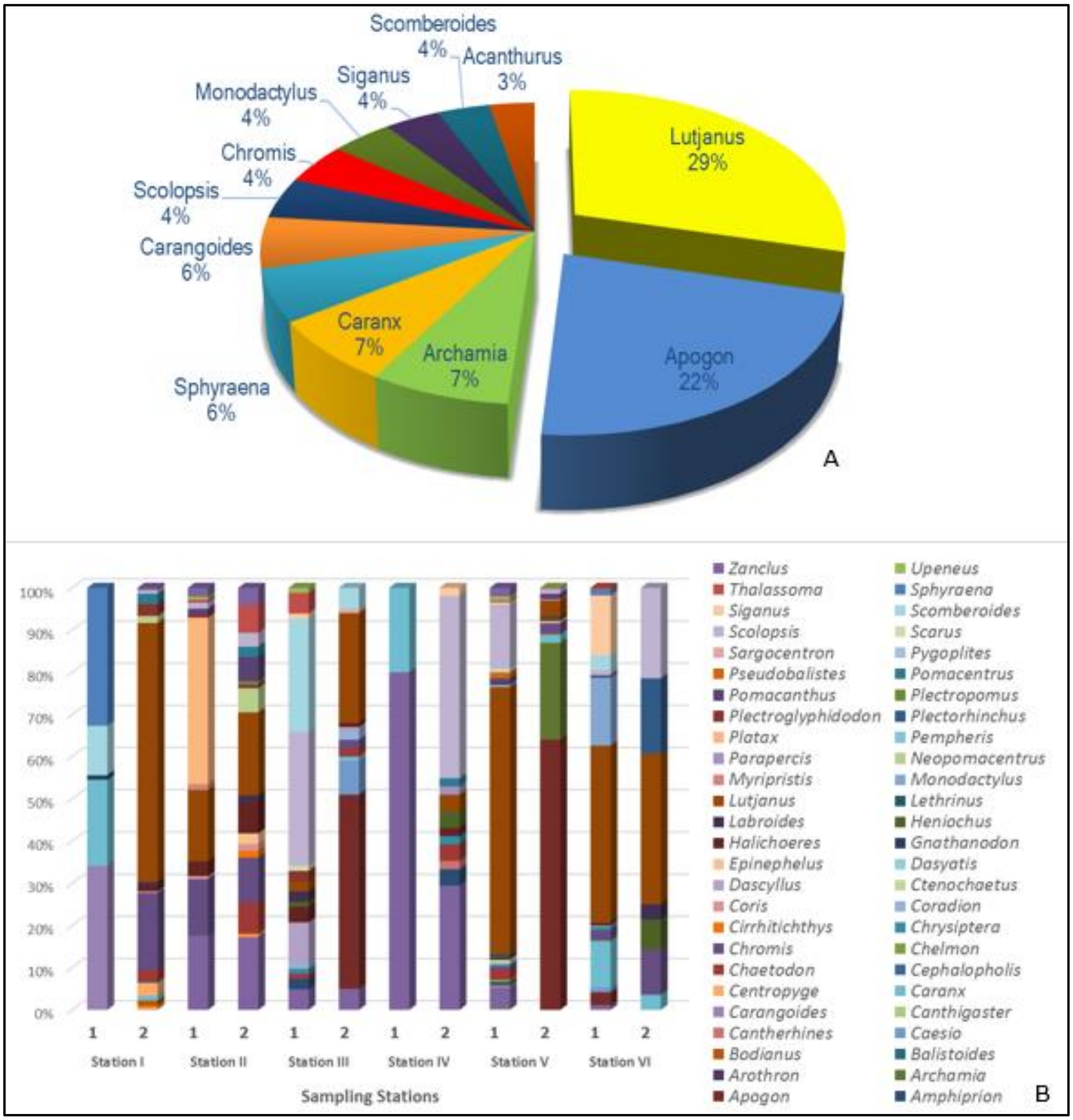


Figure 7. Composition of fish communities based on genera. A - all stations; B - each station.

The observed reef fish communities in our study (Table 2) were divided into 4 groups: carnivores, also including piscivores and invertivores; herbivores; omnivores; planktivores of both phytoplankton and zooplankton (Ferreira et al 2004; Floeter et al 2004; Carassou et al 2008; Piché et al 2010). The largest group in the coral reef area at the study site was carnivore fish, which consisted of 35 genera of reef fish, with 28 tropic genera of carnivore fish and 7 genera of both carnivores and planktivores. Carnivorous-planktivorous tropic fish can fall in the following genera: *Apogon* (Apogonidae), *Caesio* (Caesionidae), *Cephalopholis* (Serranidae), *Monodactylus* (Monodactylidae), *Myripristis* (Holocentridae), *Plectroglyphidodon* (Pomacentridae) and *Thalassoma* (Labridae). Meanwhile, herbivorous fish were from 6 genera, including 1 genus belonging to the herbivorous-planktivorous feeding type, *Amphiprion*. In addition, there were 8 genera of omnivorous reef fish and 15 planktivorous fish genera.

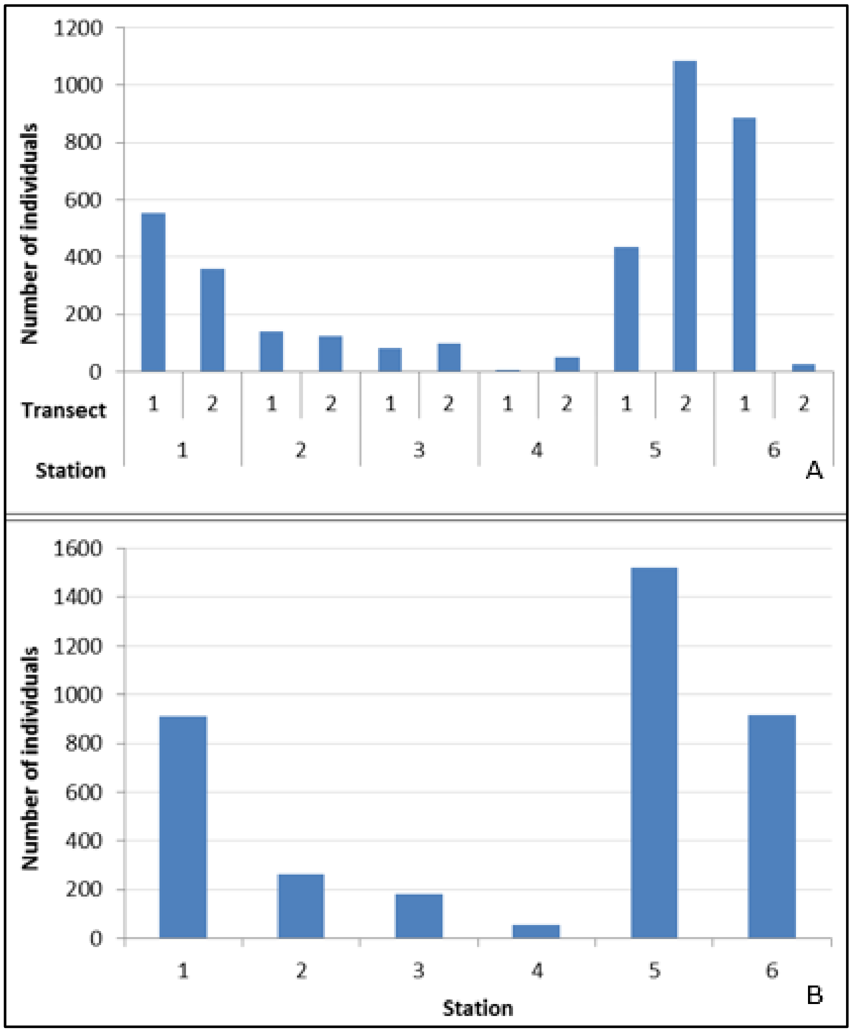


Figure 8. A - the number of counted fish according to the observation transects; B - the number of counted fish according to the observation station.

Figure 9. The observed collection of fish concentrated on large structures at the study site. A - groups of fish in structure; B - groups of fish in the lower part of the structure; C - groups of fish at the top of the structure.

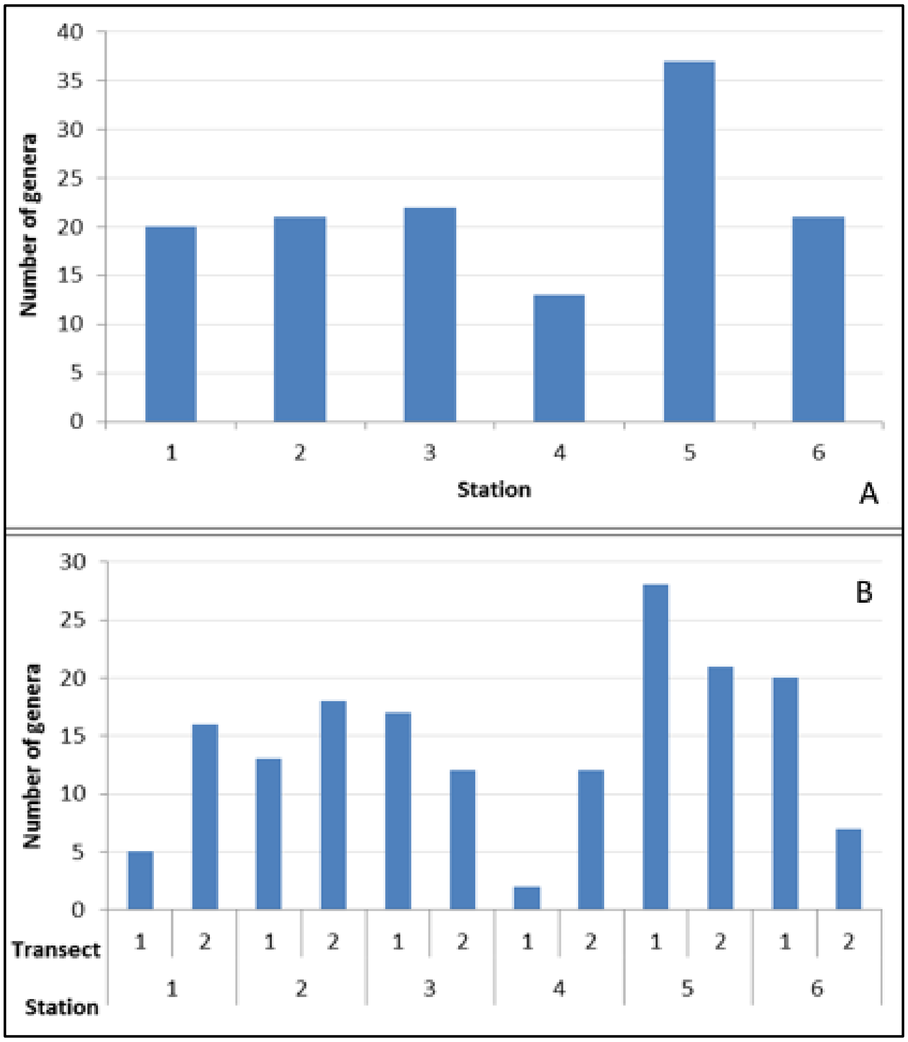


Figure 10. A - the number of fish genera according to the station; B – the number of fish genera according to the transects.

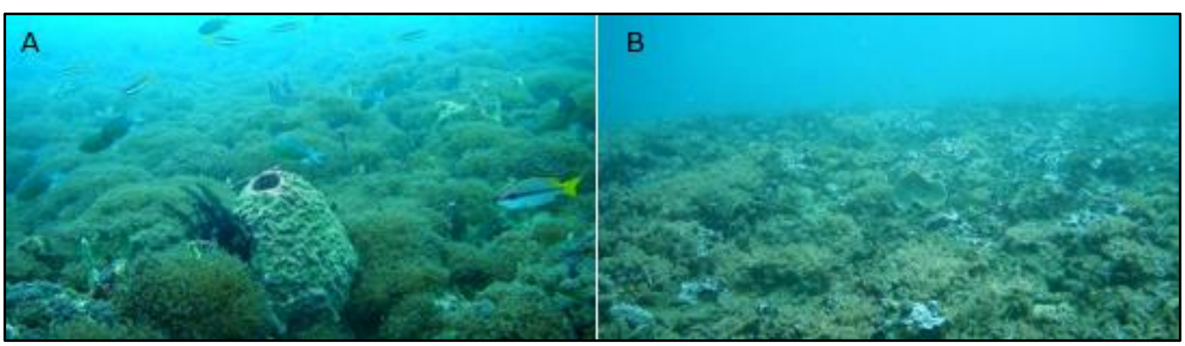


Figure 11. A - community of reef fish on hard coral; B - community of reef fish on soft coral.

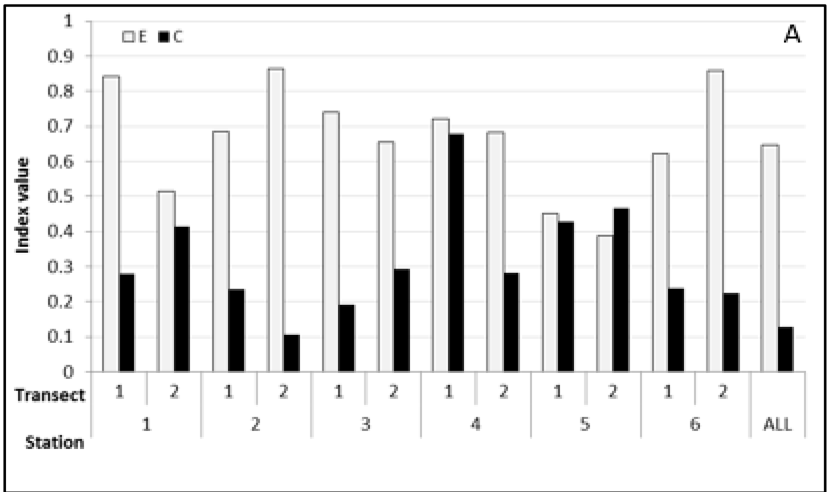
Table 2

Number of individuals and genus of reef fish on each station (ST) transect (Tr)

No	*Family*	*Genus*	*TM*	*Number of individuals per station and transect*											
				ST1		ST2		ST3		ST4		ST5		ST6	
				Tr1	Tr2	Tr1	Tr2	Tr1	Tr2	Tr1	Tr2	Tr1	Tr2	Tr1	Tr2
1	Balistidae	*Abalistes*	C									1			
2	Acanthuridae	*Acanthurus*	H			25	21	4	5	4	15	22		10	
3	Monacanthidae	*Aluterus*	O									1			
4	Pomacentridae	*Amblyglyphidodon*	H		3		1					1			
5	Pomacentridae	*Amphiprion*	HP					2			2				
6	Apogonidae	*Apogon*	CP						46				695	27	
7	Apogonidae	*Archamia*	C										249		
8	Tetraodontidae	*Arothron*	C									1			
9	Balistidae	*Balistoides*	C									3			
10	Labridae	*Bodianus*	C		5							1			
11	Caesionidae	*Caesio*	CP						8					10	
12	Monacanthidae	*Cantherhines*	O								1				
13	Tetraodontidae	*Canthigaster*	C									1	1		
14	Carangidae	*Carangoides*	C	189											
15	Carangidae	*Caranx*	C	113	4				1	1			20	97	1
16	Pomacanthidae	*Centropyge*	O		11										
17	Serranidae	*Cephalopholis*	CP		1										
18	Chaetodontidae	*Chaetodon*	C		10		9	1	2		2	11	3		
19	Chaetodontidae	*Chelmon*	C										1	2	
20	Pomacentridae	*Chromis*	P		66	19	13		2			3	24	22	3
21	Pomacentridae	*Chrysiptera*	P					1			1	2	1	7	
22	Cirrhitidae	*Cirrhitichthys*	C				2								
23	Chaetodontidae	*Coradion*	C					1	2			2			
24	Labridae	*Coris*	C			1	2						2		
25	Acanthuridae	*Ctenochaetus*	H									2			
26	Pomacentridae	*Dascyllus*	P					8	1						
27	Dasyatidae	*Dasyatis*	C											1	
28	Serranidae	*Epinephelus*	C		1		3					1	4	1	
29	Carangidae	*Gnathanodon*	C	6											
30	Labridae	*Halichoeres*	C		5	5	9	3	1		1	2	3	3	
31	Chaetodontidae	*Heniochus*	P					1			2	1	4		2
32	Labridae	*Labroides*	C		3		2	2					3	3	1
33	Lethrinidae	*Lethrinus*	C									3	1		

34	Lutjanidae	*Lutjanus*	O		221	24	24	2	26		2	277	41	373	10
35	Monodactylidae	*Monodactylus*	CP											143	
36	Holocentridae	*Myripristis*	CP			2							4		
37	Pomacentridae	*Neopomacentrus*	P		6		7								
38	Pinguipedidae	*Parapercis*	C								1				
39	Pempheridae	*Pempheris*	P									2			
40	Ephippidae	*Platax*	O			56									
41	Haemulidae	*Plectorhinchus*	C										1	1	5
42	Pomacentridae	*Plectroglyphidodon*	CP		10	1	1	2							
43	Serranidae	*Plectropomus*	C				1								
44	Pomacanthidae	*Pomacanthus*	O			2	7					7	13	4	
45	Pomacentridae	*Pomacentrus*	P		9		3				1				
46	Balistidae	*Pseudobalistes*	C									6			
47	Pomacanthidae	*Pygoplites*	O									1			
48	Holocentridae	*Sargocentron*	C						1						
49	Scaridae	*Scarus*	H					1				3			
50	Nemipteridae	*Scolopsis*	C		3	2	4	26			22	67	12	11	6
51	Carangidae	*Scomberoides*	C	65				22	5					31	
52	Siganidae	*Siganus*	H					1			1	2		126	
53	Sphyraenidae	*Sphyraena*	C	181										12	
54	Labridae	*Thalassoma*	CP			1	8	4				2	2	4	
55	Mullidae	*Upeneus*	C			1		1				4	1		
56	Zanclidae	*Zanclus*	O		2	3	5					9			
	Total individuals			554	360	142	122	82	100	5	51	438	1085	888	28
	Total genera			5	16	13	18	17	12	2	12	28	21	20	7
	Diversity index (H’)			1.36	1.43	1.76	2.5	2.1	1.69	0.50	1.69	1.50	1.180	1.87	1.6
	Uniformity (E)			0.84	0.51	0.69	0.86	0.74	0.66	0.72	0.68	0.45	0.388	0.62	0.86
	Dominance (C)			0.28	0.41	0.24	0.11	0.19	0.29	0.68	0.28	0.43	0.466	0.24	0.22

Note: TM - food trophic group; C - carnivorous; H - herbivore; O - omnivore; P - planktivorous.



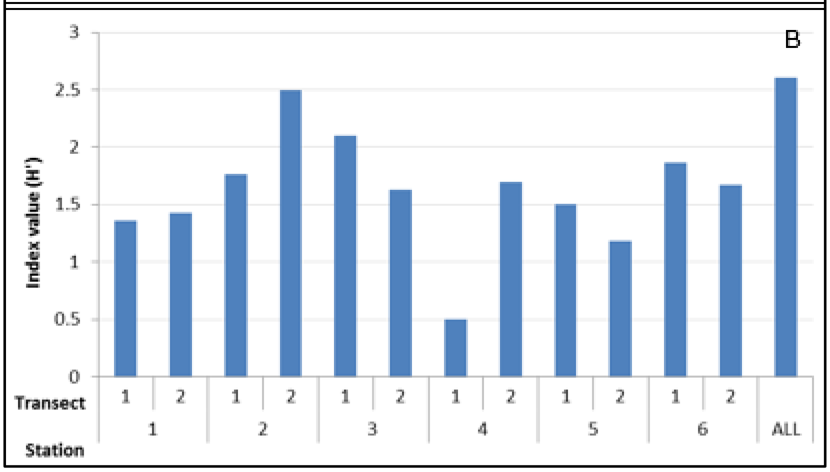


Figure 12. A – uniformity (E) and dominance (C) indexes; B – diversity index.

The analysis of the fish community structure indicated that the index values varied among transects and observation stations (Figure 12). Diversity index values (H') varied from 0.50 to 2.50, indicating low to moderate diversity. 11 transects exhibited moderate diversity levels, ranging from 1.18 (ST5 Transect 2) to 2.50 (ST3 Transect 2), while only one transect showed a low diversity level (0.50 for ST4 Transect 1). Coral fish in ST4 transect 1 numbered 5 specimens from 2 genera, 4 *Acanthurus* fish (Acanthuridae) and 1 *Caranx* fish (Carangidae). This does not indicate a stable community.

The uniformity and dominance index values also showed the differences between transects and observation stations. The uniformity index value (E) ranges from 0.39 to 0.86, while the dominance index value (C) ranges from 0.11 to 0.68. Eight of the twelve transects showed a uniform trend of species distribution and no dominance of particular species. The data indicates that the fish community populations were more stable. The transects were ST1 transect 1, ST2 transect 1, ST2 transect 2, ST3 transect 1, ST3 transect 2, ST4 transect 2, ST6 transect 1 and ST6 transect 2. ST4 transect 1 with E values of 0.72 and C 0.68, as mentioned earlier, show an unstable community of reef fish. Fewer individuals and genera than other transects indicated that this location was not an appropriate environment for supporting various types of fish. ST1 transect 2, ST5 transect 1 and ST5 transect 2 consisted of E and C index values of E=0.51, C=0.42; E=0.45, C=0.43; and E=0.39, C=0.47, respectively. The result indicated the instable tendency of the reef fish community at the related location. Some transects consisted of higher amounts of fish than other genera. Genus *Lutjanus* represented 61.4% from the total fish in ST1 transect 2 and 63.2% in ST5 transect

1. The predominant tendency in ST5 transect 2 was represented by the genus *Apogon* with 695 fish (64.1%).

The variation of coral lifeforms is presumably based on the adaptation to the Mahakam Delta environmental conditions, particularly high levels of turbidity and sedimentation, indicated by the high percentage of mud cover (Tomascik et al 1997; Edwards et al 2001; Torres & Morelock 2002; Ferns 2016). Coral reef at Muara Ilu was dominated by the HC *Galaxea* and SC genus *Sinularia*. This is similar with a previous study of Syahrir et al (2018). The existence of the *Galaxea* coral colonies is probably due to its ability to widely grow and have various morphological forms such as massive, sub-massive, laminar, encrusting and branching forms (Veron 2000). Coral colonies with the massive-columnar morphological forms were mentioned by Rogers (1990) and Edinger & Risk (2000) to be stress tolerant, especially to high sedimentation and eutrophication. *Sinuaria*, *Sarcophyton*, and *Lobophytum* as the SC genera group of the family Alcyoniidae, are found in various waters around the world (Fabricius et al 2007; Goh et al 2009; Chanmethakul et al 2010; Aratake et al 2012). This group has a rapid growth rate, able to tolerate and grow well in waters with moderate sedimentation and turbidity levels (Fabricius & Alderslade 2001; Chanmethakul et al 2010; Aratake et al 2012).

The HC group commonly has the largest coverage and widest distribution, followed by the SC group (Jayasree et al 1996). However, the SC group in this study showed a greater cover proportion than HC in some locations, especially on ST5 with HC 15.6%, SC 19.6% and ST6 with HC 4.6% SC 10.8% (Figure 6). This results were similar with those of previous studies reporting about SC domination (Fabricius 1997; Schleyer & Celliers 2003; Schleyer & Benayahu 2008; Syahrir et al 2015).

The greater number of carnivores than herbivores, omnivores and planktivores indicated that the coral reef area in the Muara Ilu waters of Tani Baru Village, Anggana District served as a feeding ground. During the process of collecting data, large types of carnivores were found, including *Sphyraena* (193 individuals), *Scomberoides* (123 individuals), *Monodactylus* (143 individuals), *Caranx* (237 individuals) and *Carangoides* (189 individuals). The observed ecological functions of the coral reefs at the research sites were as shelter or protection and nursery. This could be seen from the large number of small-sized groups of fish that hide near the coral structures (Figure 9). Sale & Douglas (1984) and Mendonça-Neto et al (2008) state that the presence of large rocks is important for small fish species, because they provide shelter.

Habitats with high structural complexity, for instance coral reefs, are commonly known to support more types of biota by providing shelter from predation and competition (Charbonnel et al 2002; Gratwicke & Speight 2005; Mendonça-Neto et al 2008). Small fish species that live here are generally less than 15 cm long and can be found in large numbers in almost all coral reef areas, having significant role in reef fish communities (Allen 2000; Bergbauer & Kirschner 2014).

The structural complexity of HC was different from SC in supporting fish communities. Syms & Jones (2001) explained that HC groups have a much larger role than SC. The SC degradation would seem to not affect the fish community. However, if the HC group decreased, the population and diversity of reef fish species would linearly decline. This was related to HC colonies that consisted of hard limestone skeletal structures, which could be used as a shelter by individual reef fish, even thought it had died (Adam et al 2014).

The coral fish communities were mostly located in the HC area, whereas only a few fish were found in the SC area (Figure 11), which is may not only due to the differences in availability of hard structures of coral as a shelter of the reef fish but also related to metabolite compounds commonly produced by soft corals. The Octocorallia group produces toxic biochemical compounds with allelopathic effects, which are useful as a space competition strategy against Scleractinia, fellow Octocorallia corals and also as a survival strategy towards fish predation (Coll et al 1982; Sammarco et al 1983; La Barre et al 1986; Kelman et al 1999; Fleury et al 2006; Hoang et al 2015).

Conclusions. In conclusion, the coral reefs in Muara Ilu waters have a total area of 36.36 Ha, consisting of two stretches, "Muara Ilu Batu Laut", covering an area of 35.11 Ha and "Muara Ilu Batu Darat", covering 1.25 Ha. The reef can be included in the moderate coral group. Our results show that coral cover is essential for the maintenance of local diversity of reef fish. The diversity of reef fish is in the medium category, with an even distribution of species and no dominance by certain types.

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