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Sedimentation Rateand Total Suspended Solid (TSS) In Melombo Area, Salurang Village, Sangihe Archipelagic Regency

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Abstract: *This study was aimed to know the sedimentation rate and the total suspended solid of the estuary in relation to the implementation of melombo culture practice area. The sedimentation rate was measured using sediment traps placed in 3 set stations and data were taken for 8 months of two weeks interval. The sediment traps weremade of PVC pipe, 11.5 cm long and 5 cm diameter and located at 20 cm above the sea bottom. Sediment samples were firstly soaked in freshwater for approximately 4 hours to remove salt content. Sedimentation rate was determined as* $\pi r^2 h$*/time length, while Total Suspensi Solid (TSS) followed the formula of Eaton, et al (1995). Results showed that the sediment trapped in station 1 ranged from 5.6 cm (109.9 cm*^{3}*) – 7.7 cm (151.11 cm*^{3}*) with an average of 6.61 cm (129.7 cm*^{3}*), station 2 from 5.3 cm (104 cm*^{3}*) to 8.5 cm (166.8 cm*^{3}*) with an average of 7.18 cm (140.9 cm*^{3}*) and station 3 from 3.8 cm (74.6 cm*^{3}*) to 7.6 cm (149.2 cm*^{3}*) with an average of 6.8 cm (133.8 cm*^{3}*), respectively. Total suspended solids (TSS) ranged from 18.28 to 50.60 with an average of29.165 (29.59%) for station 1, 27.84 to 47.48 with an average of38.99 (39.56%) for station 2, and 18.28 to 50.60 with an average of 30.405 (30.85%) for station 3, respectively.Based upon the decree of Living Environment Minister Numbered 51, 2004, for marine biota, the TSS has been above the standard seawater quality.*

Keywords*: Melombo, Sediment traps, sedimentation rate, TSS.*

I. Introduction

Sangihe Archipelagic Regency is geographically located between 4^O 4' 13'' - 4^O 44' 22'' U and 125^O 9' 28'' - 125^O 56' 57'' E, at the position between Sulawesi Island and Mindanao Island (Phillippine Republic). Its capital is Tahuna with a distance of 142 sea milesfrom Manado, the capital of North Sulawesi.It has a total area of 11,863.58 km^2 consisting of land of 736.98 km^{2}or 6.2 % (60 % flat, 40 % slope)and sea of 11,126.61 km^2 (93.8%). Forest area is about 13,820 Ha comprising protected forests of ± 12.672 Ha and mangrove forests of ± 1.148 Ha. Field conditions showed that the forests have mostly become critical land due to plantation, protected forest clear-cut,timber theft and other damages. Recent data show that the critical land in the forest area is ± 9.322 Ha, and that outside the forest is ± 53.213 Ha (BAPPEDA, 2011).

As an archipelagic area in general, this region often has natural phenomenon that could sometimes cause very high loss, such as sea storm/tidal wave, tornado, vulcano, flood and landslide. The climate is influenced by monsoons, with mean air temperature per month of 27^{o}C over 2010 following the measurements of Naha Meteorological Station.Topographic condition is mountaineous and hilly terrestrial area with labile land (latosol and aluvial) with 0 - 750 m above sea level and a transpacific vulcano chain from Hawai, Japan, Philippine ending in Mollucas so that the area is vulnerable to natural disaster.

Melomboarea is an estuary located between coral reefs and terrestrial in the river mouth of Salurang. Estuary is a body of water where occurring mixtures of tide affected-seawater and freshwater from the land so that this water condition is highly dependent upon the seawater and freshwater conditions going into the area. The higher the suspended materials contained in the water the higher the mud deposition in an estuary. Nybakken (1992) stated that deposit formation got also marine influences, since seawater contains sufficient number of suspended materials.

Recent increase in human activities along Salurang watershed has had some impact on the estuarine ecosystem. These are illegal gold mining in Salurang watershed and forest clear cut in the upstream. Gold mining activities were done by taking apart of the mound using high pressure pumps. These activities bring about increased soil erosion along the watershed. As a result, number of sediment (suspended solid) in the river increases and makes superficiality in melombo area. Factors affecting the sedimentation process in the rivermouth are waves and current patterns (Efrijeldi, 1999).

Sedimentation is the entry of sediment load in a certain aquatic environment through water medium and suspended in the environment**.**Coastal sedimentation will be a problem if it occurs in locations where there are human activities requiring relatively better water conditions with sufficient depth, such as melombo area, which is scad fishing ground, and sailing paths or those who need clear water condition, such as marine tourisms, coral reef ecosystem or seagrass beds.In other words, sediment is defined as materials concentrated in a water mass, either in organic or inorganic forms. Factors affecting sedimentation in the rivermouth are watershed topography, climate, soil type and texture, river morphometric, hydrological system and tidal energy in the rivermouth(Pickard, 1967).

Indonesia coastal waters possesses various important roles, such as food source, transportation mode and harbour, industrial area, agroindustry, tourism, residential area and fisheries (Dahuriet al., 2001). Basic concept of fishing fisheries development is Indonesia national sustainable development concept, including natural resources and environmental protection (Men. LH, 1997), sincethe coastal area holds various problems, from pollution to habitat degradations, and other longer implication, such sea level change.

Melombowaters, in the range of 0.5 – 5.0 m deep at low tide(Appendix 1), is an implementation area of melomboactivities in Salurang village located in the district of Central South Tabukan, Sangihe Archipelagic Regency. The use of melombocoastal area is for yellowstripe scad (Selaroides leptolepis)fishing activity and local sea transportation in which these activities could result in some impact on the sustainability of fish exploitation and natural resources that will eventually put strong ecological pressures due to water quality decline.

The sustainability of local wisdom "melombo"in the coastal area of Salurang is highly determined by the environmental condition of the estuary,and therefore, the aquatic physical condition study was carried out in order to promote the sustainability of the cultural wisdom melombo directing to know the sedimentation rate and the total suspended solid of the estuary on the sustainability of cultural wisdom,melombo.

II. Method

Sediment measurements were done by placing sediment traps at 3 established stations,then checked at a 2 week interval for 8 months. The sediment traps used weremade of PVC pipe, 11.5 cm long and 5 cm diameter, and then placed at 20 cm above the sea bottom. Moreover, the sediment trapplacement used a 40 cm x 40 cm x 6 cm concrete blockwhich upper part attached a 20 cm cylindrical concrete block as a base of the PVC pipe placement put on the sea bottom (Fig. 1). Trapconstruction followed Gardner (1980) in Manengkei (2003), and it was laid at 3 – 4 m depth.

Sediment samples collected in thesediment trapswere measured the height trapped, then put into the plastic bag and held in the iced box for laboratory analysis. Before sediments were measured/weighed, the samples were previously soaked in freshwater for approximately 4 jam to remove salt content in clean sediment.Then, the sediment at each station was diluted tobe 250 ml solution, taken 10% and placed on a Ø 47 mm and 0.45 µm mesh size "Whatman" filter paperwhose weight was known. The sediment was then placed on the filter and water filtering used 'vac Gast Benton Harbon,MI'-typed vacumn pump, weighed and dried in a "Memmert" oven at 90°C for 24 hours. Afterwards, final weight was taken to obtain the dry weight.

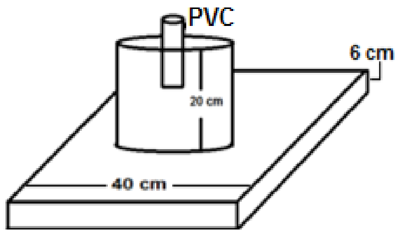


Figure 1. Sediment Traps

Sedimentation rate calculations used theπr^2h formula divided by length of time, whereπ = constant, r = ½ pipe diameter, h= sediment height in the pipe, but Total Suspensi Solid (TSS) was analyzed using the formula of Eaton et al (1995) as follows:

$$\text{TSS (mg/L)} = \frac{(\text{A-B}) \times 1000}{\text{Sample volume (mg/L)}}$$

where A = filter weight + dry residu weight (mg) andB = filter weight

III. Results and Discussion

A. Sedimentation Rate

Based on the sediment falling into the sediment trap, the sediment height in station 1ranged from 5.6 cm (109.9 cm^3) – 7.7 cm (151.11 cm^3) with an average of 6.61 cm (129.7 cm^3), station 2 from 5.3 cm (104 cm^3) – 8.5 cm (166.8 cm^3) with an average of 7.18 cm (140.9 cm^3) and station 3 from 3.8 cm (74.6 cm^3) – 7.6 cm (149.2 cm^3) with an average of 6.8 cm (133.8 cm^3), respectively (Table 1 and Fig. 2).

The highest sediment was recorded in station 2, 7.18 cm, due to its position in the rivermouth**,** then followed by station 3**.**It could probably result from mining activities in Salurang watershed and global climate changethat affects the rainfalls in Sangihe island. Based on meteorological data, rainfalls from March to September were difficult to predictdue to natural anomaly from global climate change.

Table 1. Sediment height distribution in each sediment trap from March to September 2012

Observation	Station					
	(1) **03°28'33.6"N 125°40'00.6"S**		(2) **03°28'27.4"N 125° 39' 57.5"S**		(3) **03°28'30.3"N 125°39'58.4"S**	
	Height (cm)	Volume (cm^3)	Height (cm)	Volume (cm^e)	Heighti (cm)	Volume (cm^3)
1	7,3	143.26	7,1	139.34	7,5	147.19
2	6,3	123.64	6.4	125.60	7.6	149.15
3	6.5	127.56	7.7	151.11	7.2	141.30
4	6,7	131.49	6.9	135.41	6.7	131.49
5	5,9	115.79	7.1	139.34	7.1	139.34
6	6,3	123.64	7.3	143.26	7.0	137.34
7	6,2	121.67	7.2	141.30	6.9	135.41
8	6,9	135.41	7.3	143.26	6.8	133.45
9	6,3	123.64	7.5	147.19	7.6	149.15
10	6,4	125.60	7.7	151.11	5.5	107.94
11	5,6	109.90	5.3	104.01	3.8	74.57
12	6,6	129.53	7.0	137.37	7.2	141.30
13	7,2	141.30	7.2	141.30	7.0	137.37
14	7,7	151.11	8.5	166.81	7.2	141.30
15	6,9	135.41	7.1	139.34	6.8	133.45
16	7,0	137.37	7.6	149.15	7.3	143.26
Mean	6.61	129.77	7.18	140.93	6.82	133.94

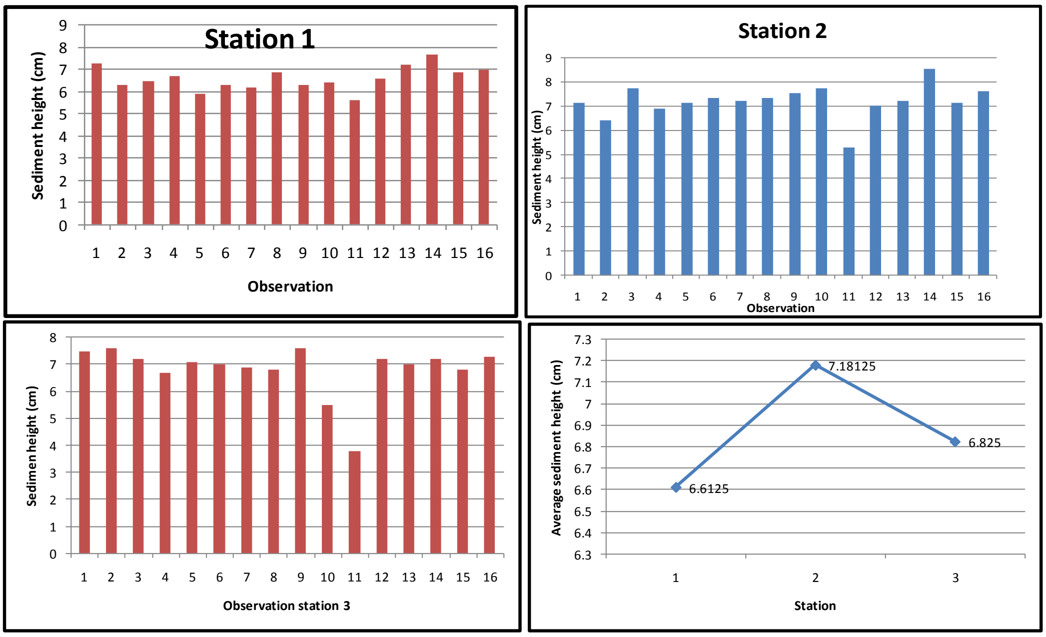


Figure 2. Sediment height distribution in each station from March to September 2012.

B. Suspended Solid (TSS)

Table 2shows that total suspended solid (TSS) in station 1 ranges from 18.28 to50.60ppm with an average of30.40 ppm (29.59%) (Table 2, Figure 3 A), instation 2 from 27.84 to 47.48 ppm with an average of38.99 ppm (39.56%) (Table 2, Figure 3 B)and in station 3 from 18.28 to44.68ppm with an average of 30.405 ppm (30.85%), respectively (Table 2, Figure 3 C).These values have exceeded the standard seawater quality based upon the decree of Living Environment Minister numbered 51, 2004, for marine biota< 20 ppm.

Table 2. Calculation table and figure of TSS mean distribution in station 1, 2, and 3,

Station 1

No.	Filter Weight (mg)	Wet Weight (mg)	Dry Weight (mg)	TSS/ltr
1	0.4574	6.89	6.96	27.84
2	0.4574	14.32	12.65	50.6
3	0.4639	9.2	6.82	27.28
4	0.4819	10.42	9.24	36.96
5	0.4615	10.05	9.75	39
6	0.4562	11.45	8.81	35.24
7	0.4632	13.51	11.17	44.68
8	0.4553	10.44	8.42	33.68
\9	0.4768	6.92	5.54	22.16
10	0.4774	6.89	4.57	18.28
11	0.5747	6.79	4.62	18.48
12	0.4672	9.87	6.42	25.68
13	0.4572	9.59	6.32	25.28
14	0.4642	8.87	6.57	26.28
15	0.4658	9.17	5.93	23.72
16	0.4774	10.23	7.83	31.32
Mean				30.405

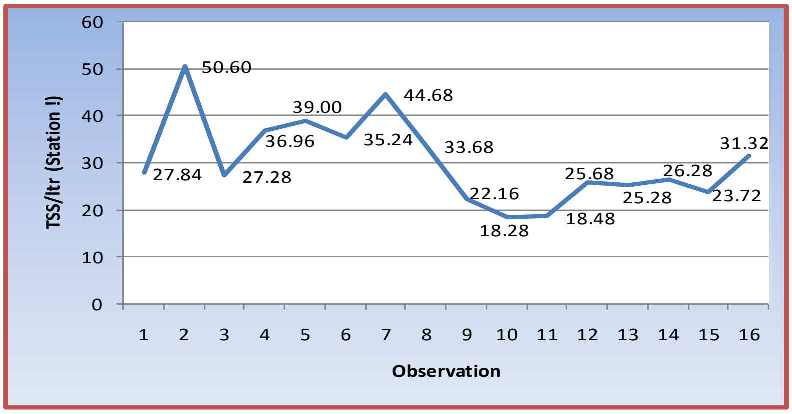
Station 2

No.	Filter Weight (mg)	Wet Weight (mg)	Dry Weight (mg)	TSS/ltr
1	0.4673	9.89	6.96	27.84
2	0.4764	14.32	11.62	46.48
3	0.4628	11.37	8.82	35.28
4	0.4729	10.42	11.35	45.4
5	0.4645	10.05	7.85	31.4
6	0.4548	11.45	9.81	39.24
7	0.4612	13,51	11.17	44.68
8	0.4567	10.44	8.42	33.68
\9	0.4565	13.92	10.55	42.2
10	0.4784	14.36	11.21	44.84
11	0.5749	15.24	11.87	47.48
12	0.4589	12.42	9.78	39.12
13	0.4789	11.78	9.57	38.28
14	0.4539	10.34	9.07	36.28
15	0.4563	11.23	8.94	35.76
16	0.4592	11.12	8.97	35.88
Mean				38.99

Station 3

No.	Filter Weight (mg)	Wet Weight (mg)	Dry Weight (mg)	TSS/ltr
1	0.4575	7.23	4.96	19.84
2	0.4594	8.26	7.23	28.92
3	0.463	9,20	6.72	26.88
4	0.4829	10.42	10.15	40.6
5	0.4615	10.05	9.75	39
6	0.456	8.44	5.81	23.24
7	0.4602	13.51	11.17	44.68
8	0.4563	9.57	8.32	33.28
\9	0.4765	6.92	7.1	28.4
10	0.4774	6.89	4.57	18.28
11	0.5746	6.79	4.68	18.72
12	0.4579	9.87	6.42	25.68
13	0.4759	11.56	9.75	39
14	0.4562	9.98	9.43	37.72
15	0.457	7.76	5.23	20.92
16	0.4678	7.3	5.37	21.48
Mean				29.165

A



B

C

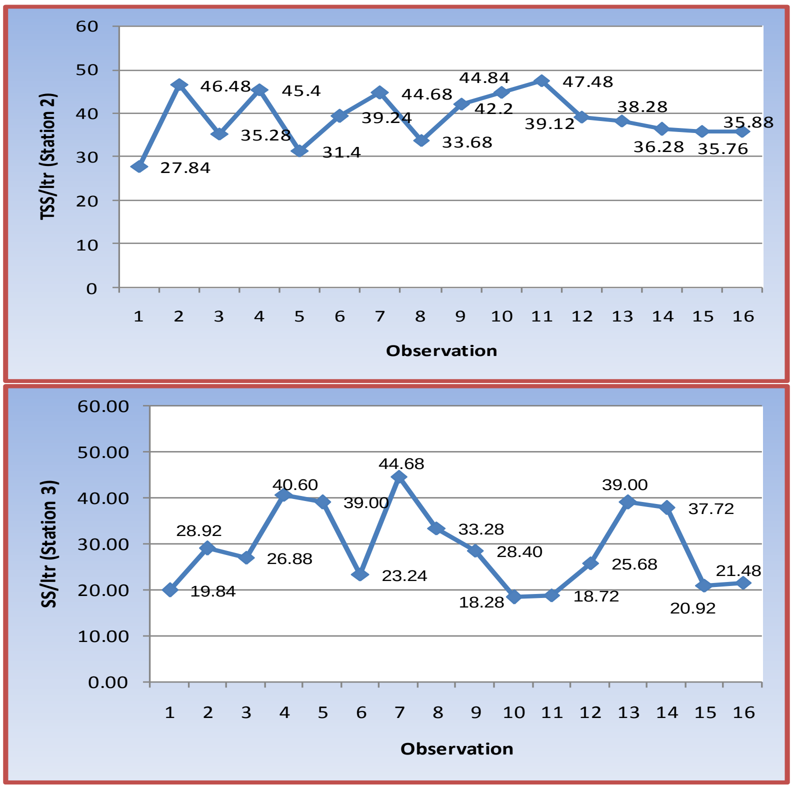


Figure 3. Mean TSS distribution in each station from Marchto September 2012.

Figure 3 exhibits that TSS distribution in each station is relatively higher than that near the river mouth, so that the area easily turns turbid when flooding and big wave occurrence. According to Manik (2003), suspended solids are derived from erosion in terrestrial area, such asresidence, agriculture, mining activity and river mouth. Suspended solids are cause of water turbidity, insoluble and cannot directly sink to the bottom (Fardiaz, 1992). On the bottom, it will gradually cover the benthic organisms and could affect the food web (Canter and Hill, 1979). Very high concentration of suspended solids could inhibit light penetration into the water column and decrease the photosynthetic process in the water (Effendi, 2003). It could also disturb fish activities in the area.

Based on climate classification of Schmidt and Ferguson (1951) and 10 year (2002-2011) rainfall data collected from Geophysical and Meteorological Center station in Naha (Bappeda**,** 2011), Sangihe Island belongs to type Aclimate with Q = 7.1%, meaning that *melombo* area is relatively wet with relatively high rainfalls. Meanwhile, during this period maximum rainfalls were 3.770 mm, minimum 1.448 mm and the average 2.521 mm. Beside that, based on humidity and air temperature data, it was apparent that the relative humidity was 83.52%, while the average air temperature was 27.39^{0}C.

Looking at the biogeophysical elements mentioned above, there are tendency of reduction in forest area and relatively high rainfalls along the year in Salurang watershed, which is supported by topographic conditions, mostly wavy to hilly, labilelatosol and aluvial soil vulnerable to erosion, and dendritic patterned riverfast flowing the water that could easily cause erosion and sedimentation *melomboarea***.** Land use is any form of human intervention over the land to fulfill their living needs. Each type of land use will have impacts on environmental damages, such as critical land occurrence, flood and drought. Thus, land management without considering the land carrying capacity and suitabilitywill result in many loses, as a result of increasingly higher erosion so that the equilibrium of natural resources could be disturbed (Sitorus, 2002). The bigger the erosion the lower the soil productivity will be.

There are two events showing the sedimentation in*melombo*ar**ea.** First, the sink of umbrella rock in the estuary (around station 2) (Figure4), in whichin 1970s to the end of 1980s, itwas still clearly seen at the depth of 5 – 10 m.The present study, based on bathymetry, the depth ranged between 1 – 5 m (Appendix 1) proving that the umbrella rock has mostly been covered by sediment and the upper part is left (Manansang, 2012). Second, seagrass ecosystem behind the reef flat was lost and most corals on the reef flat dissappeared due to sediment cover. In low tide and wavy condition, sediments will be restruck by wave and current so that the sediment is lifted up to the water column and eventually fell in *melombo* area. Since the coral reef condition was found badly damaged, it reflects that the destruction of surrounding coral reefs will still occur due to human activities or natural mortality from high sedimentation. According to DKP-COREMAP (2004), the coral reef getting stressed from environmental pressures tends to release mucus which is then attached with sediment particles.

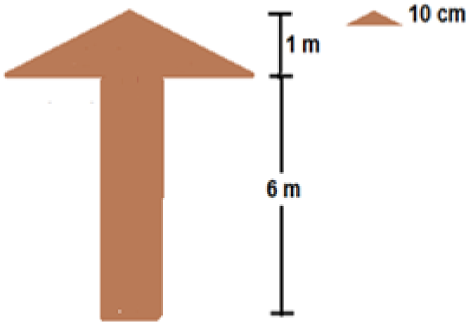


Fig. 4. Umbrella Rock

Coral coverage condition was badly damaged indicating that coral degradation has occurred from sedimentation, flow opening for fisherman's boat and natural mortality. The coral damages are mostly caused by human activities, such as illegal gold mining so that it is feared that it could suffer from more damages if there is no management effort involving all stakeholders. Damages from sedimentation could attributed with widespread dead corals in several locations. It occurs in*melombo*area and needs more attention from the communities, government and private sectors to avoid bigger coral damages around the area.

Ocean circulation was also major cause behind the global climate change,and significantly influenced the terrestrial climate. Seasonal change in sunlight and ocean temperature was a reflection of coral environmental conditions, including the equator and a parameter of changes in body tissue system of the coral. Other damage type is derived from long exposure to the air and the sunlight at low tide, usually at the reef peak. Storms could affect the coral life and break the reefs and promote sedimentation in large scaleas well (Barnes & Hughes, 1990).

The more the suspended solid carried in the water, the higher the mud sediment in the estuary. Nybakken (1992) stated that sediment formation was also affected by seawater, since it contained enough suspended materials. In this study, forest degradation caused by illegal mining activities and illegal logging in the upper watershed brought about a lot of forest areas turn to gold mining, plantation and agricultural areas.This condition has caused high erosion rate in the upstream impacting on high sedimentation in the downstream.

Water visibility ranged from 0.2 – 6 m in station 1 with an average of 1.79 m, 0.5 – 3.0 m in station 2 with an average of 1.21 m, and 1.5 – 10 m in station 3 with an average of 3.13 m, respectively (Table 3). Average visibility of three stations ranged from1.2 – 3.13m indicating that water visibility was below the standard seawater quality for marine biota established by the decree of Living Environment Minister numbered 51, 2004,>5 m. Water quality parameters of*melombo*area are in general good, and therefore could support the coral reef growth. Coral growth needs a depth range of 3 – 10 m where water depth influences corals in relation to light intensity(Thamrin, 2003 in Kasmir, 2011). All hermatyphic corals require enough light for photosynthesis. These are corals capable of constructing the reefs. They live symbiotically with algae (zooxanthellae) conducting photosynthetic process. Zooxanthellae are autotrophic macroalgae belonging to dinoflagellates. Sunlight penetration highly determines the depth of coral reef habitats (Thamrin,2006inKasmir, 2011).

Low light penetration is usually brought about by high suspended particles-containing riverwater entering the sea (Lalamentik, 2001). Turbidity and sedimentation of *melombo*area have been beyond the tolerable limit for corals. Present study showed visibility range of1.21 – 3.13m. Sedimentation and turbidity are highly potential to occurring in small islands near the mainland, so that they could be threat to the coral reef ecosystem.These could put impacts on coral growthand morphology. Rich nutrient-induced turbidity in the water will threat the corals and even be able to kill the corals, and promote algal growth, so that it could result in coral-algae competition involving a number of interactions**.**Coral community replacement dominated bymacroalgae often indicates external disturbances, not only because of overgrowth competition, but recruitment competitive inhibition as well, so that the coral reef recovery is inhibited.The recovery could occur through coral recruitment in the coastal area of Salurang.

Factors affecting the sedimentation process in the rivermouth are waves and current patterns. Salurang river brought sediment materials and wastes from the upstream and along the watershed that will be deposited in the rivermouth.According to Triatmodjo and Takeda (1993), sedimentation process is affected by tides, currents and waves.Wave energy functioning as longshore current producer could also cause abrasion. Sedimentation and erosion are two interchanging processes in relatively short time in order to achieve an equilibrium and part of river flow dynamics.Hence, fisheries resources utilization particularly in the estuary requires wise actions oriented in optimal and sustainable utilization. The exploitation patterns should also consider the environmental carrying capacity.

Table 3. Visibility measurement in *melombo* waters from March to September 2012

Measurement	**Station**		
	03⁰28'33.6"N 125⁰40'00.6"S	**03⁰28'27.4"N 125⁰ 39' 57.5"S**	**03⁰28'30.3"N 125⁰39'58.4"S**
March	1.5	1.0	3.8
	1.0	0.8	2.8
	1.0	0.5	2.5
April	1.5	1.0	2.8
	1.5	1.0	2.8
May	2.0	0.6	1.5
	1.8	0.6	1.5
June	1.5	1.0	2.8
	1.5	1.0	2.5
	1.8	1.0	2.5
July	6.0	3.5	10.0
	2.5	1.5	3.0
August	4.2	1.0	0.2
	2.6	1.5	3.5
September	1.2	1.35	3.0
	2.0	1.25	3.75
Mean	2,03	1.21	3.13

IV. Conclusion

Basic problems in Melombo area were erosion and sedimentation from illegal mining activities in Salurang watershed. People's activities were also major cause of high sedimentation rate in Melombo. In the last8 months, sedimentation rate ranged between 6.61cm (129.7cm^3) and 7.18 cm (140.9 cm^3). Total suspended solid (TSS) at each observation site has reached the seawater quality standard of <20 ppm.Thus, it is necessary to have more comprehensive policy of the local government concerning land management and land use, particularly the watershed areas in Sangihe Archipelagic Regency.

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Appendix 1. Bathymetric data