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Effects of sedimentation rate to coral reef in the Cristo Rei Sub-district waters of the Dili District of Timor-leste

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Abstract

The existence of sediments at area coral reef has a negative effect. The sedimentation rate suspended would inhibit the process of zooxanthellae photosynthesis and deposited be due smothering for coral polyp. This aim to calculate of sedimentation rate on coral reefs, and analyze the relationship and effects of the sedimentation rate to coral reefs. Observations of coral cover using of intercept transect line method, and measuring the sedimentation rate is used of the sediment traps. Data analysis will be statistically analyzed by ANOVA of F test ($P<0.05$), PCA and regression analysis (R^2). Percentage of live coral cover at five stations between 14.75 to 77.25%. The sedimentation rate values between 3.30 to 13.60 mg/cm²/day. The level of the effect sedimentation rate of percentage of coral covering was 65.40% and mortality index coral reefs were 53.60%. The level of coral mortality risk of 0.06 to 0.72%. The sedimentation rate is very negative effect on the live coral and mortality index. If it not had an effect of the sedimentation rate, the live coral cover of 91.78% and if any increased of sedimentation rate will cause Mortality Index is 0.079%.

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Introduction

Cristo Rei Sub-district territorial waters in Dili District which is located on the north coast of Timor-Leste, is affected by Banda Sea and Indonesian Through flow (ITF) characteristics as it has quite good coral reef ecosystem. Nowadays, its condition has been pushed down by sedimentation processes of rivers in the coastal area and by simultaneous temperature escalation happened throughout Australia, Indonesia and Timor-Leste (Brown and Suharsono, 1990; Engelhard *et al.*, 2001).

Coral reef ecosystems are ecosystems on shallow waters which are very productive, with their wealth of biological diversity in tropical sea (Done, 1982). Coral reefs are communities of living organisms which reside in the bottom of shallow waters in tropical regions (Supriharyono, 2000), of the continental shelves and archipelagoes in tropical waters, Dahuri *et al.* (1996). Coral reefs serve as habitats of most diverse marine organisms, their feeding grounds, spawning, rearing spots and protection for other coastal populations. (Suharsono, 2010). Coral reefs also serve as places where biological, chemical and physical cycles globally performed with high productivity, source of food and medicinal compounds, coastal barriers from waves, recreational attractions, marine culture, researching and educational sites. Hard coral diversity found along the eastern north coast of Timor-Leste reaches nearly 400 species. The average of hard coral cover was 28% with the lowest 5% and the highest 70% and destroyed and dead coral was 40% - 50% (Burke, 2002; Erdmann dan Mohan, 2012).

Human activities in Cristo Rei Sub-district in Dili District which have given sedimentation rate effect to the coral reefs are like agriculture activities, illegal loggings, slash and burn activities, urban development, road rehabilitation and construction, harbor dredging and construction, solid or liquid waste of households and hotels. As stated by Yasin (1993) that human activities can cause significant sedimentation and threaten coral reefs. Sedimentation has been the cause of coral reef degradation, especially in South and East Asia, Indonesia and Melanesia, where the rivers affect 70% of global sedimentation carried to the sea (Abdullah *et al.*, 2011). Results of the research conducted by Alongi *et al.* (2009) in Timor-Leste to Laclo River in the north coast and Carau-ulun River in the south coast of Timor-Leste showed that estimation of erosion and sedimentation yield carried out to the coastal waters were very high compared to the global standards, where Laclo River carries 6840 t/km²/year and Carau–ulun River carries 7976 t/km²/year.

Coral reefs destruction in Timor-Leste is generally caused by sedimentation coming from drainage areas, in addition to destruction caused by poisoning and explosive fishhing, ship anchor, climate change, *Acanthaster planci* and also coral diseases (Wong and Chou, 2004; Dutra, 2007; Ayling *et al.*, 2009; Erdmann and Mohan, 2012). Therefore, to know the level from the effects of the sedimentary rate to the coral reef condition in Cristo-Rei Sub-district waters in Dili District, then a research to know the coral reef covers and its environmental condition, the level of sedimentation rate which enters the coral reef ecosystem and to analyze the relationship and the effect of sedimentation rate to coral reef condition.

Materials and methods

The research was conducted in Cristo-Rei Sub-district waters in Dili District, Timor-Leste from May to July 2014, with 5 researching stations as shown in Fig.1.

Fig. 1. Map of location study in the Sub-District Cristo Rei of District Dili.

Coral Reef Measure Method

To determine each station, an observation on the coral reef conditions using the rapid reef resources inventory method (manta tow) was done in advance with observation scope 1-3 sea miles depending on the level of coral reef spread. The observation results were recorded in life form and the point plotted with GPS. In addition to observations to coral reefs, identifications on human activities along the coastal waters and estuaries presumed as the source of sedimentation transport into the coastal waters were also done.

Coral reef observations used line intercept transect method (English *et al*., 1997). Coral reef transect was done in the depth of 3-5 m in the reef flat zone (back reef) and 7-10 m in the fare reef zone (buttress zone) NOAA (2007). In each zone, line transect was done about 50 m. Benthos observation results which was passed through by the transect line were recorded in life forms along with their family and species, then they were photographed and moving photographed with an underwater camera to re-identify coral species more thoroughly.

Sedimentation Measure Method

Sedimentation rate measurement used sediment trap made of PVC pipe with 5 cm in diameter and 11.5 cm in height. The top end was insulated with monofilament net with mesh size 1 inch and the bottom end was tightly closed. Sediment traps were installed to iron bar 12 mm in diameter with 20 cm height from the bottom substrate. Sediment traps installed to each station were 4 traps. Sediment traps installed in line with the coastline and adjusted with the line intercept transect for coral reef measurement. The gap between sediment traps was 25 cm. They were installed for 30 days. Accumulated of sedimentation rate in the sediment traps for 30 days then taken and dried in an oven with 60^{o} C temperature for 24 hours. After that, weight measurement of dry sedimentation was done with analytic weight scale in units of milligram. Then, it was sieved to know the fraction grains and its sedimentary texture in units of millimeter diameter pursuant to Wentworth Scales. Sedimentation rate is stated in units of mg/cm^2/day (Roger *et al*., 1994; English *et al*., 1997, and Wibisono, 2005).

Water Quality Measure Method

To know the environment characteristics of water quality which affect the growth and the development of coral reefs, physical and chemical parameters measurement was done in each station whether it was insitu or in the laboratory referring to APHA method (1989). Water quality measured insitu included depth, sea surface temperature, transparency, current, pH and salinity. Where as water quality parameter analysis in the laboratory included turbidity, TSS, orthophosphate, nitrate, DO and BOD_5. Water quality parameter values were then compared to the Minister of Environment of Indonesia Decree Number 51 Year 2004 on sea water quality standards for marine biota.

To know the interconnection of biophysical-chemical of the waters quality in each station, was used multivariable statistical Principal Component Analysis (Legendre and Legendre, 1983). While to analyze the correlation of sedimentation rate with the coral cover percentages and mortality index, was used ANOVA analysis with F test ($P<0.05$) and Regression Analysis (R^2) were conducted (Walpole, 1995 and Kountur, 2006).

Result and discussion

Sedimentation Rate

Research results showed that average percentage of fraction spread and the type of dominated sediment was sand about 88.00-97.00%, the highest was in station 5 and the lowest was in station 1 and 3. Clay sediment was 1.50 – 5.00%, the highest was in station 1 and the lowest was in station 2 and 5, while silt sediment was 1.50- 9.00%, the highest was station 3 and the lowest was in station 4 and 5.

Analysis on sand in ø mm showed that very coarse sand was 12.45 –42.00%, coarse sand was 7.55-26.50%, medium sand was 16.25-35.70%, fine sand

was 9.20-32.70% and very fine sand was 0.85-3.05%. Therefore average fraction spread and the type of dominated sediment was sand with 92.50%, silt with 4.50% and clay 3.00% (Tabel 1).

Table 1. Percentages of sedimentation fraction spread from each research station.

Stations	Location Name	% of Fraction Sedimention Distribution (ø mm)					Type of Sediment (%)			Class Sediment
		2-1 (VCS)	1-0.5 (CS)	0.5-0.25 (MS)	0.25-0.13 (FS)	0.13-0.05 (VFS)	Sand	Silt	Clay	
1	Palpasu	34.90	7.55	16.25	26.40	3.05	88.00	7.00	5.00	Muddy sand
2	Raihenek Mutin	42.00	16.30	20.15	15.50	0.95	95.00	3.50	1.50	Sand
3	Dolok Oan	12.45	13.55	25.55	32.70	3.90	88.00	9.50	3.00	Sand
4	West of Hera Port	13.80	20.30	35.70	22.85	2.00	94.50	1.50	4.00	Sand
5	East of Hera Port	35.30	26.50	22.55	9.20	0.85	97.00	1.50	1.50	Sand

Note: VCS: Very coarse sand, CS: coarse sand, MS: medium sand, FS: fine sand and VFS: very fine sand.

Sand or silt sedimentation in the water can obstruct coral organisms development that means slowing or even decreasing their growth and causing their death caused by sand or silt sedimentation on coral polyps which are hosts of zooxanthellae. If the sedimentation is from the rivers then it will make the salinity low and excessive sedimentation will prevent coral reefs from growing (Nybakken, 1993), because there is smothering effect on the coral reefs by suspended sedimentation to the bottom sea where the coral reefs exist (Hubbart, 1997).

Sedimentation rate measurement for 30 days in each station showed value ranged from 3.30–13.69 mg/cm²/day. Sedimentation rate categorization according to Pastorok and Bilyard (1985) stated that levels of sedimentary rate on coral reefs are from light to medium and from medium to heavy (Table 2).

Table 2. Level of sedimentation rate effects to the coral reef.

Stations	Sedimentation Rate (mg/cm²/day	Level of Impacts	Category by Pastorok and Bilyard (1985)
1	7.54	Light to medium	0 – 10
2	6.455	Light to medium	0 – 10
3	4.62	Light to medium	0 – 10
4	13.69	Medium to heavy	10 – 50
5	3.30	Light to medium	0 – 10

The highest sedimentation rate was in Station 4, located in the west of Hera Port with value of 13.69 mg/cm²/day. This was caused not only by sedimentation from Hera and Bedik Rivers which entered to coral reef ecosystem, but also from the Hera Harbor dredging where the material thrown out along the coastal waters in 2001 and 2009. This value according to Pastorok and Bilyard (1985) categorized light to medium sedimentation and the medium to heavy sedimentation on coral reefs were from the large scale abundance and the number of species decrease and also on recruitments where new species invade. As happened in Station 4, coral species were less in number that was 42 species compared to other stations ranged 49-88 species from total 129 species found in all research stations.

The lowest sedimentation rate was in Station 1-3 and 5 ranged from 3.30-7.54 mg/cm²/day. This means that it gave light to medium effects to coral reefs, such as decreasing abundance and possibly decreasing recruitments and number of species. Stated by Babcock and Smith (2000) that sedimentation rate at 5 mg/cm²/day can decrease 60% coral reef of *Acropora millepora* in the level of post recruitment survival for less than eight month period.

Coral Reefs

Coral reefs condition in Cristo-Rei Sub-district waters in Dili District, Timor-Leste with percentage of living cover reefs (LC) in each station ranged from 14.75-77.25%. Dead coral (DC) was 4.75-43.00%, nutrient

indicated as algae (NIA) was 4.50-12.25% other benthos (OT) was 1.50-3.75% and abiotic was 8.00-44.80%. Wilkinson *et al.* (1992) categorized the coral cover in each station from bad to very good level. Where as the percentage of coral cover in Cristo-Rei Sub-district waters in average was 45.60 % and categorized as in medium category (Fig. 2).

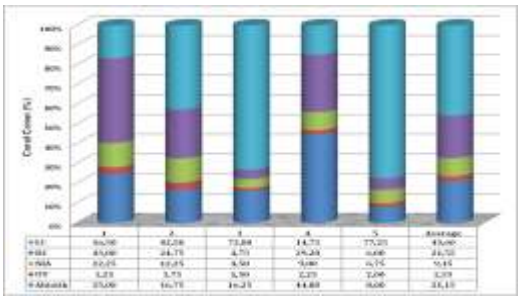

Fig. 2. Percentage coral cover in each reserch station.

Previous researches conducted in some locations in the north coastal waters of Timor-Leste such as by Wong and Chou (2004) in Atauro Island, Suco Biqueli resulted that average living coral cover was 41.01%. Coral reefs destruction and death was caused by fishing with explosives, spear fishing, fish traps and nutrients increase to the sea by sedimentation. While according to Dutra (2007) in Atauro Island, Suco Beloi with average percentage of living coral cover was 58.58%, coral reefs death was caused by sedimentation or turbidity, so the coral bleaching happened. Local fisherman commonly fishing by spear fishing where the coral reefs were stepped on to be rubles and by destructive fishing with explosives. Research results conducted by International Conservation in 2012 in the eastern part of north coast that was in Dili District (Atauro Island), Manatutu District, and Lautem District showed that average living coral cover was 28.00%. Coral reefs death was caused by sedimentation, fishcatching with poison and explosives, ship anchors, bleaching, *Acanthaster planci* as predators and coral diseases. Furthermore, Ayling *et al.* (2009) stated in his research in Nino Konis Santana National Park of Lautem District that coral reefs death was caused by *Acanthaster planci* and coral diseases.

Based on the categorization of percentage of coral covers in each station, very good category was in Station 5 (East part of Hera Port), good category was in Station 3 (Dolok Oan) and mederate category was in Station 2 (Raihenek Mutin). Those three stations are located a little farther from the estuaries compared to the Stations 1 and 4. The beach has a little mangrove forest and seagrass beds so the sedimentation effect was only ranged from light to medium, but if this condition continues, it will decrease recruitments, density and the shape of coral reefs growth will be obstructed in those three stations.

Observing from the distances of estuaries presumed as the source of sedimentation to the coastal area Station 2 and 3 are located farther from the estuary compared to the Station 1, 4 and 5. Station 2 from Bidau Santa Ana River mouth is 3.24 km, from Maloa River mouth is 4.15 km and from Comoro River mouth is 7.88 km. Station 3 is located far from Bedik/Akanunu River mouth, about 5.42 km and from Hera River is 6.25 km and other rivers are obstructed by Fatu Cama Cape (Cristo Rei). Location of Station 5 is closer to Bedik River mouth, only about 1.65 km and from Hera River mouth is 0.57 km. Despite being closed to Station 5, both estuaries give less effect of sedimentation rate to coral reefs compared to the others stations (Fig. 3) due to being obstructed by Hera Harbor breakwater.

The approach used to measure mortality rate of coral reefs was by Mortality Index analysis (MI), a comparison between dead corals and living corals which will show the risk of mortality in a certain location. The highest mortality index was in Station 1 about 0.72 with dead corals about 43.50%, followed by Station 4 about 0.67 with dead corals about 29.20% and Station 2 about 0.37 with dead corals about 24.75%. The lowest mortality index was in Station 3 about 0.06 and Station 5 abaout 0.07 with percentage of dead corals 4.75% and 6.00% (Fig. 4).
Corals death in Station 1 was caused by sedimentation and human activities, so the corals died or turned into rubles. Dominating coral type in the location was

hard corals non scleractinia like blue corals (*Heliopora coerulea*) with branching like plat leaves so the sediments was difficult to cover the polyps. While in Station 4, their death was caused by sedimentation as its location was near the Hera and Bedik/Akanunu River mouth which is only 0.49 km and 0.76 km away. Furthermore, it was caused by Hera Harbor dredging. Station 1 is located near from Maloa River mouth about 0.091 km, Comoro River mouth about 3.57 km and Bidau Santa Ana River mouth about 2.60 km.

The death of corals by sedimentation rate happens through two mechanisms. First, suspended sediment obstructs the light penetration needed for zooxanthelae photosynthesis. Zooxanthelae's density and chlorophyll concentration per area unit become less due to sediment exposures, and then bleaching happens followed by death of some coral colonies (Philip and Fabricius, 2003). Second, sediment covers the coral colony surface and causes destruction to tissues then followed by death. Mechanism to expunge the sediment from the colony surface through cilia, tentacles movement and mucus secretion needs time and extra energy so it will affect their feeding activity (Barnes dan Lough, 1999).

Water quality is an important parameter of environment to know the effect and its relation to living organisms especially coral reefs in this research. Water quality parameter measurement insitu and water sample from each station to be analyzed in the laboratory was collected during the high tide in the depth of 7.20-7.80 m. In that depth, there is an enormous water mixing as it is where the current meets from the mass of coastal waters and the mass of waters from the deep sea.

Generally, water quality parameters show normally for development and growth of coral reefs pursuant to the water quality standards for marine biota as established by the Minister of Environment Decree of Indonesia Number 51 Year 2004. Insitu measurements or in the laboratory analysis from each research station can be seen on Table 3 below.

Table 3. Physical and chemical parameter of water from each research station.

Parameters	Units	Stations					Obs.
		1	2	3	4	5	
Depth	m	7.20	7.50	7.70	7.60	7.80	Insitu
SST	°c	26.50	27.05	27.60	25.80	26.40	Insitu
Lighty	m	3	7	6	4	7	Insitu
Turbidity	NTU	0.36	0.40	0.33	2.24	0.43	Lab
TSS	mg/l	3.8	5.2	4.8	10.6	4.4	Lab
Current	m/sec	0.13	0.09	0.11	0.10	0.13	Insitu
Current Direction	(°)	245	220	270	270	250	Insitu
pH	-	7.9	7.4	7.8	7.5	8.2	Insitu
Salinity	‰	33	34	38	34	36	Insitu
Orthophospat	mg/l	0.207	0.146	0.783	0.194	0.140	Lab
Nitarte	mg/l	0.844	0.584	0.630	0.581	0.611	Lab
DO	mg/l	7.1	7.5	7.5	7.2	7.2	Lab
BOD_5	mg/l	2.95	3.25	3.10	3.20	2.55	Lab

Note: SST: Sea Surface Temperature; TSS: Total Suspend Solid; Obs: Observation; Lab.: Laboratorium.

Primary component analysis results showed some variables which have correlation with others, whether they are positively or negatively correlated. Two primary components (F1 and F2) showed 74.54% of total diversity with percentages of contribution about 45.94% and 28.60%. While component F3 and F4 showed 13.98% and 11.49% (Fig. 4).

Sations	The distance of each station with river mouth (km)					The distance beetwen each station (km)				
	Comoro River	Maloa River	Bidau Santa Ana River	Bedik River	Hera River	St. 1	St.2	St. 3	St. 4	St. 5
1	3.57	0.91	2.66	16.76	17.96	-	4.50	7.48	13.44	14.44
2	7.88	4.15	3.24	9.25	10.46	4.50	-	4.01	9.97	10.97
3	15.08	11.51	7.25	5.24	6.45	7.48	4.01	-	5.96	6.96
4	20.32	15.75	12.49	0.76	0.49	13.44	9.97	5.96	-	1.00
5	21.53	17.99	13.70	1.65	0.57	14.44	10.97	6.96	1.00	-

Fig.3. Map of research locations with rivers mouth and stations study with the distance from the mouth river.

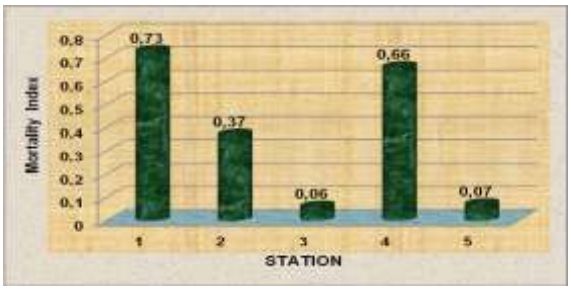

Fig. 4. Mortality Index in each researh station.

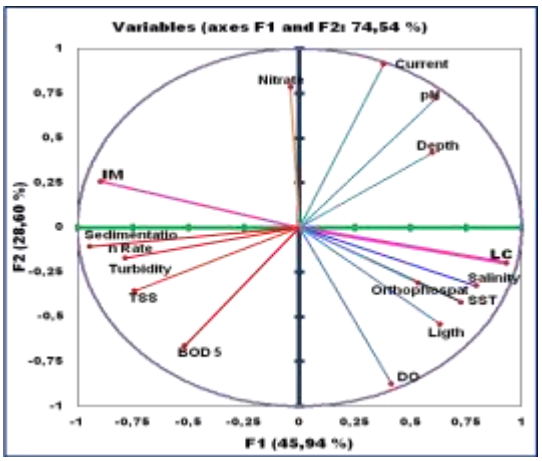

Fig. 4. Correlation chart of environmental parameters, sedimentary rate, living cover and mortality index of coral reefs.

From the correlation matrix, parameters which are negatively correlated with living cover are sedimentation rate, turbidity, TSS and BOD_5. While parameters which are positively correlated with coral cover are orthophosphate, salinity, temperature, transparency and DO. Nitrate is negatively correlated with mortality index and current velocity, pH. Depth is positively correlated with mortality index or with living coral covers.

Correlation angle of axis 3 (horizontal) and axis 4 (vertical) showed that mortality index affects axis 3, while current velocity, pH and depth contributes to axis 3, whereas nitrate contributes to axis 4. From the correlation matrix, parameter which is negatively correlated with mortality index is nitrate while which are positively correlated with it are current velocity, pH and depth.

Station 4 and 2 were characterized by sedimentation rate, turbidity, TSS and BOD_5 which are negatively correlated with living coral cover and mortality index. Sedimentation rate in Station 4 was 13.69

mg/cm²/day. This value according to Pastorok and Bilyard categorization (1985) gives medium effect to dangerous effect to coral reefs. It can cause a decrease on abundance, recruitments and number of species. Research results showed that in that station there were only 42 coral species which was the lowest compared to the other four stations.

Station 1 characteristic was dominantly by mortality index (0.73) and nitrate (0.844), their values were higher compared to other stations. Station 3 was characterized by the percentage of living cover, orthophosphate, salinity, temperature, transparency and DO while Station 5 was characterized by the current velocity, pH and depth (Fig. 5).

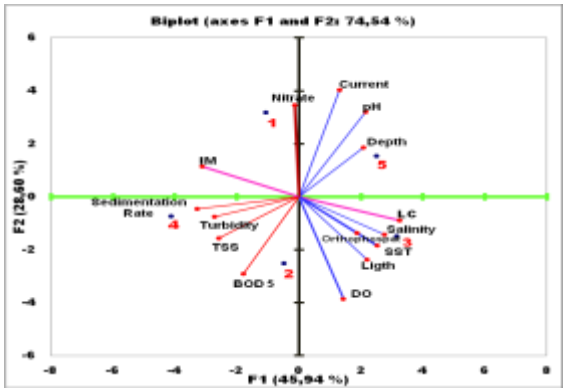

Fig. 5. PCA - biplot of environmental parameters, sedimentary rate, living cover and mortality index of coral reefs.

Anova analysis or F test on sedimentation rate of coral reef condition or mortality indexes of stations, with trust value of 5% showed that it was significant for coral cover (0.005**) and significant for its mortality index (0.016*). Therefore, H1 hypothesis was accepted and H0 was denied as there were effects of sedimentation rate to coral reef.

Strong relationship can be seen from the regression analysis in determination coefficient (R^2), where the sedimentation rate gave effects to coral reef cover about 65.40% (0.654). While about 34.60% was affected by other environmental factors (Fig. 6).

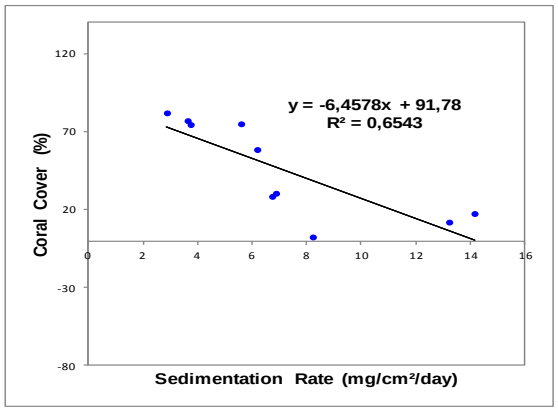

Fig. 6. Relation of sedimentation rate with the percentage of coral covers.

Determination coefficient for mortality index was 53.60% (0.536), while about 46.40% was affected by other environmental factors (Fig. 7). According to Ghozali (2006) statistically stated that to measure the goodness of fit for R^2 value if the value >0.50 is the high accuracy.

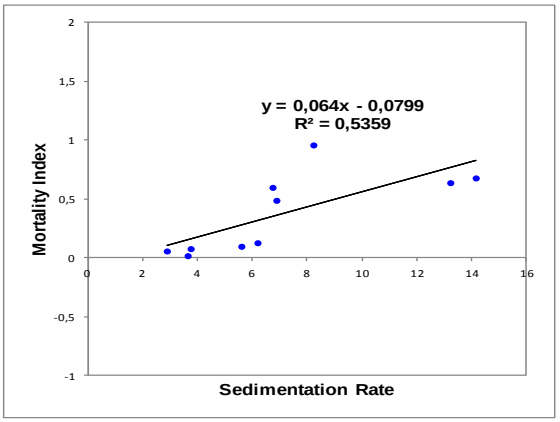

Fig. 7. Relation of sedimentation rate with mortality index of coral reefs.

Based on the regression analysis, the higher sedimentation rate, and the higher mortality rate of coral reefs. In every increase of sedimentation rate unit, it will cause coral reef death about 0.0799 mortality index.

Conclusion

1. Coral reef condition in the Cristo Rei Sub-district, Dili District at the moment in each research station was categorized badly to very good with percentage of living coral (LC) cover 14.75% -

77.25% with categorization of percentage of coral covers in each station, very good category was in Station 5 (77.25%), good category was in Station 3 (73%), mederate category was in Station 2 (42.50%) and bad category was in station 1 and 4 (16.50% and 14.75%).

2. Average sedimentation rate was categorized light to medium and medium to heavy with value from 3.30 – 13.68 mg/cm²/day. The highest sedimentation rate to coral reef from medium to heavy was in Station 4 (13.68 mg/cm²/day) but for category ligh to medium was in Station 1 (7.54 mg/cm²/day), Station 2 (6.46 mg/cm²/day), Station 3 (4.62 mg/cm²/day) and Station 5 (3.30 mg/cm²/day).

3. Sedimentation rate was giving very significant effects to living coral cover and significant effects to mortality index. In every increase of sedimentation rate unit, it will cause coral reef death about 0.0799 mortality index.

To manage and preserve the diverse living organism ecosystem of coral reefs from the effects of sedimentation rate is as follows:

1. Transplantation of coral reefs and reforestation on degraded as a result of anthropogenic , so it can be restored to the original state in accordance with the function of ecological functions
2. The prohibition of the use in the area of river banks and coastal border as a green pathway
3. Increasing community participation / fishermen in the management of coral reefs through community groups

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