Status of corals and reef fishes community near mining operation site in Tubay, Agusan del Norte, Philippines

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Abstract. This study aims to determine the (a) percent cover of benthic community; (b) species richness, diversity, abundance and biomass of reef fishes; (c) correlation between live hard coral cover and reef species richness, abundance and biomass; and (d) sedimentation rate of the four sampling stations near mining operation site in Tubay, Agusan del Norte. Regarding the live hard coral cover, Punta Binuangan and Binuangan Dako have Fair Coral Cover (25-49.9%). Punta Binuangan noted of having fair and moderate fish diversity and fish density indices. Concerning fish biomass Pier 5 fall under very low category (1-3.0 mt km^{-2} y^{-1}) while the remaining stations fall under low biomass category. Among the four sampling stations, Pier 5, near mining operation obtained the highest sedimentation rate (1.896 mg cm^{-2} d^{-1}); highest abiotic component (48.48%), but Poor Coral Cover (< 24.9%), very poor reef fish richness and very low fish biomass.

Key Words: coastal waters, sedimentation rate, abiotic component, coral cover, reef fish richness, reef fish biomass.

Introduction. Caraga Region is considered as the mining destination in Northeastern Mindanao, Philippines. The Mines and Geosciences Bureau (MGB) of the Department of Environment and Natural Resources (DENR) in the country had reported in 2009 that the iron ore deposit in the region is the biggest in the world and the nickel and gold deposits is the largest in the country. In Caraga Region, copper, chromite and coal are among the rich deposits for mining in which coal as the primary lignite reserve in the Philippines located in three of the region's four provinces – Agusan del Sur, Surigao del Norte and Surigao del Sur (Caraga Watch 2009; Balanay et al 2014). Mining is aggressively pursued in the Philippines to boost the country's economy, reduce foreign debt, and increase employment. However mining may affect the biodiversity by changing the species composition, species structure and community structure of the living organism inhabited in the area. Mining introduced sediment in the coastal waters. The turbidity of natural waters increases as a result of higher sediment concentration, reducing the light available to aquatic plants and phytoplankton for photosynthesis (Ripley 1996). Heavy sedimentation may result in light shading, sediment abrasion on the coral surface, smothering of coral tissue and may eventually lead to its death (Hodgson 1990; Stafford-Smith 1993). The complex food web on the reef can be affected by excessive sedimentation by killing corals, sponges or other benthic organism that serve as food for commercially important fish and shellfish (Rogers 1990). Besides increased sediment loads can cover benthic organisms entirely in streams and oceans, destroying important food sources for predators and decreasing available habitat for fish to migrate and spawn (Johnson 1997).

Tubay, Agusan del Norte is located at northeastern Butuan Bay. It has a total coastal stretch of 19.5 km composed of sandy coast on the southern and combination of rock formations, cliff, white sand and pebbles on the northern. Its marine water is the largest in the whole Bay with an approximate municipal water area of 28,000 ha. In this municipality one of the mining companies established in 2006 was located at La Fraternidad and Binuangan, Tubay, Agusan del Norte where one of the Marine Fish Sanctuary (MFS) was established before (Nalam 2014).

This study was conducted to determine the: a) percent cover of major benthic categories, b) species richness, abundance and biomass of reef fishes, c) measure the sedimentation rate in the permanent coral reef monitoring stations, d) calculate the coral reef fishes diversity and abundance and determined the relationship between live hard coral cover to the reef fish species richness, abundance and biomass.

Material and Method. This study was conducted on July 2015 at Tubay, Agusan del Norte which is located at northeastern Butuan Bay.

Establishment of permanent monitoring station. Permanent monitoring concrete blocks were established in the coral reef monitoring sites near mining operation area; Binuangan Dako, Binuangan Gamay, Punta Binuangan and Pier 5 stations. Concrete blocks were established at 10 m interval, these served as permanent marker for regular monitoring activities to ensure exact location of the sites to be monitored (Figure 1). Three replicated transects line with 50 m length were established per monitoring stations.

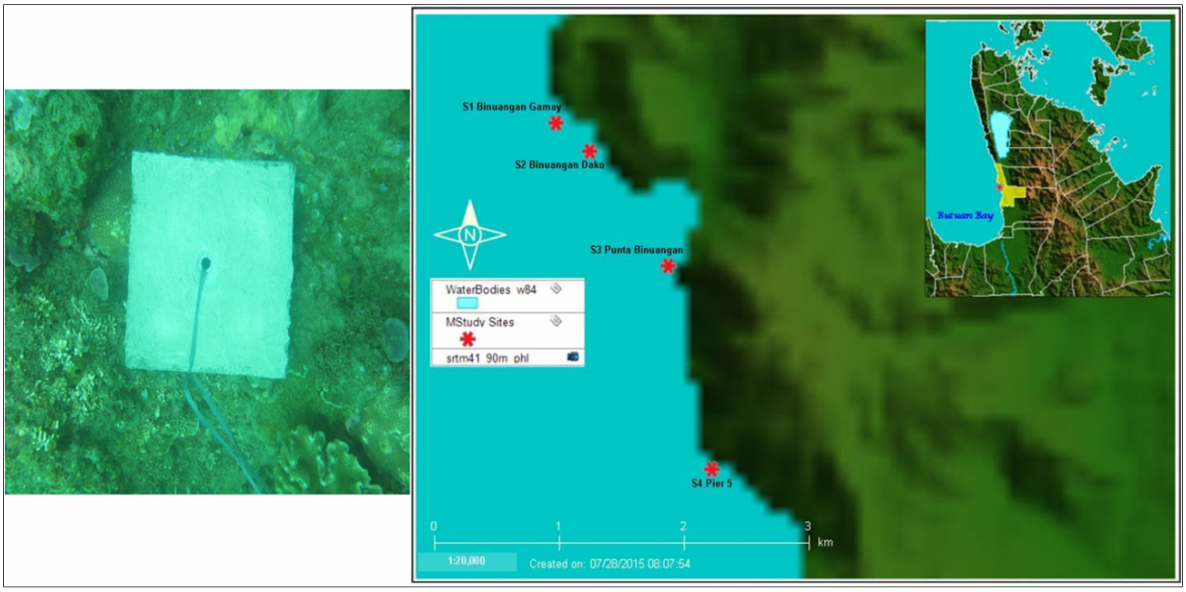

Figure 1. Map of permanent monitoring stations near Mining site in Tubay, Agusan del Norte and the permanent concrete block marker established in the monitoring stations of Mining site.

Photo transect/benthic survey. Coral reefs near mining operation site in Tubay, Agusan del Norte were studied using the digital fixed photo-transect method, a modification of the video transect technique by Osborne & Oxley (1997). This method used Canon power shot G10 underwater 15 MP camera attached to an aluminum bar with a linear distance of 1-m. Photographs of the calibrated 50-m transect were taken every m using this 1-m calibrated aluminum bar, to come up with 51 photo frames per 50-m fixed transect. Each of the 50 photo frames consisted of 5 points of coral life forms.

The coral life forms were identified using the standard coral life form code as described by Uychiaco et al (2001). Summary data showing percent cover and number of occurrences of each life form, these life forms were calculated using a Coral Point Count with Excel Extension, a visual basic program (Kohler & Gill 2006). Reef health was assessed using a 4-point index established by Gomez et al (1981, 1994a, 1994b) and Department of Environmental and Natural Resources Administrative Order (DAO 2013) such as poor having 0-24.9% live hard coral cover, fair (25-49.9% cover), good (50-74.9% cover) and excellent (75-100% cover).

Reef fish survey. Fish visual census was done in the same transect line used in the benthic survey. Reef fish survey was done by swimming along the 50-meter transect line and all fishes that fall within the 50-meter transect line and all fishes fall within the 10 -meter with along the transect line were identified up to the species level as possible. For each species identified, its total length in cm was visually estimated and counted (English et al 1997).

Based on the individual length per species, biomass was computed using the relationship $W = aL^b$, where W = weight in grams, L = total length in cm, and a, b = are growth coefficient values that can be taken from the published literatures (Anderson & Neumann 1996; Letourneur et al 1998; http://www.fishbase.org.ph). Fish abundance data were expressed regarding of biomass (mt/km^2) and density (individuals/500m^2).

Reef fishes are categorized into 3 groups. Economically important food and aquarium fishes are grouped as target species (important to fishery), fish directly linked to coral health are called indicator species, and fishes that are neither target nor indicator are called major species (visually dominant species with no commercial value) (English et al 1997). Fish biomass index was based on Nanola et al (2010): very low 1-3 mt/km^2, low 3.1–10 mt/km^2, medium 10.1–20 mt/km^2, high 20.1–50 mt/km^2, very high > 50 mt/km^2. Species richness and density indices used Hilomen et al (2000) for between-station comparisons.

Collection of sediments. Sediment traps were installed along the transect line of the coral reef monitoring stations (Figure 2). Sedimentation rate was estimated at each station at a depth of 4-6 m using two sediment traps installed vertically to the reef and placed about 50 m apart. Traps were 5 cm diameter PVC cylinders with a height of 11.5 cm. Each set of traps consist of 3 replicated cylinders were used for estimating vertical fluxes of sediment. The mouths of the traps lay approximately 20 cm above the sea bed. Traps were deployed on June 27 and 28, 2015. The trap contents were filtered onto 0.45 Im filter papers and over dried until constant weight was obtained.

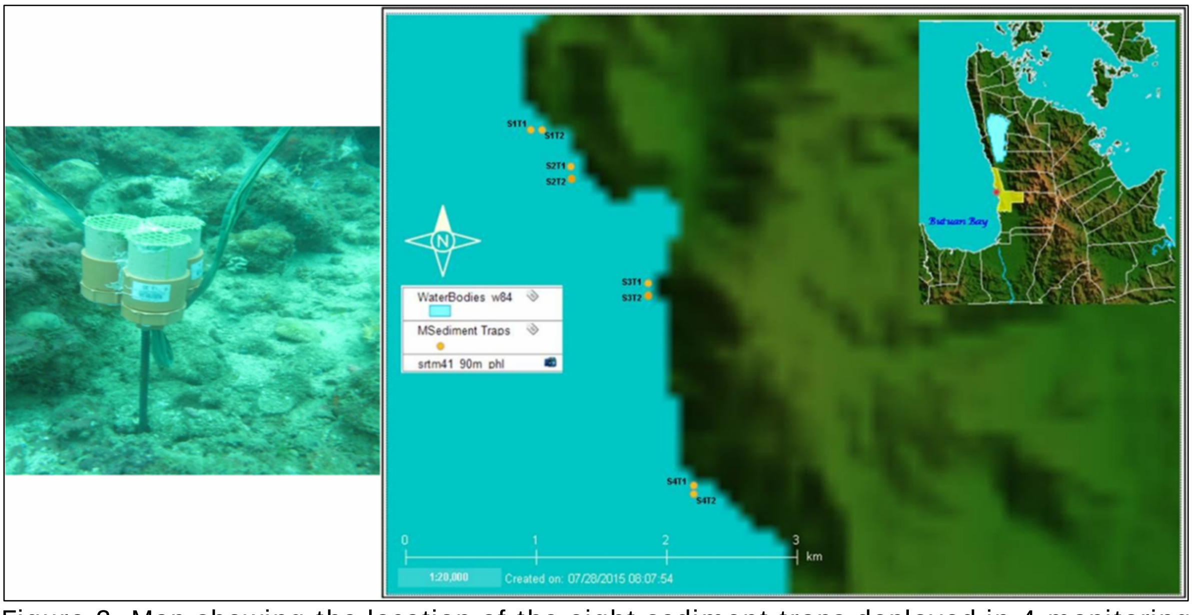

Figure 2. Map showing the location of the eight sediment traps deployed in 4 monitoring stations and the sediment trap measuring 5 cm internal diameter, 11.5 cm high.

Statistical analysis. Biodiversity indices of coral reef fishes, correlation analysis and One-Way–ANOVA were calculated using Paleontological Statistical Software Package (PAST) developed by Hammer et al (2001).

Results and Discussion

Benthic components of the bottom substrate. The benthic components were categorized into six major components, namely live hard corals, soft corals, algae, other fauna, dead corals and abiotic components as well (Figure 3). Pier 5 had the highest percent cover in terms of abiotic components (48.48%) followed by Binuangan Gamay (26.72%), Binuangan Dako (11.69%) and Punta Binuangan (7.04%) respectively. It can be notice also from the results and during the assessment period that Pier 5 had the highest combined percent cover in terms of algae, and abiotic components such as rubbles, coral fragments and silts. According to Roxas et al (2009), the combined percent cover of the mentioned components suggests that there is recent death of corals in the area.

However, among the four stations, Punta Binuangan has the highest percent cover of dead corals. This occurrence might be attributed to some human activities such as coastal development, sediments, boat and diver damage, and damaging fishing practices (Gomez 2004). Gomez (2004) also added that such activities can cause disturbances and will alter natural conditions of reefs ecosystem, making corals become stress, thus, leading to coral mortality. Since, Punta Binuangan is near to coastal barangay/community, this might be the reason of high percent cover of dead corals in the area wherein the mentioned human activities possibly happened in the area.

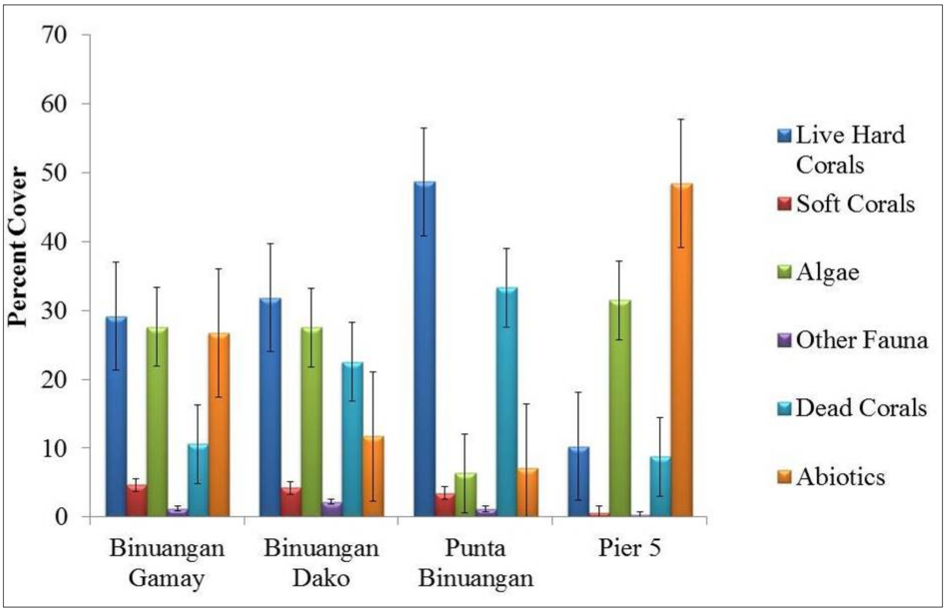

Figure 3. Percent cover of benthic components in the four sampling stations near mining operation site in Tubay, Agusandel Norte. Error bars denote SEM.

In addition, there are ten major hard coral categories by life form being identified in the four sampling stations (Table 1). Hard corals are crucial because of its capability as reef builders. In addition, different life forms will provide further information about the present reef condition and even suggest factors that are influencing it (Waheed et al 2004).

The results show that coral encrusting has the highest cover among the ten life form categories (10.29±10.60), followed by coral massive (10.12±15.57), coral sub-massive (2.51±7.41), coral Mellipora (2.43±4.36) and coral mushroom (0.95±3.83). The high percent cover of the mentioned coral life form categories can be ascribed to the reasons that they can withstand from disturbances such as wave (Allen 1996) better than other life form categories.

Table 1
Mean (±SD) of hard coral categories in the four sampling stations near mining operation site in Tubay, Agusan del Norte

Hard coral categories	*Binuangan Gamay*	*Binuangan Dako*	*Punta Binuangan*	*Pier 5*	*Average Mean ± SD*
Acropora Branching (ACB)	1.62±8.26	0.53±4.62	0.91±4.49	0±0	0.77±4.34
Acropora Digitate (ACD)	0±0	0±0	0.37±1.89	0±0	0.09±0.47
Acropora Sub-massive (ACS)	0±0	0.09±0.77	0±0	0±0	0.02±0.19
Coral Branching (CBR)	0.59±2.82	0.51±2.75	2.21±8.42	0±0	0.82±3.50
Coral Encrusting (CE)	13.1±1.82	6.99±12.12	19.25±22.76	1.83±5.67	10.29±10.60
Coral Foliose (CF)	1.65±6.8	4.85±12.05	0.18±1.53	0.1±0.83	1.69±5.30
Coral Massive (CM)	9.98±15.24	6.55±11.52	17.74±22.96	6.21±12.56	10.12±15.57
Coral Mellipora (CME)	0.41±3.29	9.14±12.61	0.18±1.53	0±0	2.43±4.36
Coral Mushroom (CMR)	1.09±4.21	1.71±6.5	0.98±4.6	0±0	0.95±3.83
Coral Sub-massive (CS)	0.71±3.04	0.64±3.24	6.86±16.29	1.82±7.08	2.51±7.41

Coral mushroom for instance can move by using its tentacles and according to Castro & Huber (2003), coral mushroom can turn the right way up when knocked over by wave actions or strong currents. However, Genus *Acropora* were hardly found in the area particularly in Pier 5 where occurrence of *Acropora* was not found, and only *Acropora* branching was noted in the entire area (0.77±4.34). According to Waheed et al (2004), *Acropora* are sensitive to sediments and have limited abilities in trapping and removing sediments from their surfaces, sediments decrease light penetration and clogs coral polyps. Removal of sediment requires the production of large amounts of mucous, which is an energetically demanding activity and excess mucous production over long time periods stresses the coral host, further reducing growth and reproductive capacities (Van Bochove et al 2006). These reasons can be ascribed to the poor occurrence of *Acropora* in Pier 5 since this area is very near to mining operation wherein the upland activities can load heavy sediments to that area and Pier 5 also has the highest sedimentation rate compared to the three remaining stations.

Regarding on percent live hard coral cover (Figure 4), Binuangan Gamay, Binuangan Dako and Punta Binuangan can be classified in "fair category" (25–49.9% live hard coral cover). Only Pier 5 can be classified in poor category (0–24.9% live hard coral cover). This classification was based on the categories stipulated in the study of Gomez et al (1981, 1994a, 1994b) and based on the Guidelines for the Implementation of the Sustainable Coral Reef Ecosystems Management Program set by the Department of Environmental and Natural Resources, Philippines (DENR 2013).

Nonetheless, the four sampling stations located near mining operation site in Tubay, Agusan del Norte can be classified in fair category, the same condition reported by EPRMP on 2014. However, there is a remarkable decrease of coral cover in Pier 5 having 42.9% percent coral cover during the assessment conducted by EPRMP on 2014 it considerably declined to only 10% in this recent assessment. Furthermore, a slight decrease of live hard coral was also noted in Binuangan Gamay (40.41% to 29.15%) and Binuangan Daku (48.44% to 31.83%), and no perceptible changes were observed in Punta Binuangan during the assessment of EPRMP on 2014.

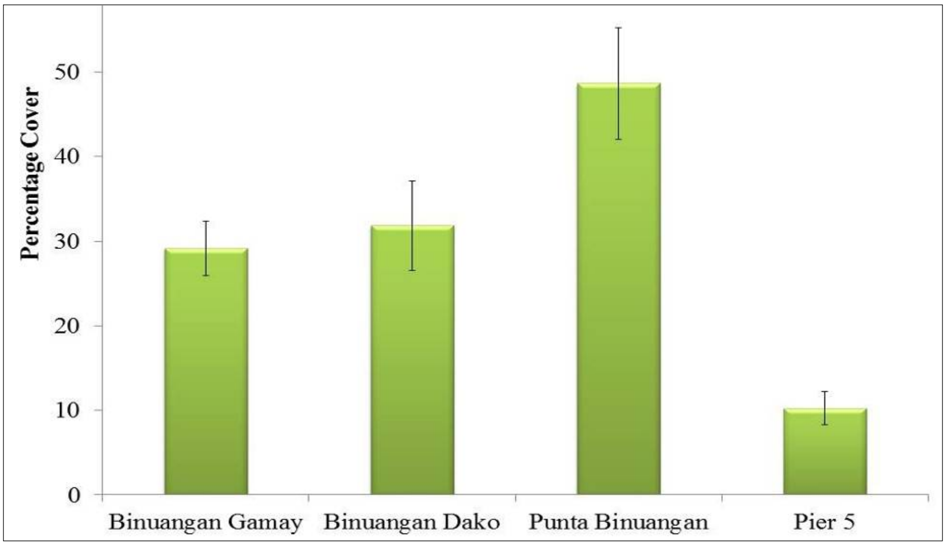

Figure 4. Percent cover of live hard coral in the four sampling stations near mining operation site in Tubay, Agusandel Norte. Error bars denote SEM

Reef fishes. Fish communities were assessed along benthic survey in three replicated transects in each sampling station. Underwater visibility during sampling was quite good, estimated to be greater than 10 m.

A total of 102 species belonging to 25 families of reef fishes were recorded in the four sampling stations near the vicinity of mining station. Species richness and abundance are shown in Figure 5. Among the four stations, Punta Binuangan reef has both the highest number of reef fish species (32±45 species) and number of fish individuals (446±528 individuals/500 m^2). The lowest species richness with only 25 species/1000 m^2 and classified as very poor was observed in Pier 5 reef station. Reef fish density index in Pier 5 was categorized as poor (202–676 individual/100 m^2) based from fish density category of Hilomen et al (2000). The lower fish density in Pier 5 could be attributed to the noise disturbance generated during loading of ores onto the barge. The fish survey was conducted few minutes after the scheduled loading of ores in Pier 5. On the other hand, the three other stations have a moderate fish density category which falls within 677–2267 indidividual/500 m^2.

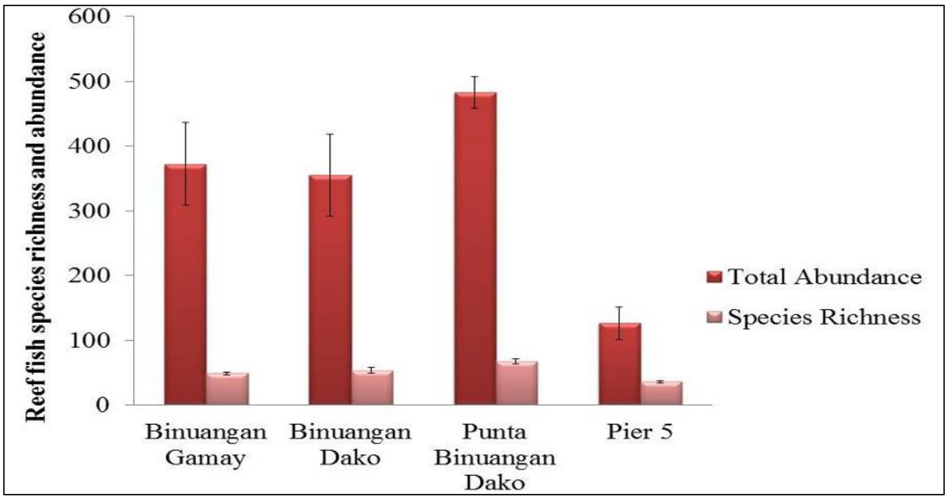

Figure 5. Species richness and abundance (fish individual/500 m^2) of reef fishes recorded in the four sampling stations near mining operation site in Tubay, Agusan del Norte. Error bar denotes SEM.

Fish diversity index in Punta Binuangan and Binuangan Dako stations were categorized as moderate with 55 species/1000 m^2 and 48 species/1000 m^2 respectively. The target or commercially important species group recorded in Punta Binuangan has the highest abundance among the four stations (Figure 6). A school of striped eel catfish (*Plotosus lineatus*) contributed for higher abundance and biomass of reef fishes in Punta Binuangan reef station. Only few target species (3 individuals in 3 transects) and coral indicator species (6 individuals in 3 transects) were recorded in Pier 5 station. Based on the classification of fish biomass by Nanola et al (2010), Punta Binuangan, Binuangan Dako and Binuangan Gamay stations fall under the low fish biomass category (3.1-10 mt/km^2) while Pier 5 station fall under very low category (1-3.0 mt/km^2) as shown in Figure 7.

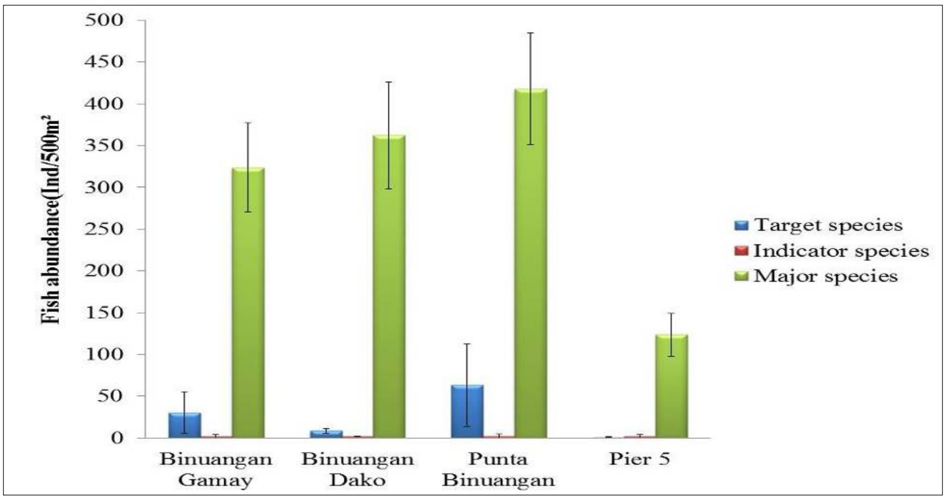

Figure 6. Average reef fish abundance of major species, coral indicator and target species recorded near mining operation site in Tubay, Agusandel Norte. Error bar denotes SEM.

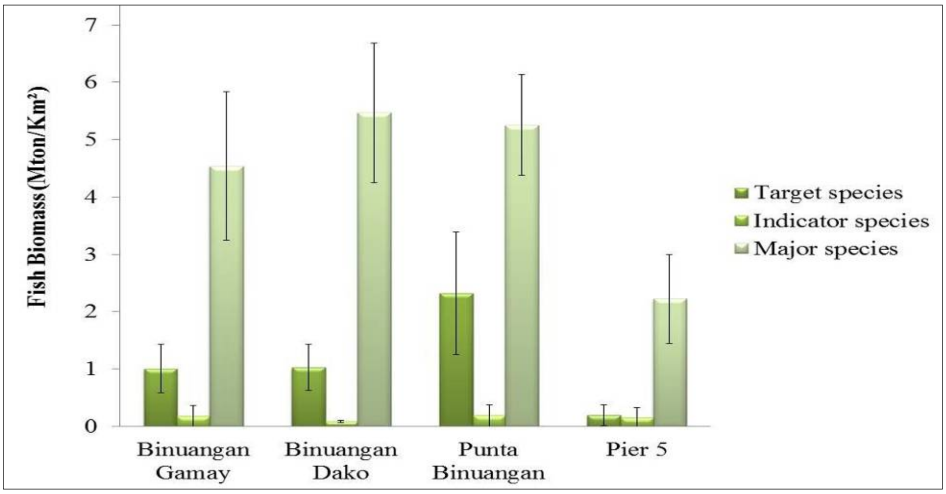

Figure 7. Average reef fish biomass of major species, coral indicator and target species recorded near mining operation site in Tubay, Agusan del Norte. Error bars denote SEM.

In the study of Komyakova et al (2013) they found out that fish species richness and total abundance were strongly associated with coral species richness and cover. Regression tree analysis in their study revealed that coral species richness regarded for most of the variation in fish species richness (63.6%), while hard coral cover demonstrated more variation in total fish abundance (17.4%). The findings of their study suggest that reduced coral biodiversity may ultimately have an equal, or greater, impact on reef-associated fish communities.

In terms of species diversity (Figure 8), Punta Binuangan obtain the highest value of H'=2.63467, followed by Binuangan Dako (H'=2.5153), and Binuangan Gamay

(H'=2.4913). Pier 5 obtain the lowest value of H'=2.29. Based on the classification of diversity value and its qualitative equivalence by Fernando (1998), Punta Binuangan and Binuangan Dako fall under moderate category while Binuangan Gamay and Pier 5 fall under low species diversity category. The result may imply that Punta Binuangan and Bunuangan Dako are moderately stressed. According to Goncalves & Menezes (2011), the habitat structure with a value above 3.0 indicate a stable habitat and values lower than 1.0 indicate pollution and the degradation of habitat. The possible reason why Punta Binuangan and Binuangan Dako fall under a moderate condition compared to Binuangan Gamay and Pier 5 that falls under low species diversity condition are due to the high live hard coral percent cover in Punta Binuangan and Binuangan Dako.

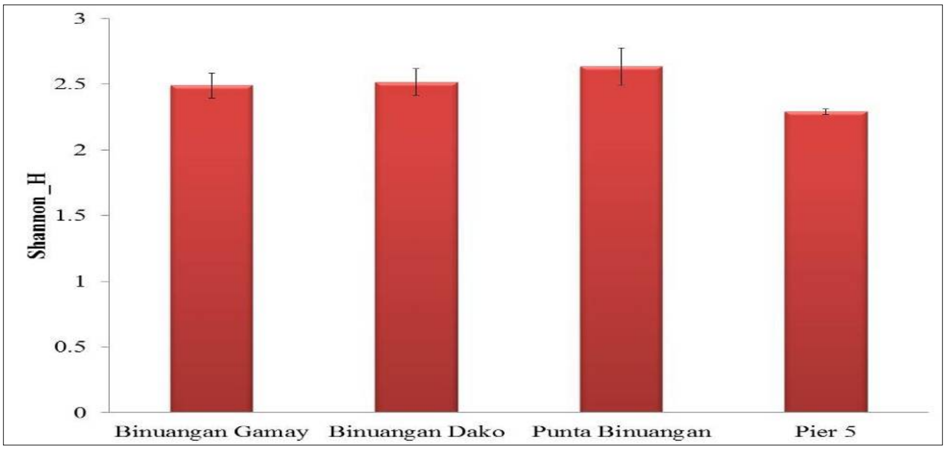

Figure 8. Diversity indices of reef fish in four sampling stations near mining operation site in Tubay, Agusan del Norte. Error bars denote SEM.

Sedimentation rate. Among the four sampling stations Pier 5 obtained the highest sedimentation rate (Figure 9) with the value of 1.896 mg cm^{-2} d^{-1}, followed by Punta Binuangan with a sedimentation rate of 1.725 mg cm^{-2} d^{-1}, Binuangan Dako with 0.339 mg cm^{-2} d^{-1} and Binuangan Gamay which obtain the lowest sedimentation rate of 0.254 mg cm^{-2} d^{-1}. Despite of the higher sedimentation rate observed in Pier 5 the value is far from the suggested sedimentation rates of >50 mg cm^{-2} d^{-1} (equivalent to 500 g m^{-2} d^{-1}) by Pastorok & Bilyard (1985) which is considered catastrophic for some coral communities. The maximum sedimentation rates that can be tolerated by different corals ranges from <10 mg cm^{-2} d^{-1} to >400 mg cm^{-2} d^{-1} (Pastorok & Bilyard 1985). On the other hand One way ANOVA analysis revealed that the sedimentation rate of Binuangan Gamay and Punta Binuangan Dako, Binuangan Gamay and Pier 5, Binuangan Dako and Punta Binuangan, BinuanganDako and Pier 5 have significant difference at $p < 0.05$.

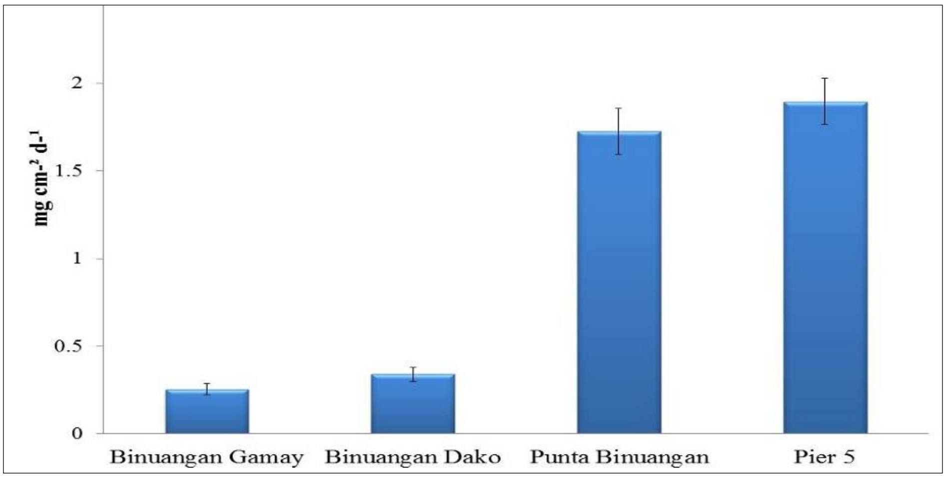

Figure 9. Average sedimentation rate in the four sampling stations near mining operation site in Tubay, Agusan del Norte. Error bars denote SEM.

Correlation analysis. Pearson correlation revealed that live hard coral cover is correlated with the reef fish species richness (Figure 5), reef fish abundance (Figure 6) and reef fish biomass (Figure 7). Based on the classification value given by Mukaka (2012), live hard coral cover is highly positively correlated with reef fish species richness, while the correlation of the live hard coral cover and coral reef fish are moderately correlated, both are significantly different ($p < 0.05$). On the other hand the correlation analysis between live hard coral cover and reef fish species biomass are low positively correlated and not significantly different ($p > 0.05$). Reef building corals are important structural species for the construction of the reef architecture (Connell et al 1997; Jones & Syms 1998; Bozec et al 2005). Coral provides food and shelters to fishes and to mobile organisms (Hixon 1991; Friedlander & Parrish 1998; Bozec et al 2005), which are in turn food sources for many reef fishes. Sano et al (1984) as cited by Bozec et al (2005) shows that a decrease in structural complexity of branching *Acropora* spp. resulted in a decrease in fish diversity and abundance due to a reduction in shelter availability.

Conclusions. Based on the results of the study it was concluded that sedimentation rate of the four sampling stations is in the tolerable condition. The coral condition index of the sampling stations fall under fair category. However, Pier 5 obtained the highest sedimentation rate, lowest live hard coral cover. In terms of reef fish species richness, abundance and biomass, Pier 5 station categorized as very poor, poor and very low respectively. On the contrary Punta Binuangan listed as having the largest live hard coral cover, reef fish species richness and biomass. Regarding of species diversity Punta Binuangan and Binuangan Dako fall under moderate category while Binuagan Gamay and Pier 5 fall under low species diversity category. Among the four sampling stations Punta Binuangan noted of having the highest species diversity and Pier 5 having the lowest species diversity. Pearson correlation revealed that live hard coral cover are highly correlated in reef fish species richness, moderately correlated in reef fish species abundance and low correlated in reef fish biomass.

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