Vol. 5 January 2014
CHED Accredited Research Journal, Category A
Print ISSN 2094-5019 • Electronic ISSN 2244-0461
doi: http://dx.doi.org/10.7828/ajob.v5i1.481

Asian Journal of Biodiversity
This Journal is in the Science Master Journal List of
Thomson Reuters (ISI) Zoological Record

Assessment of Biodiversity and Water Quality in Association with Land Use in the Alanib River, Mt. Kitanglad Range Park, Philippines

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ABSTRACT

Inventory and assessment of aquatic biodiversity were conducted in Alanib River in Mt. Kitanglad, Bukidnon, which is one of the Long Term Ecological Research (LTER) sites in Mindanao. The species richness and abundance of fishes, macroinvertebrates, plankton and also vascular plants in the riparian vegetation were evaluated in relation to the influence of land use, water quality and elevation. The results of this study revealed that there were 2 species of fishes, 6 orders of macro-invertebrates 14 species of plankton and 237 species of vascular plants were identified. The surrounding land uses and human activities along the river were found to have significant impact on the overall water quality and biodiversity of the aquatic biota and riparian vegetation of Alanib River. The increasing human population and agricultural intensification at the lower section of the river contributed to the relatively lower water quality, presence of pollution tolerant phytoplankton and macro-invertebrate groups as well as invasive species of vascular plants. Hence, the overall results of this study revealed that the integrity of Alanib River in terms of its biophysical and chemical condition is severely threatened especially in the downstream section due to various anthropogenic activities which can degrade its overall environmental quality.

Keywords - Assessment, stream health, river, biodiversity, composition, Mindanao

INTRODUCTION

The Mount Kitanglad Range National Park (MKRNP) is one of the protected areas and remaining frontiers of the Philippines located in the north-central portion of the Bukidnon Plateau. This national park has a total land area of 47,270 hectares which is covering the 7 municipalities and one city of the province of Bukidnon (Saway and Mirasol 2004). The park is the habitat of at least 58 families and 185 species of trees and other woody vegetation species (Canoy and Suminguit 2001) 19 species of ferns and 1 species of fern allies as Philippine new records (Amoroso et al. 2011), 63 species mammals 25 species of reptiles 26 species of amphibians and 168 species of birds (Canoy and Suminguit 2001). Almost 50% of known species of fauna are endemic and highly threatened species. Due to its richness in biodiversity, it became a protected area through

Republic Act8978 and later declared as an ASEAN Heritage Park on October 2009.

The MKRNP is also part of the ancestral domain of four indigenous tribes in the province of Bukidnon, namely the Manobo, Talaandig, Maranao and Maguindanao. These indigenous tribes are currently living along the buffer zones and dependent mainly on subsistence farming and hunting. Aside from its cultural significance, the park is also the source of potable water of the surrounding municipalities and the head water of some river and lakes in Bukidnon which are providing power generation, irrigation and domestic use (Saway and Mirasol 2004). Despite of its biological, economic and cultural significance, the park has been severely threatened by man-made activities such as slash and burn farming, illegal logging, eco-tourism and agricultural intensification (Canoy and Suminguit 2001).If these problems will continue unabated, it will result to habitat degradation and loss of endemic and threatened species of flora and fauna. One of the components which could be severely affected is the highly sensitive riverine ecosystems. These anthropogenic activities within the MKRNP could lead to frequent occurrences of riverine flooding and landslides, soil erosion, bacterial and chemical contamination, and variation in stream discharge patterns. As a result, the integrity of stream habitat and riparian vegetation within the MKRNP will degrade over the next decade if the lack of information, awareness and policy regarding the protection and conservation of the biological resources are not strictly addressed.

The health of riverine ecosystems could be assessed by examining the relationships of various abiotic and biotic factors such as land use, water quality, riparian vegetation, and aquatic biodiversity (Pan et al. 2004; Pausas and Austin 2001; Rios and Bailey 2006).For instance, land use alters the texture and composition of the land surface and therefore influences water quality and physical habitat condition, which will eventually decrease biological integrity (Pan et al. 2004).According to Richards and Host (1994), there is also an important implication in the relationship between watershed characteristics and in stream variables for understanding ecological linkages. It was supported by Rios and Bailey (2006) and Dudgeon (1994) where relationship between physico-chemical properties and biotic factors (macroinvertebrates, plankton, fishes) were studied. Furthermore, several studies have shown that land use has a strong influence on river chemistry and its biotic components (Pierre et al. 2000). On the other hand, agricultural intensification increases with elevational decline and affect important ecosystem services such as vegetation shifts, biodiversity, phytomass production, carbon sequestration and water relations. Generally, species richness increases up to an elevation ranging between 2,200 to 3,000 m above sea level (masl)in montane environments (Becker et al. 2007).

The MKRNP is also one of the Long Term Ecological Research (LTER) sites in Mindanao. However, no studies have been conducted to assess the freshwater species composition and distribution in relation to land use and elevation in order to assess the status, condition and integrity of this riverine ecosystem. Hence, there is high paucity of information with regards to the current status and condition of environmentally significant riverine ecosystems such as the Alanib River in particular and in the Philippines in general. This is one of the reasons why the Philippines ranks number eight in the world as one of the biodiversity hotspot (Myers et al. 2000).

OBJECTIVES OF THE STUDY

This paper assessed the biodiversity and water quality of Alanib River in order to provide detailed information on current river health conditions and to quantify the biodiversity and water quality variability in relation to its surrounding land. The species composition and distribution of fishes, macro-invertebrates, plankton, and vascular riparian vegetation of the river at the different sampling sites were determined. The physico-chemical parameters such as temperature, pH, DO, EC, turbidity, TDS, ORP and sedimentation rate were also determined.

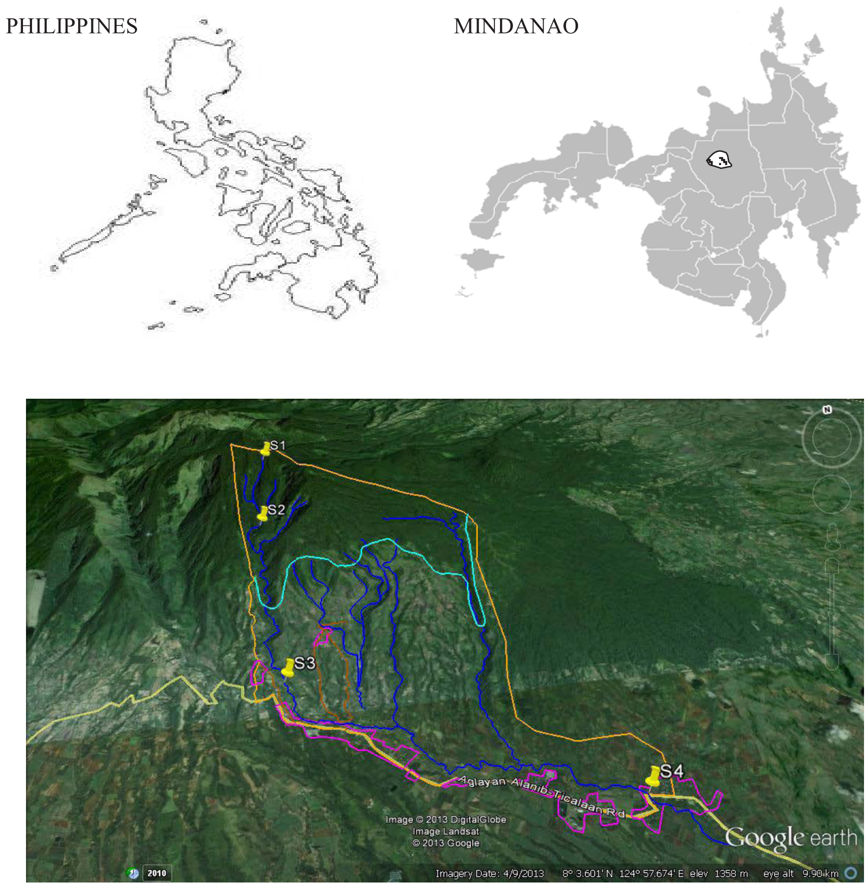
MATERIALS AND METHODS

Table 1. Geographic location, elevation, and surrounding land uses of the sampling sites at Alanib River, Mt. Kitanglad, Bukidnon.

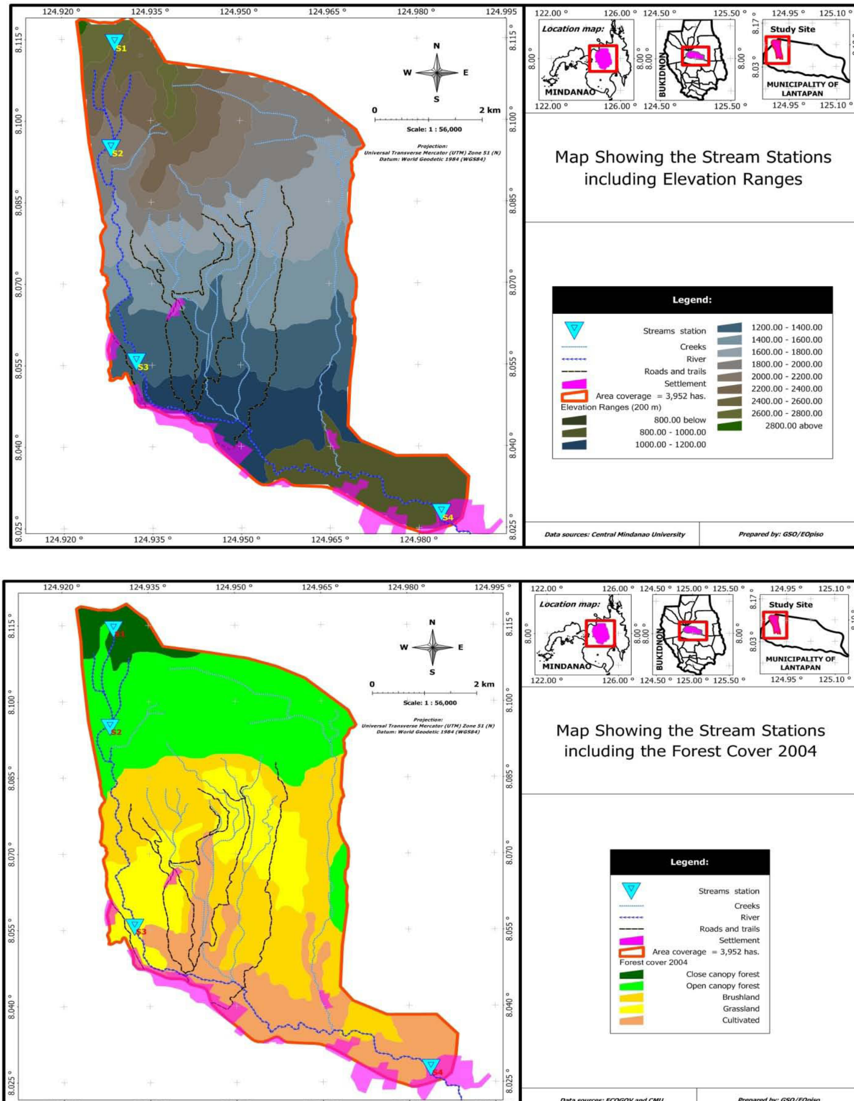
Alanib River	Elevation (m, asl)	Latitude	Longitude	Surrounding land use
Upstream (S1)	2,111	08˚05.697’	124˚55.425’	Forest
Midstream1 (S2)	1,684	08˚03.485’	124˚55.929’	Forest
Midstream2 (S3)	1,207	08˚03.523’	124˚55.909’	Agricultural (high valued crops)/Forest
Downstream (S4)	752	08˚01.603’	124˚59.117’	Residential/Agricultural

Description of the study area

One of the environmentally significant river systems in MKRNP is the Alanib River which is situated in the southern part of Mt. Kitanglad Range National Park. This river system serves as the permanent study area for the diversity studies, assessment/reassessment and monitoring of the flora and fauna of riverine ecosystems in order to elucidate the influence of land use, water quality and elevation on the integrity and health of riverine ecosystems. The Alanib River is located under the municipality of Lantapan, Bukidnon, Mindanao Island, Philippines (Fig. 1 and Fig. 2). Four (4) sampling stations with 100 m transect each were established based on elevation and human impact. The topography of the river is sloping from upstream to downstream with elevation varying from 2,111 to 752 masl in which the two sampling sites were located at elevations above 1,800 masl. Its headwater is located at Mt. Dulang-dulang and traverses various types of surrounding land uses (e.g forest, agricultural, agro-forestry, grassland and mixed agricultural and residential areas) before it drains to the valley bottoms towards the Manupali River which is one of the tributaries of Rio Grande de Mindanao. The riverbanks and riparian vegetation are dominated by forest, agricultural (high valued crops), and residential land uses. The river is also used for washing of clothes and bathing of the nearby residents and source of potable water of the municipality of Lantapan. The river consists of large rocks with numerous water pools and falls in the upstream side. The specific location, elevations and surrounding land uses of the sampling sites are presented in Table 1.



Upstream (S1); Midstream 1(S2); Midstream 2(S3); and Downstream (S4)
Fig. 1. Location of the Study Sites in Alanib River, Mt. Kitanglad, Bukidnon.



Upstream (S1); Midstream 1(S2); Midstream 2(S3); and Downstream (S4)
Fig. 2. Elevation of study sites and forest cover along Alanib River, Mt. Kitanglad, Bukidnon.

Sampling and Analysis

A transect walk was conducted over the established 100 m transect line along the river course for each sampling station.

The fishes were collected using backpack electro fishing oriented with hand net and medium pole seine net. Morphological characters and morphometrics of the collected species were then recorded (e.g color, number of fins, barbells if present, head and tail shape, body and mouth structure, total length and body weight) for the preliminary identification of the species. FishBase 2013 key for Philippine freshwater fish species was primarily used in identifying the species. For the voucher, each species was preserved in 10% alcohol and stored in 90% ethanol for further analysis in the laboratory. Other species were returned alive to the river.

The macroinvertebrates were sampled using a D-frame net with 250 μm mesh size adapting the method by USEPA (2012). Leaf-pack sorting method and rock rubbing method were also employed. The collected samples were transferred to labelled plastic tubes, fixed with 95% ethyl alcohol and were brought to the laboratory for sorting and identification. To have a uniform data set, identification was only up to the order level using different taxonomic keys from journals and monographs(e.g. Meyer 2009; Nelson 2004; SWCSMH 2013).

In the case of plankton, one (1) L plastic containers were used to collect stream water in triplicates at each upstream, midstream and downstream sites. In each bottle 10 ml Lugol's solution was added. For zooplankton 15 L grab samples were filtered through plankton net and the 50 ml concentrate was added with 0.5 ml Lugol's and 0.5 ml 4% formalin. All samples were allowed to settle for one (1) week in the laboratory after which the supernatant was gradually decanted until 20 ml concentrate was left. Drops of shaken samples were mounted on a glass slide and examined at higher magnification of the inverted bright field microscope for species identification with reference to monographs and images (Botes 2001; Bellinger and Sigee 2010) and consultation with experts. Also, an aliquot of one (1) ml was placed in the Sedgewick-Rafter counter slide and individuals of species were counted to express species density (units/L).

Lastly, only vascular plants were surveyed in the established sampling area. Plants observed in the riparian vegetation were photographed, collected and identified. Local names and local uses were recorded for each plant. Representative plants were collected and prepared as voucher specimens.

Moreover, the variation of riparian and aquatic biota composition in relation to land use and elevation were analyzed in Statistical Analysis Software (SPSS v. 21 by SPSS Inc.). Pearson correlations of water quality parameters, species composition and land cover and elevation were used to measure the strength and nature of the influence of land use and elevation on riparian and aquatic biota composition.

RESULTS AND DISCUSSION

Water quality condition and sedimentation rate

The measured water quality and sedimentation rate of Alanib River is shown in Fig. 3. The temperature ranged between 14 to 24 °C, which increased from upstream to downstream (S1 to S4) could be attributed to the elevation effect. The water turbidity of Alanib River was 0 NTU except for the downstream side (S4) with 14.22 NTU. Similarly, pH increased from upstream to downstream side which may be influenced by some factors such as agricultural run-off, presence of calcareous sediments and other anthropogenic activities. The amount of dissolved oxygen (DO) of water which has a significant impact on the chemical and biological processes in aquatic ecosystems showed no significant variation between sampling sites, i.e. from upstream to downstream. High DO (> 20 mg/L) in all sampling sites was attributed to the presence of riffles and waterfalls. Besides, the low water temperature could increase oxygen holding capacity of the water. The total dissolved solid (TDS) of the river which is a measure of the concentration of dissolved ions in the water showed a decreasing trend from upstream to downstream. These differences of the measured water quality parameters of the different sampling sites could be mainly due to their difference in elevation and surrounding land uses. Moreover, the measured parameters were within Philippine Water Standard requirement except for the pH at the downstream side which was slightly above the 8.5 maximum pH requirements. The deterioration of water quality parameters in downstream section of the river may be attributed to the increased agricultural activities and the presence of residents along the banks which can modify the physical condition and water quality of the river as also observed by Scalley and Aide, (2003) and Moscovchenko et al. (2009). On the other hand, sedimentation of the river influences the water quality which can reduce the penetration of light to the bottom of the river and decline the dissolved oxygen present in water (Tumanda et al. 2005). However, the sedimentation of the river showed an increasing trend from upstream to downstream. This is mainly because the downstream is surrounded by residential and agricultural areas while S1 to S2 sampling sites were dominated by intact forest with minimal human activities.

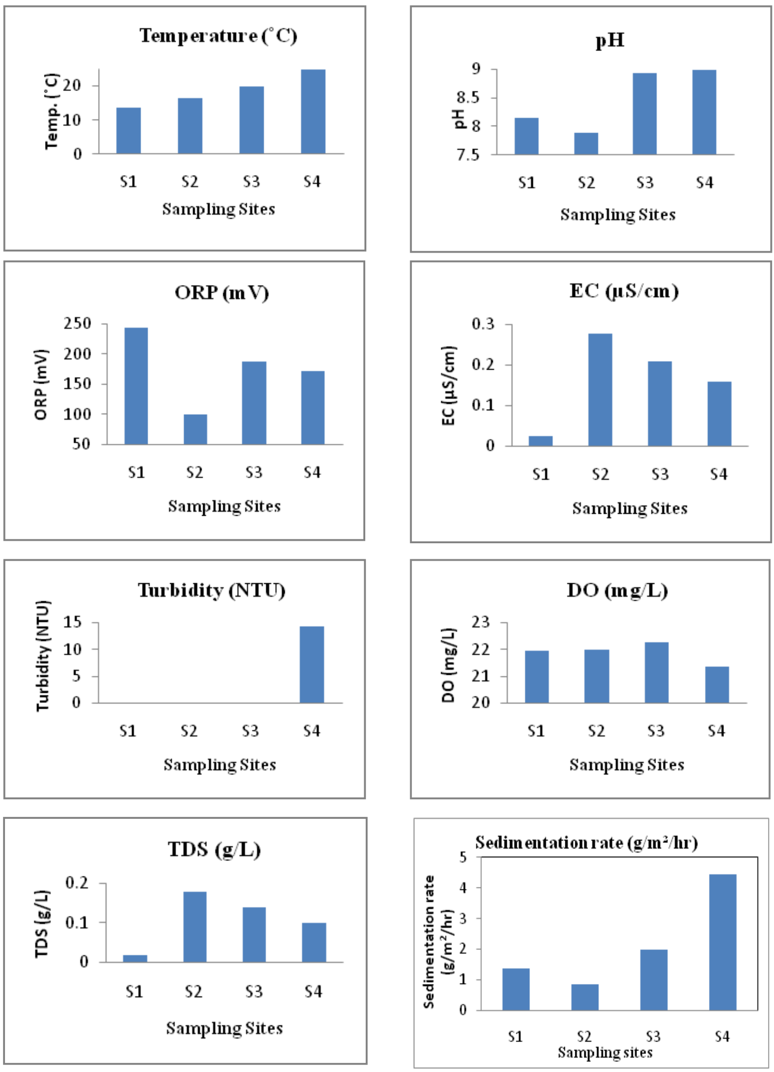


Fig. 3. Measured water quality of Alanib River, Mt. Kitanglad, Bukidnon at the Upstream (S1); Midstream1 (S2); Midstream2 (S3); and Downstream (S4)

Biodiversity assessment

Fishes

The fishes were found only at the downstream (S4) at an elevation of 752 masl and water temperature of 24.71°C. The 12 fish individuals collected represented 2 species and 2 families (Plate 1). Both species were native with small body sizes. These were *Puntius binotatus* (Valenciennes 1842) (Cyprinidae) and *Sicyopterus lagocephalus* (Pallas 1770) (Gobiidae) which are widely distributed in Asia and Indo-Pacific, respectively. The former is also found in all over Southeast Asia (Jenkins et al. 2009) while the latter is widely distributed in northern and western Asia, and French Polynesia (Boseto 2012). Fishes are limited to inhabit inhigh elevation (2,111 masl) and low water temperature (13.77 ^{0}C) of Alanib River. Fish species has an optimum growing temperature range of 25-30 ^{0}C (Kausar and Salim 2006). In warm environment fishes have a longer growing season and faster growth rate and tend to have a shorter life span while in very low temperatures growth is retarded. Also, temperature affects food consumption, feed conversion and other body functions which influence fish species richness (Lessard and Hayes 2003). Furthermore, fishes are sensitive to many changes in water quality and habitat structure caused by human activities and by natural causes (Pidgeon 2004) and fishes are decreasing worldwide because of human-caused degradation of aquatic habitats (Moyle et al. 2013).

Macroinvertebrates

There were 6 orders of macro-invertebrates namely Coleoptera, Hemiptera, Odonata, Trichoptera, Plecoptera and Ephemeroptera (Plate 2). Plecoptera had the highest number individual count followed by Hemiptera, Trichoptera and Coleoptera while the least was Ephemeroptera (Fig.4). The abundance of Plecoptera which are extremely sensitive to water pollution indicates the river is clean and well-oxygenated while Hemipterans are known to be tolerant on environmental extremes (Flores and Zafaralla 2012; Meyer 2009). The Hemipterans are also known to endure low pH less than 4.5 and are among the last to disappear when streams tend to acidify (SWCSMH 2013). The co-existence of these two macroinvertebrate orders in the same sampling station also indicates that water quality is good. Moreover, the presence of biocontroller insects (e.g. Odonata) which serve as predators in an aquatic ecosystem could also affect the macro-invertebrate composition in Alanib River. The macroinvertebrates were highest at the downstream. Macroinvertebrate species composition and abundance in this study could have been affected by the surrounding land use of the sampling station which also supports the findings of Rios and Bailey (2006), Pierre (2000), Richards (1994) and Dudgeon (1994) that land use influences macroinveretebrate population in aquatic ecosystems.

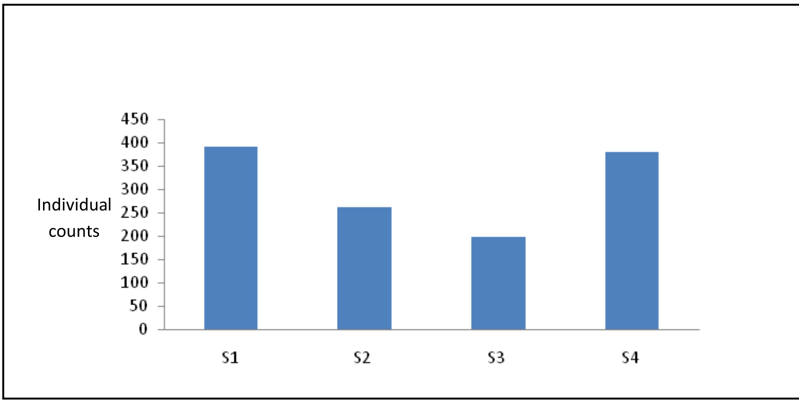


Fig. 4. Individual Counts of Macroinvertebrate groups at the Upstream (S1), Midstream1 (S2), Midstream2 (S3) and Downstream (S4) of Alanib River, Mt. Kitanglad, Bukidnon.

Plankton

The phytoplankton is represented by 4 groups and 14 species (Plate 1). These are Chlorophyta, Cryptophyta, Bacillariophyta and Euglenophyta in which the Chlorophytes dominated (Fig.5). Among the 14 species, *Sphaerozosma sp., Staurastrum* sp., *Volvox* sp., *Spherocystis,* and *Diatoma* were abundant. The presence of *Staurastrum* sp., *Volvox* sp. and *Euglena* indicates that water is polluted (Sharma and Bhardwa 2011; Oommen and Kumar 2011; Edward and Ugwumba 2010). The absence of zooplankton in Alanib River could be attributed to some factors such as high elevation and low temperature, basic pH, less sunlight and limited nutrients. This is somehow expected since the surrounding land use where these two pollution tolerant phytoplankton were found are greatly influenced with anthropogenic activities. It was also observed that most species were found at midstream 1(S2) and the least from the upstream (S1) of Alanib River. High phytoplankton concentration could be expected frommidstream2 (S3) since it is surrounded by agricultural land use. This type of land use can affect the increase of nutrient availability on a specific location of a water system which may trigger the increase of phytoplankton population. The few phytoplankton species and low counts along the Alanib river course of Mt. Kitanglad supports the earlier report of Stomp et al. (2011) that phytoplankton diversity decreased with increasing latitude and altitude. Mt. Kitanglad is the highest mountain range in Bukidnon and the fourth highest mountain in the Philippines. This is also noticeable on the shown trend of phytoplankton species composition over the sampling stations. Plankton are considered bioindicator. Its composition, abundance and distribution correlates with environmental condition of an aquatic ecosystem. Hence, knowledge on the plankton population is significant on assessing the current health status of Alanib River and this serve as baseline information for conservation management. Proper conservation management is essential for Alanib River considering the fact that this has an important role in the over-all biological diversity in Mt. Kitanglad Range Park. Moreover, it serves as the source of potable water among the residents near the river and neighboring municipalities.

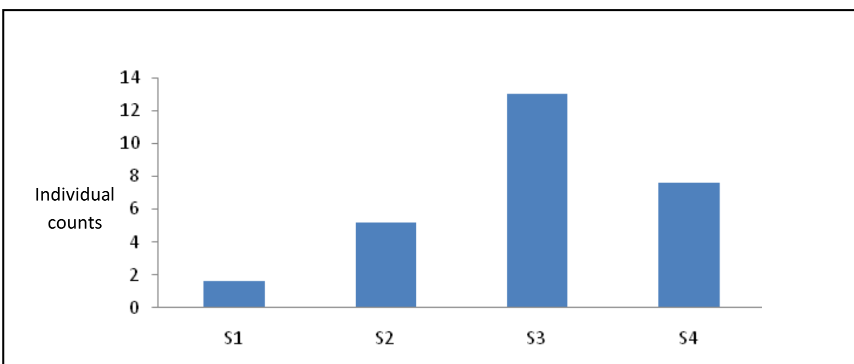


Fig. 5. Individual Counts of Phytoplankton species
at the Upstream (S1), Midstream1 (S2), Midstream2 (S3) and Downstream (S4) of Alanib River, Mt. Kitanglad, Bukidnon.

There were 240 species of riparian vascular plants found in all sampling site along the Alanib River. Of these 171 species were angiosperms, 3 were gymnosperms and 66 species were pteridophytes. Table 2 shows the species richness of riparian vascular plants in Alanib River. High species richness in the upstream (S1) and midstream 1 (S2)(Table 2) was observed in the area, which is similar to the study of Lubos et al. (2013) that there is a decreasing number of species from the upstream to downstream. However, species richness in the downstream (S4) was lower as compared to the midstream2 (S3) which could be due to the conversion of forests into agricultural lands for the cultivation of the cash crops like celery, parsley, baguio beans, spring onions, sayote in the area. Both sides of the banks are characterized by having large trees and inhabited with different species of ferns and other herbaceous flowering plants. Furthermore, some of the areas were cleared for the expansion of the plantation crops and with some abandoned areas dominated with *Pennisetum* sp. and other grasses. This area had also the abundance of planted giant bamboos and tree ferns (*Sphaeropteris glauca*). Although the area had low species richness, there could be no sign of coliform contamination since there were no inhabitants in the area and no signs of soil erosion. The midstream2 (S3) had lower species richness, but had the presence of some rare and economically important plants like *Medinilla cumingii, Schefflera* sp., *Solanum* sp. (Hagpa) etc. Although few have survived many introduced tree species were observed like *Gmelina arborea*, Neem tree, *Swietenia macrophylla*, *Leucaena leucocephala* as reforestation tree species. Some of the invasive species like *Tithona diversifolia*, *Lantana camara*, *Mikania*, *Impatiens montalbanica*, *Mimosa invisa*, *Spathodea campunalata*, *Piper aduncum* and *Cassia spectabilis* were observed in midstream 2 (S3) which were not observed in the downstream. Probably these invasive species were uprooted during farming field preparation for the cash crops.

Further, it was observed that in the downstream (S4) intact forest vegetation was found before the water dam. However, after the water dam, lesser trees were observed. Jansson et al. (1999) reported that riparian floras are increasingly fragmented with multiple dams which brought about by the disruption of natural dispersal pathways and subsequent changes of riverine communities. The downstream riparian vegetation had no evidence of reforestation efforts. A total of 8 species of threatened plants were observed in Mt. Kitanglad. Most of these threatened species are found in the upstream (S1) and midstream 1 (S2) (Table 3).

Table 2. Species Richness of Riparian Vascular Plants in Alanib River, Mt. Kitanglad, Bukidnon

Plant group	Sampling Sites			
	Upstream (S1)	Midstream1 (S2)	Midstream2 (S3)	Downstream (S4)
Angiosperms	53	41	78	52
Gymnosperms	3	2	0	0
Pteridophytes	52	36	9	4
Total	108	79	87	56

Table 3. List of Threatened Riparian Vascular Flora in Alanib River, Mt. Kitanglad, Bukidnon.

FAMILY/SPECIES	Assessment
ASPLENIACEAE	
Asplenium apoense Copel. in Perkins	Vulnerable
BLECHNACEAE	
Diploblechnum fraseri (A. Cunn.) De Vol	Vulnerable
CYATHEACEAE	
Alsophila fuliginosa H. Christ	Endangered
Sphaeropteris glauca (Blume) R.M. Tryon	Vulnerable
LYCOPODIACEAE	
Huperzia serrata (Thunb.) Rothm	Vulnerable
OPHIOGLOSSACEAE	
Ophioglossum pendulum L.	Endangered
POLYPODIACEAE	
Belvisia glauca (Copel.) Copel.	Vulnerable
PSILOTACEAE	
Tmesipteris zamorae Gruezo and Amoroso	Vulnerable

Vascular riparian vegetation

CONCLUSIONS

The surrounding land uses and human activities along Alanib River were found to have significant impact on the overall water quality and biodiversity of aquatic biota and riparian vegetation of the river. Along the upper sections of the river which was surrounded by intact forests, the water quality of Alanib River was still potable except for the downstream which exhibited high turbidity and pH beyond the Philippine and USEPA regulatory standards. In the case of aquatic biota, fishes were only at the downstream since fish can only survive in water with 25-30° C and the water temperature in S1 of Alanib River was below 20° C. On the other hand, macroinvertebrate orders Plecoptera and Hemiptera were the most abundant observed at Mt. Kitanglad. The Hemiptera and Plecoptera population was generally decreasing from upstream to downstream with more Hemipterans than Plecopterans suggesting a decreasing water quality across sampling stations. This correlates with the phytoplankton population from upstream to downstream wherein the presence of pollution tolerant phytoplankton was observed only at the midstream and downstream. The decreasing water quality along the sampling stations could be associated with the increase of nutrient availability in these sampling sites as a result of agricultural run-off. In the case of vascular riparian plants, high species richness was observed in the upstream while the presence of invasive species was observed in the sampling area surrounded by various high valued agricultural crops.

Overall, this study has shown strong indication that the integrity of Alanib River was affected by its surrounding land uses based on its current biophysical and chemical condition.

ACKNOWLEDGMENTS

The authors would like to express our sincerest gratitude to the Commission on Higher Education (CHED) under the auspices of the Office for Policies, Planning, Research and Information (OPPRI) for funding the research project. Thanks are also due to the administration of CMU and Center for Biodiversity Research and Extension in Mindanao (CEBREM) for their assistance and support, the local researchers namely; Benjo Logramonte, Mary Cris Cudal and Verne Lloyd Calunsag in helping us in the data collection and Mr. Guiller Opiso who served as our GIS specialist in making the maps. Lastly, this project would not be possible without the permit from DENR X and Protected Area Management Board (PAMB) and the support of the local community in the study area.

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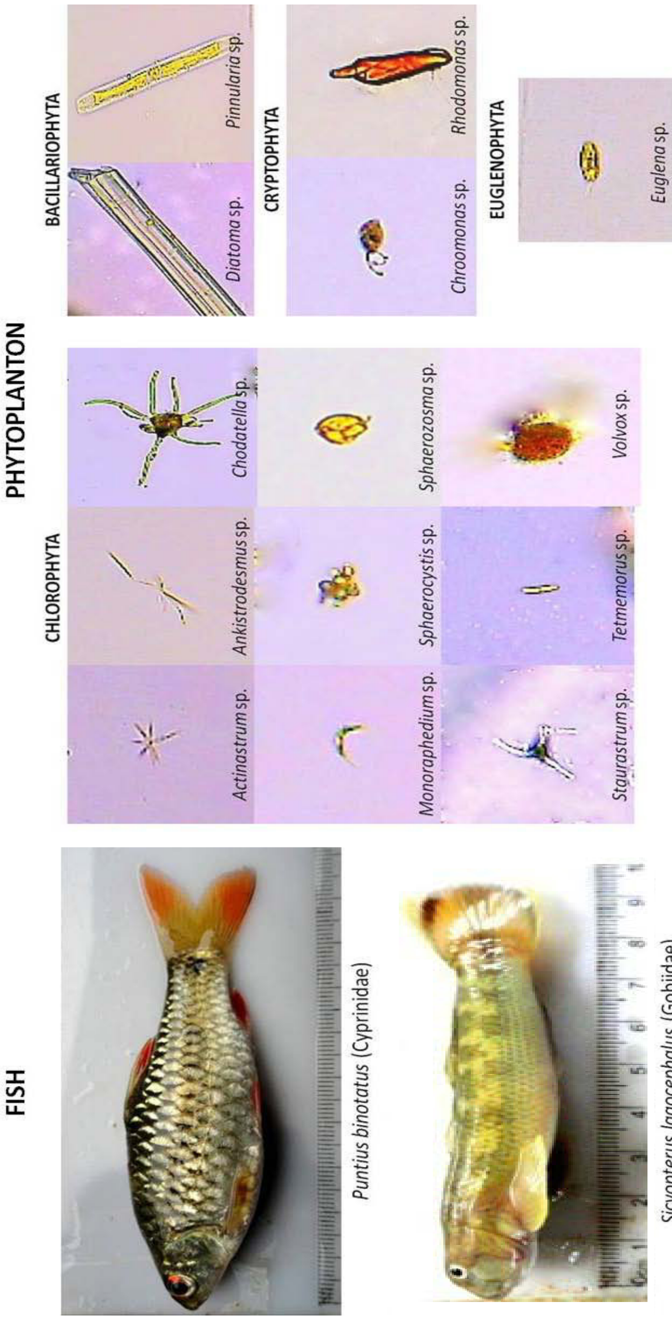

Plate 1. Fish and Phytoplankton
in Alanib River, Mt. Kitanglad, Bukidnon.

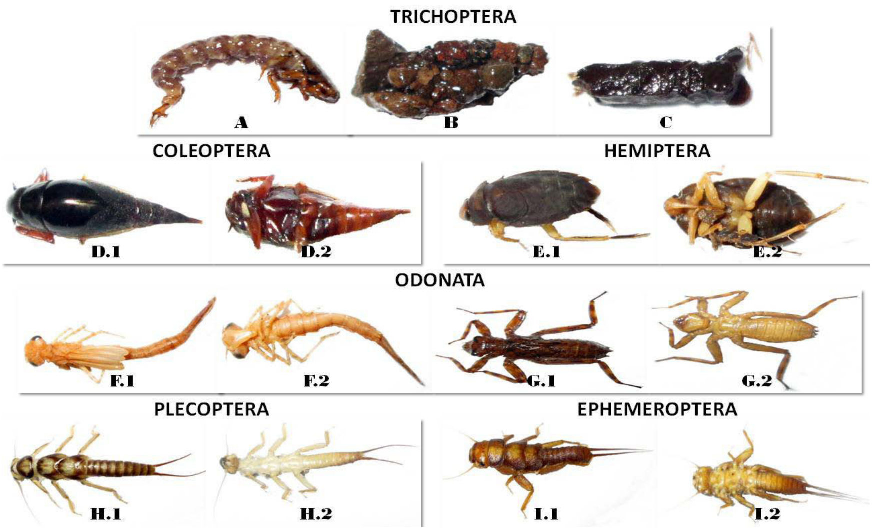

Plate 2. Macroinvertebrates in Alanib River, Mt. Kitanglad, Bukidnon. (A) Caddisfly, (B) Caddisfly with stone case, (C) Caddisfly with wood case, (D.1) Whirligig beetle dorsal view, (D.2) Whirligig beetle ventral view, (E.1)Creeping water bugs lateral view, (E.2) Creeping water bugs ventral view, (F.1) Damselfly dorsal view, (F.2) Damselfly ventral view, (G.1) Dragonfly dorsal view, (G.2) Dragonfly ventral view, (H.1) Stonefly dorsal view, (H.1) Stonefly ventral view, (I.1) Mayfly dorsal view and (I.2) Mayfly ventral view.