Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2015; 3(5): 398-405

Received: 22-08-2015
Accepted: 24-09-2015

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Aquatic macroinvertebrates diversity and Riparian Channel and Environmental Inventory in Gibong River, Philippines

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Abstract
This study aimed to assess the diversity of aquatic macroinvertebrates and its implications towards the water quality of Gibong River, Philippines. Riparian, Channel Environmental (RCE) inventory was undertaken to describe the integrity of the riparian vegetation. Selected physicochemical parameters were determined to support the presence of bioindicator macroinvertebrates species. A total of 18 macroinvertebrate species were collected, mostly arthropods (87%) and molluscs (13%). Upstream stations have the highest number of species because of its intact vegetation while midstream stations had the least, probably due to environmental stress. The RCE scores for the three locations –upstream, midstream and downstream garnered “fair” to “very good” ratings. All the physicochemical properties of Gibong River were within desirable limits except for the dissolved oxygen (DO) of midstream and downstream stations which were lower than the acceptable limits. Improvement of the riparian vegetation is highly recommended to enrich the diversity of macroinvertebrates in this river.

Keywords: RCE, macroinvertebrates, diversity, physico-chemical, parameters

Introduction
During the International Decade for Action “Water for Life” 2005-2015, freshwater biodiversity is the overriding conservation priority [1]. Hence, sustaining biological diversity for nature conservation in terrestrial, marine, and freshwater environments is a priority [2]. Consequently, the taxonomic diversity that is the most important element in the assessment of biological diversity in freshwater plays a vital role as the basis for nature protection [3].
The presence of macroinvertebrates can determine the quality of the water. The application of this biomonitoring tool is used worldwide [4]. The invertebrate fauna that can be captured by a 500 µm net of a sieve is called as macroinvertebrate. These are the animals belonging to the following families such as arthropods, molluscs, annelids, nematodes, and Platyhelminthes [5, 6]. These animals live in the water such as streams, rivers, wetlands and lakes for all or part of their lives [7, 8]. Since macroinvertebrates are sensitive to the different physical and chemical conditions, their survival is related to the water quality making them good bioindicators [7, 9].
Aside from using macroinvertebrates as the bioindicator, the use of physical and chemical limnology would also determine the quality of the water [10, 11]. The changes in physical and chemical characteristics would provide valuable information on the water quality of the river [12, 13]. These are the pH, conductivity, total dissolved solids, temperature, dissolved oxygen, salinity, transparency, chemical oxygen demand, nitrate and phosphate [14].
Using the Riparian, Channel and Environmental (RCE) Inventory would further evaluate the physical and biological condition of small streams within a particular landscape [15].
Gibong River is situated in Prosperidad, Agusan del Sur, Philippines. It is a first class municipality in the province. According to the 2010 census, it has a population of 76,628 people and has a land area of 505.2 km². Gibong River has tributaries all the way from Mabuhay, Maug, San Martin, Magsaysay, Los Arcos, Las Navas, and Azpeitia. On developmental aspect, midstream flow of Gibong River is being tapped for irrigation purposes that presently provide services to 3,558 hectares of rice fields enclosing areas of three adjoining municipalities. Destruction therefore of this river bank vegetative scenery from upstream to downstream means food shortage.
This study aimed to assess the physicochemical water quality and macroinvertebrate diversity of Gibong River, Prosperidad, Agusan del Sur, Philippines. In comparing the physical and biological conditions between water bodies, the numerical scores from the data gathered in assessing the riparian and channel inventory is used.

2. Materials and Methods
2.1 Period of the Study
The study was conducted on July 27-31, 2015.

2.2 Description of the Study Site
The upstream of Gibong River has a continuous line of vegetation, with a mixture of trees, vines, shrubs, and ferns. The uppermost portion of this station has clear water and riffles. Substrates consist of rocks and clay. An irrigation system is located at the uppermost part of the midstream of Gibong River and this station also is exposed to the national highway where there is very minimal vegetation. There are residents found nearby in this location and human activities such as bathing and washing are very evident. Substrate consists of rocks and gravel. The downstream section of Gibong River is populated by several households. Quarrying of the gravel is very evident in this station. A global positioning systems (GPS) was used to determine the exact location of sampling sites with corresponding coordinates and its elevation. For each study site, three subpoints, 100 m-apart was used to gather samples for the different study parameters (Figure 1). Some tributaries that contribute to the waterbody are coming from small and large scale gold mining areas in Agusan del Sur.

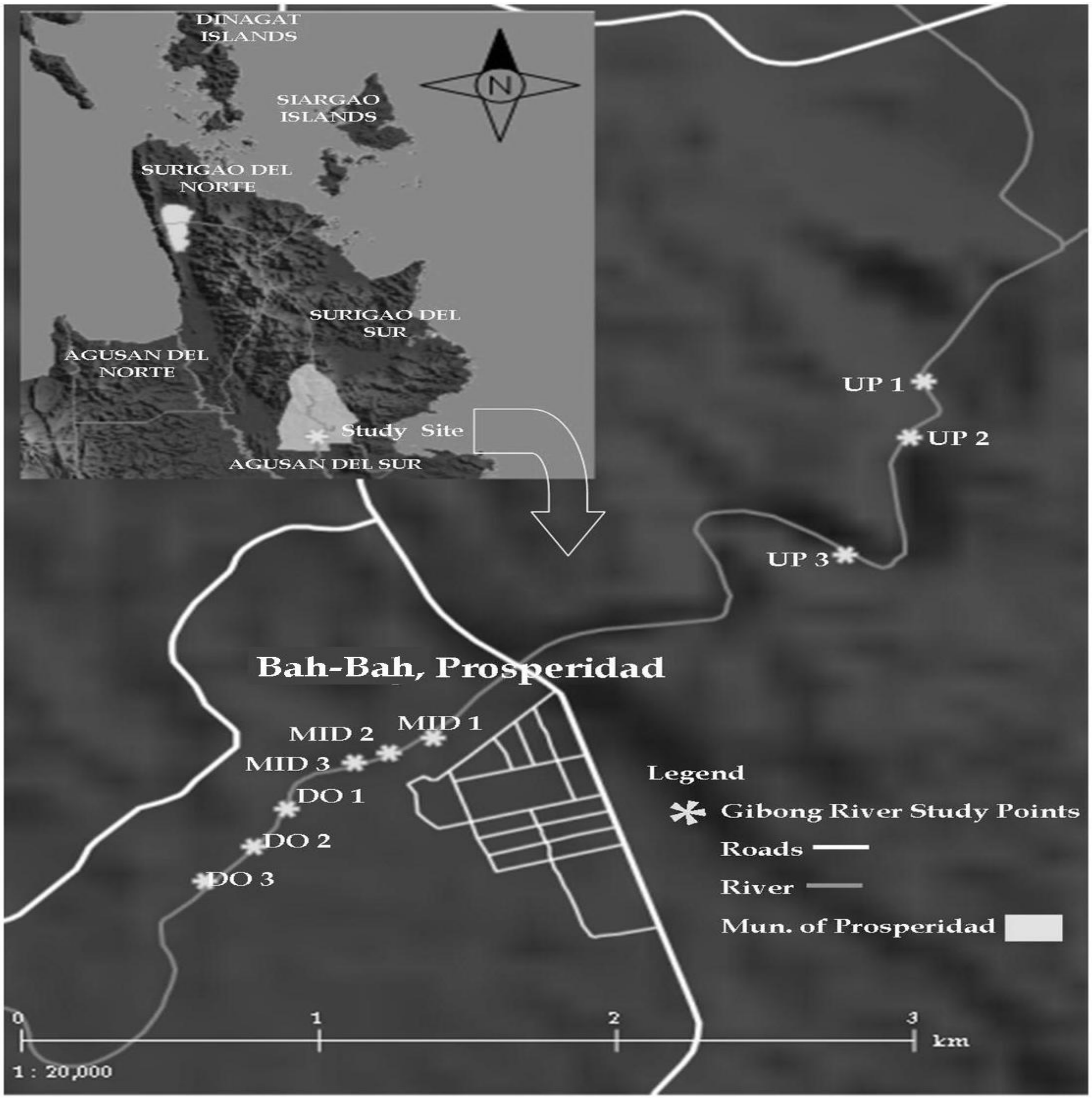

Fig 1: Stations within the premises of Gibong River, Prosperidad, Agusan del Sur, Philippines

2.3 Riparian Channel and Environmental (RCE) Inventory
A riparian channel evaluation was conducted to assess the physical and biological condition of small streams in the lowland landscape [15]. It consists of sixteen characteristics that define the structure of the riparian zone, stream channel morphology, and the biological condition of the study stations [15]. The generated numerical score was used to compare the physical and biological condition of different freshwater bodies studied. There were 16 characteristics arranged in hierarchical order from landscape to macrobenthos to be assessed. The evaluator walked along the 100-m length of the stream containing the three freshwater biological stations in evaluating the 16 characteristics of RCE parameters. Table 1 served as a guide to obtain the class rating and the recommended action.

Table 1: Scoring reference for RCE [15]

Class score	Score	Evaluation	Recommended Action
1	293-360	Excellent	Biomonitoring and protection of the existing status
2	224-292	Very Good	Selected alterations and monitoring for changes
3	154-223	Good	Minor alterations needed
4	86-153	Fair	Major alterations needed
5	16-85	Poor	Complete structural reorganization

2.4 Water quality assessment

There were triplicate readings at 30-m distances within each of the 100 reach for each station for determining some physico-chemical parameters (Table 2). Dissolved oxygen, pH, Temperature, Total Dissolved Solids, and Conductivity were measured on site using a Waterproof Cyberscan CD 650 multimeter kit (®Eutech Instruments).

Table 2: List of Physico-chemical parameters with their corresponding unit of measurement, method of analysis, sample volume needed, reference and instrument.

Parameters	Unit	Method of Analysis	Sample Volume	Reference/Instrument
1.Conductivity	µS	Direct method (electrode)	Determined on site	Portable Conductivity probe^{Cond600}
2.pH	Range 0-14	Direct method (electrode)	Determined on site	Portable pH Meter, probe^{pH600}
3.Temperature	°C	Direct method (electrode)	Determined on site	Portable Conductivity probe^{Cond600}
4.Total Dissolved Solids (TDS)	Ppm	Direct method (electrode)	Determined on site	Portable Conductivity probe^{Cond600}
5. Dissolved Oxygen (DO)	mg/L	Direct method (electrode)	Determined on site	Portable Meter, probe^{DO600}

2.5 Establishment and Sampling Procedures

The sampling followed the Reach-wide benthos (Multihabitat) procedure of SWAMP [16] with some modifications. Each elevation covered a 100-meter reach for the determination of the physico-chemical water quality and collection of macroinvertebrates. Each elevation gradient has triplicate. A 500 µm D-net measuring 0.3 m wide (-1.0 ft. frame width) was used and placed in the water as to the mouth of the net is perpendicular and faced the flow of the water. Twenty (20) jabs or kicks were taken over the length (100 meters) of every replicate. The jabs/kicks contained from the multiple habitats that are composited containing a single homogeneous sample. The collected samples from every jab were placed in the container or vials and preserved in a 95% ethanol or 10% formalin with its corresponding label and sample identification.

2.6 Sorting, Photo Documentation and Species Identification

In the laboratory, the collected samples were rinsed thoroughly with running water in a 500 µm-mesh sieve to remove fine sediments. Macroinvertebrates were then sorted, counted, placed in glass vials and were preserved using 95% ethanol. Vials were labelled with a code that stands for stream name, sampling location and taxonomic group.

The collected samples were identified up to the lowest practical level, generally genus and species with the aid of LASEZ (Leica Application Suite) ver. 1.7.0. Larger organisms were counted and documented by the use of the digital camera. Reliable internet sources and journals were used to identify the macroinvertebrate [6, 17]. Its classification as to their tolerance value depended on their response to definite changes in water conditions.

2.7 Water Quality Indices

Taxa Groupings

The macroinvertebrates were grouped into 3 Taxa-Taxa 1, Taxa 2 and Taxa 3 based on their sensitivity or tolerance to pollution or aquatic disturbance [18]. Taxa 1 were found in good water quality and are pollution-sensitive organisms. These include species belonging to orders Ephemeroptera, Plecoptera, Trichoptera and Coleoptera. Taxa 2 species can exist in a wide range of water quality conditions, or moderate water quality. These include species belonging to orders Hemiptera, Diptera, Odonata, Decapoda and Veneroida. Taxa 3 specimens are species that can exist in a varied range of water quality conditions and highly tolerant to poor water quality. This taxon will include Tubificida, Gastropoda, Hirudinidae, Cerithioidea and Isopoda.

2.8 Measuring Water Quality Using Water Quality Index (WQI)

Species were scored according to their classification using a matrix that has its corresponding points of a particular macroinvertebrates species regardless of its abundance. The sum that obtained for all scored species and divided to the total of species that were scored [19]. The resulting value was the WQI, described in Table 3.

Table 3: Water Quality Index (WQI) [19]

Score	Indication
7.6-10	Very clean water
5.1-7.5	Rather clean-clean water
2.6-5.0	Rather dirty-water average
1.0-2.5	Dirty water
0	Very dirty water (no life at all)

2.9 Measuring Water Quality Using Average Score per Taxon (ASPT)

The classifications of the organisms were up to species level. Species were scored using the Biological Monitoring Working Party (BMWP) based on the classification of the family it belongs [20, 21]. ASPT was calculated by adding the individual scores obtained of all indicator species that were present and divided by the number of species that are present [18]. The ASPT values correspond to the water quality (Table 4).

Table 4. Average Score per Taxon (ASPT)

Score	Indication
5 and above	Excellent
4-4.5	Good
3-3.5	Moderate
2-2.5	Poor
1-1.5	Very Poor

2.10 Analysis

Several diversity indices, namely Abundance, Evenness, Richness and Shannon-Weiner Index were determined using the Paleontological Statistics Software (PAST®). One-way ANOVA was used to compare the differences of physico-chemical data between elevations with $p<0.05$ set as a significant value.

3. Results and Discussion

3.1 The riparian channel evaluation (RCE)

For RCE Inventory, a 100-m length of the river of the three stations was selected. The scores for each character in each location were recorded and summed up. It can be seen in Table 5 the RCE scores for all stations. Based on the scoring reference for RCE [15] (Table 1), station 1 garnered a score of 265 and rated *"very good"* mainly because its vegetation is still intact. Stations 2 and 3 were rated *"fair"* with the scores of 89 and 114 respectively, basically because of its less dense vegetation. By taking seriously the recommended actions [15] (Table 1), the scores of the three sampling stations will be improved resulting to a well diverse aquatic community.

Table 5: RCE criteria and scores for the respective study stations [15].

Catchment \ Sampling Station	Upstream	Midstream	Downstream
1. Land zone pattern beyond immediately zone.	20	1	20
2. Width of riparian zone from stream edge to field.	20	5	5
3. Completeness of riparian zone.	20	1	5
4. Vegetation of riparian zone within 10 m of channel.	15	1	5
5. Retention devices	10	10	5
6. Channel structure	10	1	5
7. Channel sediments	10	5	5
8. Stream bank structure	25	5	15
9. Bank undercutting	20	5	1
10. Stony substrate, feel and appearance	25	15	15
11. Stream bottom	15	5	1
12. Riffles and pools and meanders	20	10	1
13. Aquatic vegetation	15	5	10
14. Fish	15	15	15
15. Detritus	10	5	1
16. Macrobenthos	15	5	5
TOTAL	265	89	114

3.2 Physico-chemical assessment

Table 6 and figure 2 and 3 showed the six selected physicochemical parameters of the three sampling stations. All the physicochemical parameters of the upstream were within its acceptable limits [22]. The high value of dissolved oxygen in the location indicated a good water quality and diverse macroinvertebrate community [22] due to its intact riparian vegetation. In midstream and downstream stations, the value for dissolved oxygen is 3.16 and 4.18 respectively. These values were found to be lesser than the acceptable limits [23] especially the midstream that has the lowest value. Hence, it indicated that the quality of the water is less desirable for aquatic life [9]. This observation could be due to first, less dense riparian vegetation. Second, the area was very exposed to the direct sunlight especially the midstream where the national highway is passing across it. Third, other establishments such as university and residence are located on near its premises. Moreover, there is a significant difference in conductivity, temperature and TDS in the three sampling stations. Dissolved oxygen for the upstream areas was significantly higher compared to the midstream and downstream stations. There is no significant difference in the pH in all sampling stations. Bray-Curtis similarity and Principal Component analyses revealed that the physico-chemical features of upstream station differ with that in midstream and downstream areas (Figure 3). The upstream area has intact riparian vegetation and no households were found in this area.

Table 6: Physico-chemical features of the three sampling stations within Gibong River.

Parameters \ Sampling Stations	Upstream	Midstream	Downstream
Conductivity (µS)	280.5±2.55016	338.133±2.82391	330.533±5.92068
pH (1-14)	7.92667±0.0233333	7.84667±0.0384419	7.74667±0.0868588
Temperature (ºC)	26.9±0.264575	31.6667±1.26798	31.3667±0.762306
TDS (ppm)	295.667±1.2252	351.7±3.15647	344.8±6.76782
DO (mg/L)	5.57333±0.270883	3.16±0.633798	4.18±0.20232

Standard values				
DO	pH	TDS	Salinity	Conductivity
> 5 mg/L	6.5-8.5	<1000 mg/L for	<0.5 mg/L for	<1,500 uS/cm

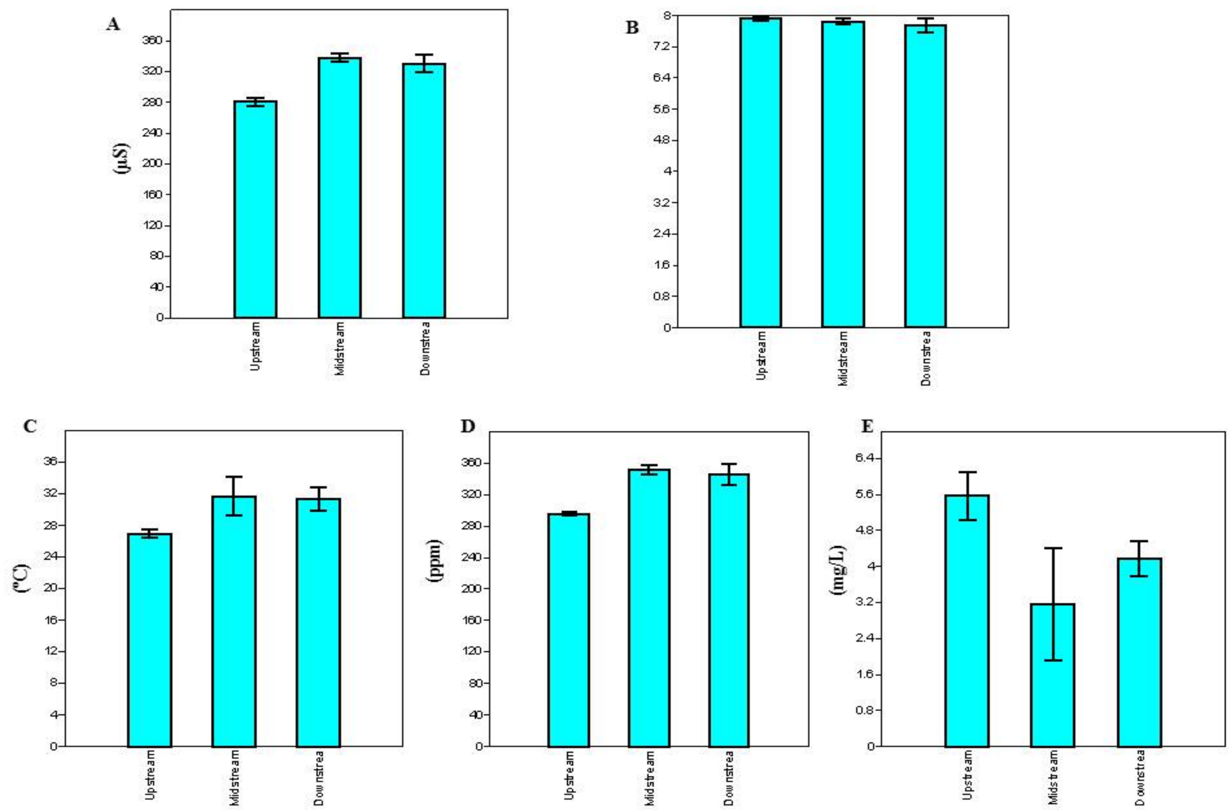

Fig 2: Physico-chemical features of the three study stations within Gibong River, Prosperidad, Agusan del Sur. A: Conductivity, B: pH, C: Temperature, D: TDS, E: DO

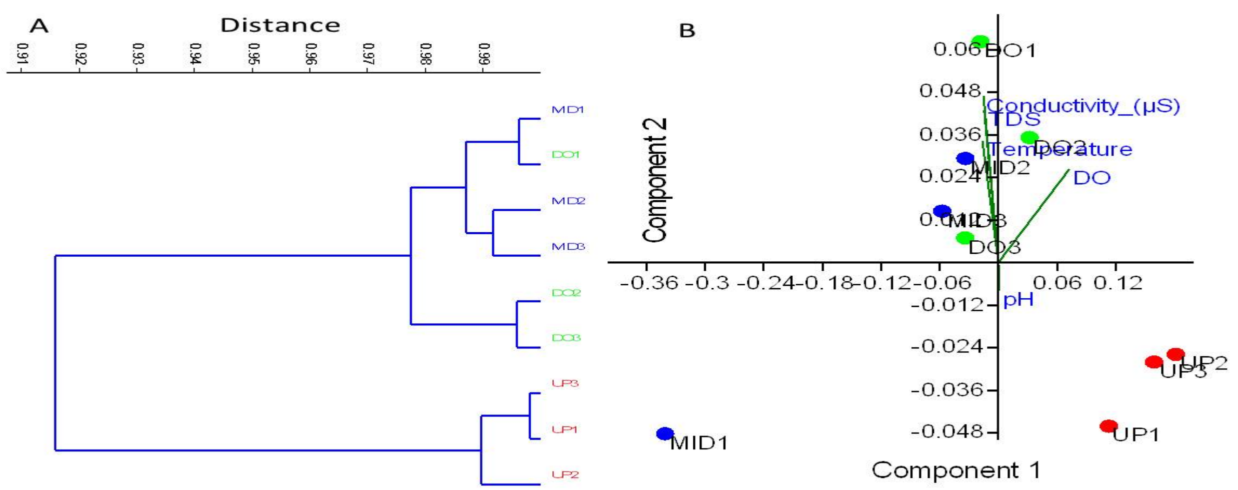

Fig 3: Multivariate relationships between study stations based on their physico-chemical features. A: Dendrogram of similarity of study stations based on physico-chemical features; B: Principal component analyses (PCA) showing distinct groupings/relationships physicochemical data for Upstream (red), Midstream (blue) and Downstream (green) stations.

3.3 Diversity of Macroinvertebrates

Table 7 presented the WQI and ASPT scores based on the presence of the bioindicator aquatic macroinvertebrate species. Based on the WQI scores, results showed that the water quality of the upstream of Gibong River was assessed as *"rather dirty water-average"* with a score of 3.83. Its midstream and downstream had a score of 1.61 and 1.94 respectively and rated as "*dirty water"*. For its ASPT, upstream, midstream and downstream have the scores of 3.5, 1.89 and 2.278 respectively. Upstream rated as *"moderate"*, midstream and downstream were both rated as *"poor"* water quality. This result could be due to lesser number of families belonging to Taxa 1 also known as pollution sensitive species (Table 8). Furthermore, human activities such as urbanization (putting up of national highway and building structures) and human wastes [12, 24, 25] contribute much to this rating in midstream and downstream stations.

There are 18 aquatic macroinvertebrate species from 16 families collected (Table 8) composed mostly of arthropods (87%) and molluscs (13%) (Figure 4). Upstream station of Gibong River had the most number of species, dominated by Family Ephemeroptera (Arthropoda). Its midstream station had

the most number of individuals which belongs to the Family Gerridae (Arthropoda) but has the least number of species.
Among the three sampling stations, the upstream area has the most diverse macroinvertebrate community (Table 9), Notably this station also exhibited lower water temperature and highest value in DO (Table 6). To fully characterize the quality of the water, there is a need to determine the levels of heavy metals both of the water and sediments to determine if heavy metal contamination also serve as a factor in the diversity and composition of pollution sensitive macroinvertebrates in the river.

Table 7: Aquatic macroinvertebrates from the three sampling stations within Gibong River their ASPT and WQI scores

Species	Sampling Sites, WQI and ASPT																	
	UP1	UP2	UP3	TOTAL	WQI	ASPT	MID1	MID2	MID3	TOTAL	WQI	ASPT	DO1	DO2	DO3	TOTAL	WQI	ASPT
Dytiscus marginalis	3	0	0	3	5	5	0	0	0	0	0	0	0	0	0	0	0	0
Palaemonid sp.	6	2	2	10	4	6	0	0	0	0	0	0	0	0	0	0	0	0
Macrobrachium rosenbergii	1	0	0	1	8	6	0	0	0	0	0	0	0	0	0	0	0	0
Pandalus borealis	0	0	0	0	4	0	4	1	0	5	4	6	0	1	1	2	4	6
Chironomus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	2
Rhithrogena germanica	28	0	0	28	10	10	0	0	0	0	0	0	0	0	0	0	0	0
Gerris marginatus	1	0	5	6	5	10	28	0	95	123	5	10	16	0	0	16	5	10
Rhagovelia obesa	2	0	0	2	5	10	0	0	0	0	0	0	0	0	0	0	0	0
Diplonychus rusticus	0	0	0	0	0	0	3	0	0	3	5	5	0	0	0	0	0	0
Ischnura sp.	0	0	0	0	0	0	23	5	0	28	6	5	22	0	11	33	6	5
Erythrodiplax berenice	0	0	0	0	6	0	3	0	0	3	6	5	0	0	0	0	0	0
Namamyia plutonis	2	0	0	2	10	7	0	0	0	0	0	0	0	0	0	0	0	0
Notopala sublineata	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	6	6
Pila ampullacea	3	4	4	11	3	3	3	2	0	5	3	3	2	2	4	8	3	3
Planorbula armigera	2	0	1	3	3	3	0	0	0	0	0	0	1	0	0	1	3	3
Bithynia tentaculata	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	3	3
Melanoides tuberculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	3
Corbicula fluminea	5	2	1	8	6	3	0	0	0	0	0	0	0	0	0	0	0	0
Total				**74**	**69**	**63**				**167**	**29**	**34**				**67**	35	41
					3.8333	3.5					1.6111	1.89					1.9444	2.278

7.6-10--*very clean water*; 5.1-7.5--*rather clean- clean water*; 2.6- 5.0--*rather dirty water- average*; 1.0- 2.5--*dirty water*; 0--*very dirty water (no life at all)*

Table 8: Inventory of aquatic macroinvertebrates and their corresponding Taxa groupings based on sensitivity/ tolerance to pollution

Phylum	Order	Family	Scientific Name	Common Name	Taxa
Arthropoda	Coleoptera	Dytiscidae	*Dytiscus marginalis*	Diving Beetle	1
	Decapoda	Palaemonidae	Palaemonid sp.	Small sized-Freshwater Shrimp	2
			Macrobrachium rosenbergii	Freshwater prawn	2
		Pandalidae	*Pandalus borealis*	Native shrimp	2
	Diptera	Chironomidae	*Chironomus* sp.	Midge fly larvae	3
	Ephemeroptera	Ephemeridae	*Rhithrogena germanica*	Mayfly Nymph	1
	Hemiptera	Gerridae	*Gerris marginatus*	Water Strider	2
			Rhagovelia obesa	Water Strider (small)	2
	Heteroptera	Belostomatidae	*Diplonychus rusticus*	Water bug	2
	Odonata	Coenagrionidae	*Ischnura* sp.	Damselfly nymph	2
		Libellulidae	*Erythrodiplax berenice*	Dragonfly nymph	2
	Trichoptera	Odontoceridae	*Namamyia plutonis*	Caddisfly larva	1
Mollusca	Architaenioglossa	Viviparidae	*Notopala sublineata*	River Snail	3
	Caenogastropoda	Ampullariidae	*Pila ampullacea*	Apple snail	3
	Hygrophila	Planorbidae	*Planorbula armigera*	Ramshorn snail	3
	Neotaenioglossa	Bithyniidae	*Bithynia tentaculata*	Mud Bithynia	3
		Thiaridae	*Melanoides tuberculata*	Malaysian trumpet snail	3
	Veneroida	Bivalvia	*Corbicula fluminea*	Golden clam	1

Taxa 1- Pollution sensitive organisms found in good water quality
Taxa 2- Can exist in wide range of water quality conditions; generally moderate water quality
Taxa 3- Can exist in wide range of water quality conditions; highly tolerant to poor water quality

Table 9: Diversity indices of aquatic macroinvertebrates in the three sampling stations within Gibong River

Sites Indices	Upstream	Midstream	Downstream
Taxa_S	10	8	8
Individuals	74	167	65
Dominnance_D	0.2067	0.573	0.3373
Shannon_H	1.879	0.8792	1.389
Simpson_1-D	0.7933	0.427	0.6627
Evenness_e^H/S	0.6547	0.4015	0.5012

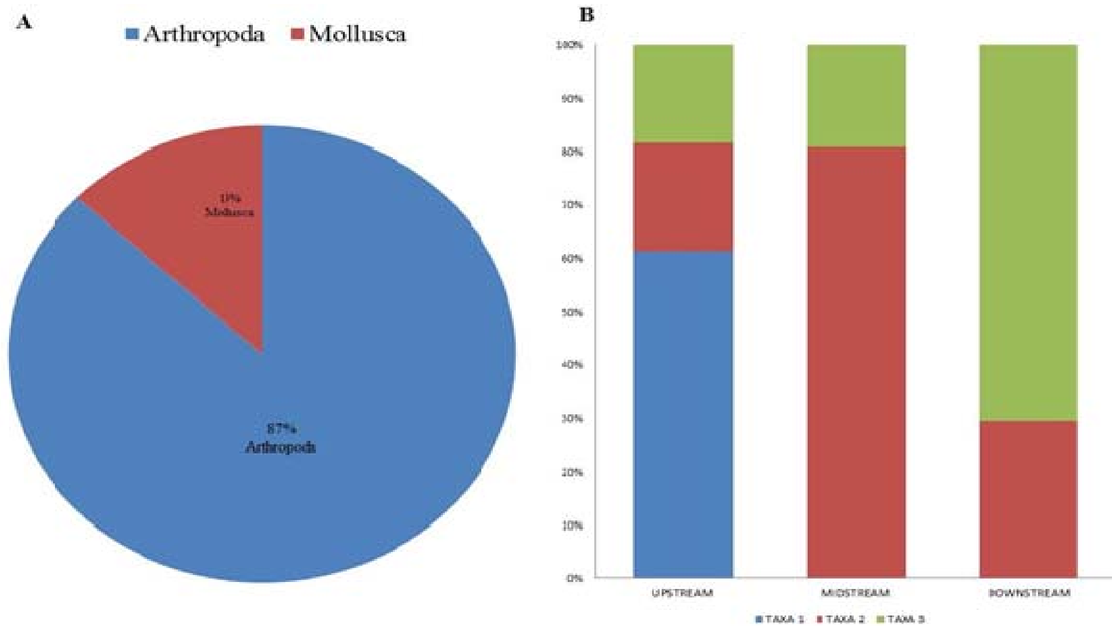

Fig 4: Percent (%) composition of major phyla of aquatic macroinvertebrates (A); and Taxa groupings of indicator macroinvertebrates in the three sampling stations (B) along Gibong River, Prosperidad, Agusan del Sur.

Figure 5 showed the two different clusters based on the macroinvertebrates found in three sampling stations. The first cluster compose of macroinvertebrates collected from the upstream areas (UP1), the second cluster comprise the rest of samples collected from the other stations. The distinct grouping was due to the presence of unique species found only in the upstream areas such as *Rhithrogena germanica, Namamyia plutonis, Macrobrachium rosenbergii, Rhagovelia obesa, Dytiscus marginalis* and *Corbicula fluminea.*

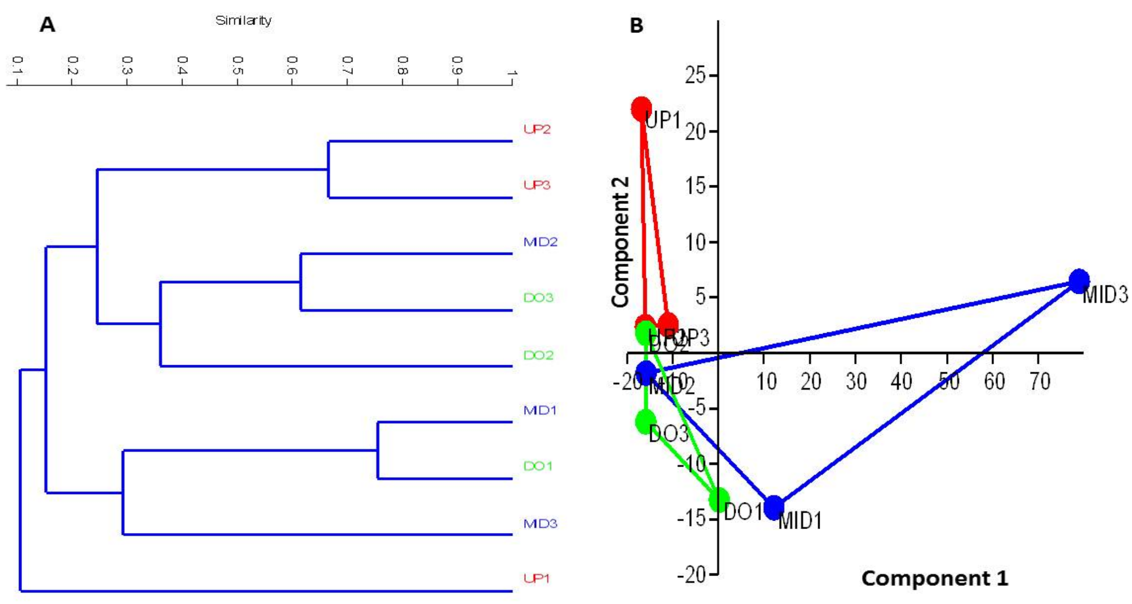

Fig 6: Multivariate relationships between sampling stations based on the population of the macroinvertebrates. A: Dendrogram of similarity of macroinvertebrate populations B: Principal component analyses (PCA) showing distinct groupings/relationships of macroinvertebrates in the three study stations in Gibong River, Prosperidad, Agusan del Sur, Philippines.

4. Conclusion

The study is the first to report the diversity of macroinvertebrates in Gibong River, Philippines. This study used these three parameters in assessing the water quality of Gibong River with three sampling stations namely: Gibong upstream, Gibong midstream and Gibong downstream. Results showed that the RCE scores for the three locations –upstream, midstream and downstream garnered *"fair"* to *"very good"* ratings (scores 89-265). All the physical and chemical properties of Gibong River were within desirable limits such as conductivity, temperature, pH, and TDS except for the DO of midstream and downstream stations which are lower than the acceptable limits. This indicates that midstream and downstream less desirable water quality and less diverse macroinvertebrate community. WQI scores revealed that the upstream is *"rather a dirty water-average"* with a score of

3.83. Midstream and downstream both rated as *"dirty water"* with scores of 1.61 and 1.94 respectively. ASPT scores showed that the upstream is *"moderate"* (3.5), midstream and downstream both are *"poor"* (scores 1.89 and 2.278 respectively).

There were 18 species from 16 families of aquatic macroinvertebrates collected within the three sampling sites. *Gerris marginatus* had the most number of individuals found. Of the three stations, Gibong upstream had the most number of species mainly because its intact vegetation. The midstream station had the least number of species found due to pollution from urbanization, domestic wastes and least riparian vegetation. The improvement of riparian vegetation in key locations of the river is highly recommended to enrich the diversity of macroinvertebrates. Analyses of heavy metals (i.e mercury, lead, cadmium, nickel and arsenic) will be necessary to characterize further the water as some tributaries to Gibong River are coming from small and large scale mining areas.

5. Acknowledgement
The authors are grateful to the Biology Department of Caraga State University for allowing the authors to use their equipment.

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