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C O N T E N T S

PRELIMINARY ASSESSMENT OF WATER QUALITY OF DONATA FALLS IN POLILLO, QUEZON, PHILIPPINES USING MACROBENTHOS

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Abstract: The macrobenthos distribution and productivity are directly influenced by physico-chemical parameters of freshwater systems which make them a good bioindicator. This study presented a preliminary assessment of Donata Falls to provide baseline information regarding its aquatic health status. No significant differences were observed among parameters measured, which include dissolved oxygen, conductivity, pH and temperature. Based on the mean values of total nitrogen (14.09 ppm) and phosphorus (0.11 ppm), falls can be classified as oligotrophic. Macrobenthos were collected using bucket method. The macrobenthos community represents 1 species under Class Gastropoda, 2 species under Order Coleoptera, 3 species under Order Odonata and 1 species under Order Oligochaeta, Ephemeroptera and Tricoptera. *Nerita* sp. under Class Gastropoda obtained the highest abundance (37.03%) followed by Family Coenagrionidae under Order Odonata with 24.07% abundance. Abundance of these organisms would suggest that the falls has a good water condition. Family biotic index (FBI), biological monitoring working party (BMWP) and average score per taxon (ASPT) were also calculated. The average FBI value was 1.50 suggesting that there is no apparent organic pollution in the area. Moreover, BMWP score (65.6) and ASPT score (6.56) indicate that the falls has moderate to clean water condition.

Keywords: *macrobenthos, Modified Family Biotic Index, Biological Monitoring Working Party, Average Per Taxon*

1. INTRODUCTION

Macrobenthos are a community of organisms that live at the sediment water interface. These organisms have a body size of 0.5 mm to 1.0 mm or higher. Macrobenthos are mostly composed of invertebrates—worms such as polychaetes and oligochaetes, mollusks like bivalves and gastropods, and crustaceans such as amphipods and decapods (Tagliapietra & Sigovini, 2010). Macrobenthos play an important role in aquatic food chains. They form an important link between autotrophs and heterotrophs since they act as primary consumers of phytoplankton; thus, transferring primary productivity to organisms at higher trophic level. Moreover, they also participate in the breaking down of organic matter (Raveenthiranath, 1990).

Aside from their essential role in the aquatic food chain, the presence of macrobenthos is also a good indicator of the aquatic health status of aquatic bodies. Macrobenthos species are sensitive to any changes in physical and chemical parameters of water. Macrobenthos structure, metabolism and reproduction respond quickly with respect to the presence of pollutant. Moreover, their close association with the sediment and limited mobility restrict their ability to avoid adverse conditions, making them a suitable tool in detecting different types and levels of stresses (Iliopoulou-Georgudakia *et al.*, 2003).

River systems are among the ecosystems more sensitive to pollution. Rivers have always been the focus for human settlement and recreation. The water is used for transportation, irrigation, recreation, and development of port and boating facilities. Aside from such usage, rivers are also used as a convenient dumping ground for sewage, rubbish, and industrial wastes (Bhuiyan *et al.*, 2013). These activities can induce disturbance and damage to the ecology of the waterway.

Donata Falls is located in Barangay Sabang, Polillo, Quezon, Philippines. Polillo (14° 50' north altitude, 122° 05' east longitude) is a group of about 24 small islands and islets located on the east coast of Luzon Island facing the Pacific Ocean, and bounds the east part of Lamon Bay at about 18 miles from the coast of Real and Infanta, Quezon Province, Philippines (Gonzales, 2007). The river-falls system is used as recreational site and fishing grounds for the residents adjacent to the area. Despite these ecosystem services, there is no available report regarding the trophic status of the falls. However, determining trophic status is essential as it will influence the services that may be provided to humans.

Since there is no study available on the water quality of the waterfalls in Polillo, Quezon, Philippines, this study was therefore aimed to investigate the current physico-chemical status of Donata Falls by biomonitoring species composition of macrobenthos in the area. The study will serve as baseline data regarding the water quality of Donata Falls, and is also intended to promote ecotourism in this part of the Philippines.

2. METHODOLOGY

2.1 Study site

The study was conducted in Donata Falls, Polillo Quezon, Philippines. Sampling was carried out at 5 stations - 2 stations in the upstream, 1 station in the midstream and 2 stations in the downstream, with 100 meters interval. Stations 1 (14°38’41.3”N: 121°54’52.9”E) and 2 (14°38’40.5”N: 121°54’51.8”E) represent the two stations in the upstream area. This area is characterized with large pool areas which have a rocky substrate and is almost covered with canopy. Station 3, the midstream area (14°38’39.9”N: 121°54’51.4”E) is the part where the actual falls is located. The area is characterized with shallow rocky channel with very turbulent water. Station 4 (14°38’38.7”N: 121°54’51.0”E) and Station 5 (14°38’37.8”N: 121°54’49.9”E) are located in the downstream area. These two stations have a shallow and narrow channel with fast flowing water. Also the channel is less covered by the canopies. Figure 1 shows the map of the sampling area.

For the collection of samples, each station was divided into three sampling points and triplicates of sediment sample were collected for every point. Triplicate samples collected per station were pooled to come up with the macrobenthos species present per station.

2.2 Physico-chemical parameters

2.2.1 Conductivity, dissolved oxygen, temperature and pH

Measurements of conductivity, dissolved oxygen (DO) concentration, temperature and pH were done at each sampling point using PASCO Water Quality Meter. Conductivity, dissolved oxygen, pH and temperature probe were dipped at about 6 inches below water surface until stable reading was observed. This was done three times for each sampling point and the average measurement was recorded. Differences among the values measured was evaluated using One-way Analysis of Variance (ANOVA).

2.2.2 Nutrient contents: total nitrogen and total phosphorus

The nutrient contents of the water samples were determined through tests conducted at the Bureau of Soil and Water Management. Two hundred fifty (250) mL of water was collected from each station. Water samples were filtered using a 30 µm mesh net to remove debris and other impurities, and then kept in an ice box prior to testing. Brucine method and ascorbic acid molybdate method were used to test the nitrate and phosphate concentration, respectively.

2.2.3 River flow rate

The speed of water flow of the river was determined using the procedure set by the United States Environment Protection Agency (US-EPA) (2012). A ten (10)-foot stretch was measured and a marker was placed each at the beginning point and at the end point of the river reach. A ping-pong ball was dropped in the water surface at least three feet upstream of the beginning point. The timer began once the ball reached the beginning point and ended upon reaching the final point. This was done three times and the average speed was recorded.

The width of the river was measured for each stretch at the beginning point, at the end point, and at mid-distance, and the average width calculated. The depth of the river in the beginning, middle, and end point was also measured. Measurements of depth were done at two opposite points on the river bank, and one point in the middle, giving nine values of water depth. Water depth value was reported as mean.

The river flow rate was calculated using the formula of Murdoch and Cheo (1996):

$$\text{Flow Rate} = \frac{ALC}{T}$$

where: A = average cross-sectional area of the river (mean width x mean depth)
L = length of river stretch examined
C = coefficient factor for substrate type (0.9 for smooth substrate, 0.8 for rocky substrate)
T = time it took the ball to travel from beginning point to end point

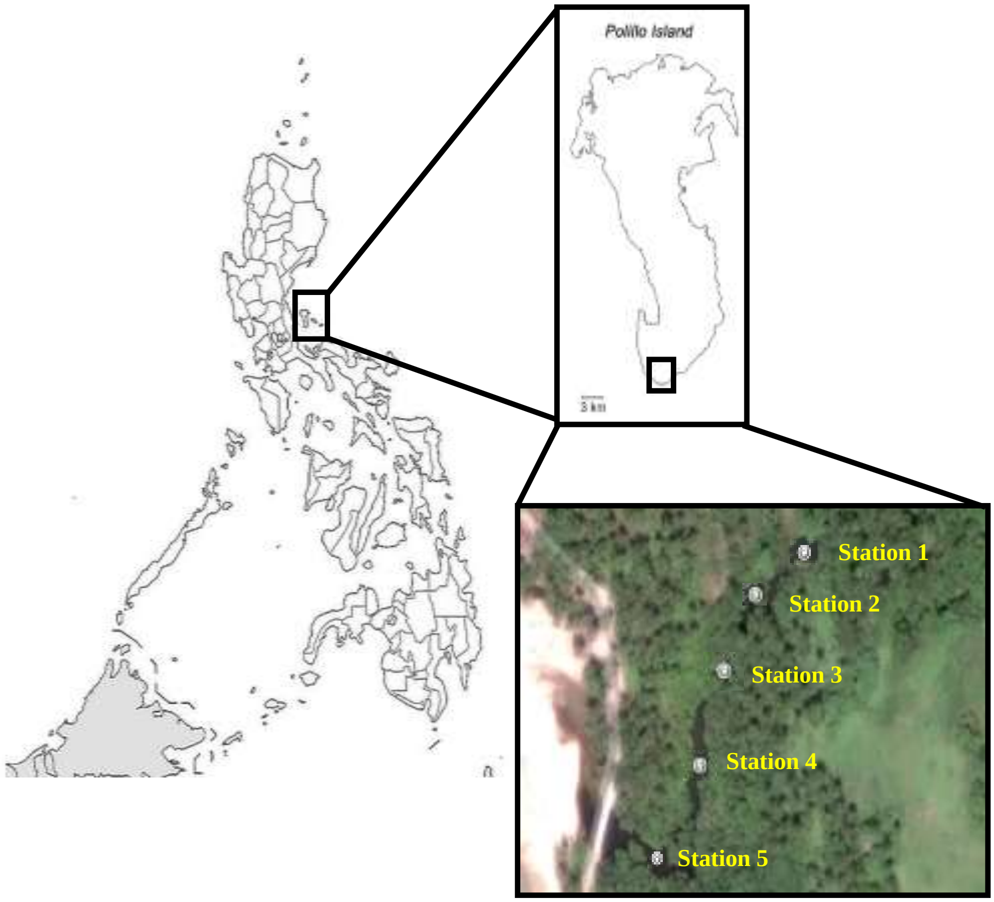

Figure 1. Sampling stations within the grounds of Donata Falls, Polillo, Quezon Philippines. (image from maps.google.com.ph)

2.3 Collection of samples

2.3.1 Macrobenthos collection

Bucket method was used in collecting macrobenthic organisms. Soil sediments were collected using a shovel, and transferred in a calibrated five (5) gallon bucket until the sediment reached the five (5) gallon mark. This was done five times to come up with a total of 25 gallons of sediment per point. All sediment samples were placed in zip lock bags and were preserved with 120 mL buffered formalin per 1 gallon of sediment.

Sediments collected were filtered in a 1mm pore sieve to remove fine particles. Macrobenthic organisms were manually picked using forceps from the remaining sediment samples. The separated macrobenthos were stored in a small airtight plastic container and were preserved using buffered formalin. Organisms collected were identified to lowest possible taxa using the identification guide by Epler (2001) and Bouchard (2004).

Abundance of macrobenthos was calculated using the formula:

$$\text{Abundance} = \frac{\text{number of individuals of species A}}{\text{volume of sediment}}$$

The relative frequency on each macrobenthic species was also determined. Frequency measures the number of times a particular species appeared in the sampling station. This was calculated using the fomula:

$$\text{Relative Frequency} = \frac{\text{Frequency of species A}}{\text{Total Frequency Value of All Species}}$$

2.3.2 Family Biotic Index (FBI) and Average Score Per Taxon (ASPT)

To assess the water quality of the falls, family biotic index (FBI) (Planfkin *et al.,* 1989) and average score per taxon (ASPT) (Friedrich *et al.,* 1996) were used. FBI provides a single tolerance value which is the average tolerance values of all species within the benthic arthropod community. FBI was modified to the family-level with tolerance values ranging from 0 (very intolerant) to 10 (highly tolerant) based on their tolerance to organic pollution.

$$FBI = \sum \frac{x_i t_i}{n}$$

where:

x_i= number of individuals in the taxon i^{th}
t_i = tolerance value of the i^{th} taxon
n = total number of organisms in the sample

Calculated family biotic index value range of 0.00 to 3.50 indicates excellent water quality, 3.51 to 4.50 signifies very good water quality, and 4.51 to 6.50 shows good water quality. If the calculated index value falls within 5.51 to 6.50, it indicates fair water quality. On the other hand, an index value from 6.51 to 7.50 signifies fairly poor water quality, 7.51 to 8.50 shows poor water quality, and the index range from 8.51 to 10.00 indicates very poor water condition.

ASPT represents the average tolerance score of all taxa within the community. To calculate the ASPT, biological monitoring working party (BMWP) was first determined. BMWP provides single values, at the family level, representing the tolerance to pollution. The greater the tolerance towards pollution, the lower the BMWP score (Mackie, 2001; Friedrich *et al.,* 1996). BWMP was calculated by adding the individual scores of all families and Order Oligochaeta represent within the community. ASPT was then calculated using the formula:

$$ASPT = \frac{BMWP\ Index}{N}$$

where:

N = number of families present in the sample

The calculated score has its corresponding indication as provided by the Taxa Tolerance Value guide of Bode *et al.* (2002) such that an ASPT score of 6 and above indicates excellent water health; ASPT score of 5.00-5.99 indicates a doubtful quality of water; a score of 4.00-4.99 indicates moderate pollution present in the site, and a score lower than 3.99 shows that the water is suffering from severe pollution.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical parameters of the falls

The different environmental parameters measured in the five stations were summarized in Table 3. The values of dissolved oxygen (DO), pH, conductivity, temperature, total nitrogen and total phosphorus showed no significant variation across the 5 sampling stations ($p > 0.05$), except for flow rate ($p < 0.05$). For flow rate, slowest flow rates were measured in the upstream, in stations 1 and 2 with flow rates of 5.87 ft^3/s and 4.01 ft^3/s, respectively. The fastest flow rate was noted (23.47 ft^3/s) midstream, where the actual falls is located. Fast flow rate was also observed in stations 4 and 5 with 17.6 ft^3/s and 11.73 ft^3/s, respectively. Starting from the midstream going down to the downstream, faster flow rate was documented; this could be attributed to the geomorphology of the river-falls system. Since the channel of the river is narrow and shallow, faster flow rate was observed (Greene, 1999). For upstream area, it has large pool areas which are less influenced by flow, thus low flow rate was documented (Klemes, 2000).

According to the Water Quality Guidelines and General Effluents Standards (2016) of the Department of Environment and Natural Resources, the obtained mean values of temperature (22.50˚C), dissolved oxygen (10.51mg/L), pH (7.62), conductivity (13.07 µS/cm), total nitrogen (14.09 ppm) and total phosphorus (0.11 ppm) for Donata Falls were within the required level for water quality parameters under Class A. Water body under this class is intended as source of water supply requiring conventional treatment. Water quality parameters under Class A should have the following parameter values: temperature ranges from 20˚C to 30˚C, dissolved oxygen should be a minimum of 5 mg/L, pH value range of 6.5 to 8.5, and the maximum phosphorus concentration should be 0.5 ppm.

3.2 Macrobenthos species composition

The macrobenthic organisms collected during the sampling period were identified and classified to the lowest possible taxa. Table 4 shows the summary of species composition of macrobenthos in Donata falls during November 2013, as well as their abundance. A total of ten (10) taxa were identified. This is distributed to 5 Orders namely: Coleoptera, Ephemeroptera, Odonata, Oligochaeta and Tricoptera, and one (1) Class, Gastropoda. Oligochaetes collected were identified up to order level only, while species under Order Ephemeroptera, Odonata and Tricoptera were identified up to family level, which is composed of one (1) family of Ephemeroptera (Family Baetidae), three (3) families of Odonata (Family Coenagrionidae, Cordulegastridae and Gomphidae) and one (1) family of Tricoptera (Family Philopotamidae). For Order Coleoptera, two (2) families were identified, Family Dysticidae and Gyrinidae. Coleopterans were identified up to genus level, *Neophorus* sp. and *Gyretes* sp. For Class Gastropoda, two (2) species were documented and classified up to genus level (*Melanoides* sp. and *Nerita* sp.).

Among the five stations, station 1 and 2 (upstream) had the highest number of taxa 7 and 5, respectively, while stations 3 (midstream), 4 and 5 (downstream) obtained the lowest number of taxa (n=3). The perceptible differences might be ascribed to the variation of flow rate which is the key abiotic determinant of organisms in lotic ecosystem (Allan, 1995). Flow rate in the upstream is relatively slower (station 1 - 5.87 ft^3/s; station 2 - 4.01 ft^3/s) as compared to the midstream (23.47 ft^3/s) and downstream (station 4 - 17.60 ft^3/s; station 5 - 11.734 ft^3/s). Although macrobenthos have adaptation for flowing water, very fast flow would tend to wash away benthic organisms, especially in the midstream where the falls is located. Stations 4 and 5 have a shallow and narrow channel which made the flow rate faster (Greene, 1999). Furthermore, stations 1 and 2 were characterized to have numerous and large pool areas. These pool areas would serve as suitable habitat for macrobenthos since these areas are less influenced by water flow. In addition, the absence of macrophytes, benthic algae (periphyton) and detritus could also limit the abundance and diversity of species in the midstream and downstream. These are important for macrobenthos since they serve as a major food source for this community (Khan *et al.*, 2014; Tanida, 2014).

Table 3. Environmental parameters in the different stations at Donata Falls.

Station	**Dissolved Oxygen (mg/L)**	**pH**	**Conductivity (µS/cm)**	**Temperature (^{O}C)**	**Flow Rate (ft^3/s)**	**Total Nitrogen (ppm)**	**Total Phosphorus (ppm)**
1	10.30 ± 0.12^a	7.46 ± 0.21^a	13.33 ± 0.33^a	22.53 ± 0.03^a	5.87^a	15.09	0.08
2	$10.57 \pm 0.0.9^a$	7.52 ± 0.09^a	13.00 ± 0.01^a	22.47 ± 0.01^a	4.01^a	9.68	0.04
3	10.37 ± 0.09^a	7.52 ± 0.09^a	13.00 ± 0.01^a	22.47 ± 0.02^a	23.47^b	15.87	0.22
4	10.67 ± 0.09^a	7.80 ± 0.04^a	13.00 ± 0.01^a	22.51 ± 0.01^a	17.60^b	15.09	0.07
5	10.67 ± 0.09^a	7.80 ± 0.01^a	13.00 ± 0.01^a	22.55 ± 0.01^a	11.73^c	14.71	0.15
Mean	10.51 ± 0.05	7.62 ± 0.06	13.07 ± 0.33	22.50 ± 0.01	12.54	14.09	0.11

**values for dissolved oxygen, pH, conductivity and temperature are reported as mean ± standard error ($s/\sqrt{n}$)*
*** values with the same superscript are not significant at 95% confidence level*

Table 4. Abundance and relative frequency of macrobenthos in Donata Falls.

TAXA	**Abundance/m³**						
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Mean Abundance**	**RF* (%)**
Class Gastropoda							
1. *Melanoides* sp.	35	35	175	0	0	49	60
2. *Nerita* sp.	35	455	35	0	35	112	80
Order Coleoptera							
3. Family Dysticidae *Neoporus* sp.	105	0	0	0	0	21	20
4. Family Gyrinidae *Gyretes* sp.	0	105	0	0	0	21	20
Order Ephemeroptera							
5. Family Baetidae	35	0	0	35	0	14	40
Order Odonata							
6. Family Coenagrionidae	280	70	0	105	0	91	60
7. Family Cordulegastridae	0	0	0	35	35	14	40
8. Family Gomphidae	0	35	35	0	0	14	40
Order Oligochaeta							
9. Oligochaete	35	0	0	0	0	7	20
Order Tricoptera							
10. Family Philipotamidae	35	0	0	0	0	7	20

**RF = Relative Frequency*

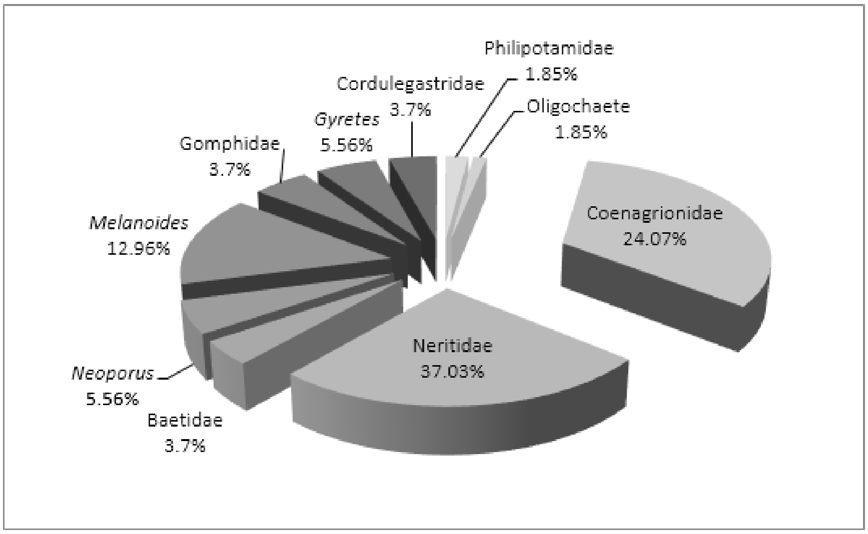

Figure 2. Relative abundance of macrobenthos collected from Donata Falls.

In terms of mean abundance (Table 4) and relative abundance (Figure 2), it was observed that *Nerita* sp. was the most abundant species in the macrobenthic community followed by species under Family Coenagrionidae and *Melanoides* sp. Abundance of *Nerita* sp. in the study site could be attributed to their tolerance to a wide range of environmental conditions, ranging from undisturbed to disturbed ecosystem (Andrews, 1995). Moreover, female organisms can produce large numbers of eggs per mating (Hughes, 1989). Coenagrionidae was the second most abundant. Abundance of Coenagrionidae larvae is possibly due to the reproductive strategies and adaptation of Coenagrionidae in lotic ecosystem. Coenagrionidae, like other Odonates are hemimetabolus, and only go through three stages in their life cycle: the egg, larvae and adult. Absence of the lengthy stage, the pupae stage, fasten the life cycle of this macrobenthos. Additionally, female Coenagrionidae lay their eggs on plant tissues above or below water surface, thereby ensuring the survival and high hatchability of eggs, which in turn adds to their abundance in tropical waters (Watson and Farrel, 1991). Moreover, the prevailing water condition of the falls might also influence the abundance of this organism. According to Catling (2005), Coenagrionidae is sensitive to pollution, thus implying the falls could have good water quality. On the other hand, *Melanoides* is considered as invasive species with features of an r-strategist; these characteristics could explain the abundance of these species. Moreover, the said characters have allowed this thiarid to rapidly reach a high population density in its new habitat. It is also an iteroparous organism that protects its young. Thiarids are also capable of parthenogenesis, displays phenotypic and genetic variability, and possesses ecological plasticity (Quintana *et al.,* 2001-2002; Letelier *et al.,* 2007; Pointier *et al.,* 2011; Peso *et al.,* 2011).

3.3 Family Biotic Index (FBI) and Average Score Per Taxon (ASPT)

Family Biotic Index (Planfkin *et al.,* 1989) is a measure of the macroinvertebrate assemblage tolerance towards organic enrichment. It measures the health of a stream on a scale of 1-10 that is based on the macroinvertebrate communities present. The lower the index score is, the healthier the stream water. Table 5 shows the summary of biotic index calculated per station. The lowest calculated FBI value was observed in station 3 with 0.33 value, and the highest index was calculated in stations 4 and 5 with values 2.11 and 2.16, respectively. Despite increased FBI values in the downstream, the values of FBI among all the stations are still within the range of FBI values for good water quality. Furthermore, the mean FBI value (1.50) suggests that the falls is in good condition. FBI values ranging from 0.00 to 3.50 indicate that a freshwater system has an excellent water quality, or that there is no apparent organic pollution in the area.

As verification for water quality assessment using FBI, biological monitoring working party (BMWP) and average score per taxon (ASPT) were also ascertained. A river with BMWP score greater than 100 is categorized as having very good water quality. On the other hand, ASPT score greater than 6 indicates clean water. The calculated BMWP and ASPT were 65.6 and 6.56, respectively. BMWP score fall within the range of moderate clean water, whereas ASPT score suggest that the falls have clean water. Findings from ASPT would back up the result for the calculated FBI. It is now deduced that Donata Falls would have a moderate to clean water. Good water quality of the falls could be attributed to the absence of rampant anthropogenic activity in the area.

According to Gambihr *et al.* (2012), human activities can influence the distribution, quantity and chemical quality of water sources. Human activities are the main contributor to the pollution loading in aquatic systems. Industrial, commercial and domestic effluents that are directly released in aquatic bodies are the major pollutants in freshwater systems. Donata Falls is not directly accessible to humans and the river-falls stretch is not inhabited by humans, thus preserving the good water quality of the falls.

The results of the study are similar to the findings of the study by Flores and Zafaralla (2012) wherein the Mananga River in Cebu, Philippines was also found to be dominated by gastropod *Nerita* and *Melanoides.* Likewise, similar are the results of the study by Dacayana *et al.* (2013), where they assessed the bethic macroinvertebrate assemblage in Bulod River in Lanao del Norte, Philippines to evaluate its water quality. Bulod river was dominated by insect larvae Coenagrionidae and mollusks such as *Nerita*, *Melanoides*, and clams and mussels. The water quality of the river turned out be good based on the abundance of these indicator species and the calculated FBI values of 3.94 to 3.96.

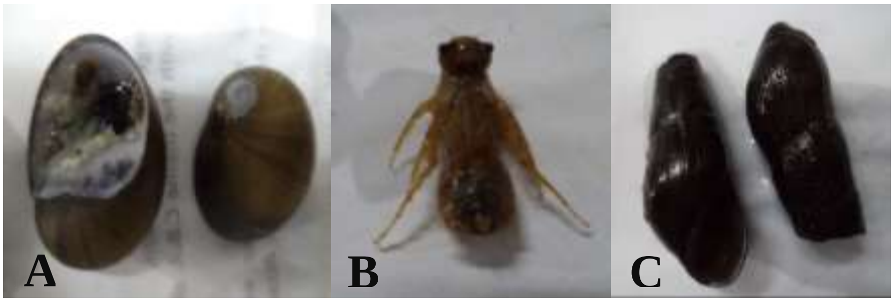

Figure 3. The top three most abundant macrobentos taxa in Donata Falls. A) *Nerita* sp.; B) Coenagrionidae larvae; C) *Melanoides* sp.

Table 5. Summary of Family Biotic Index (FBI) values computed for 5 stations.

	Station 1	Station 2	Station 3	Station 4	Station 5	Mean
Family Biotic Index Value	1.12	1.77	0.33	2.11	2.16	1.50

4. CONCLUSIONS

Based on the results obtained, the following were deduced: the macrobenthos of Donata is composed of 10 taxa with *Nerita* sp. and Coenagrionidae larvae being the most abundant, and the falls is oligotrophic having a moderate to clean water based on the indicator species present, physicochemical parameters, and biological indices computed.

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