Benthic Macroinvertebrates as Indicators of Pollution in Mapalyao Stream of Nueva Vizcaya Using the Hilsenhoff Family-Level Biotic Index

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ABSTRACT

This is a fourth of a research series on Nueva Vizcaya's freshwater quality employing benthic macroinvertebrates as bioindicators. The study determined the water quality of the Mapalyao Stream using macroinvertebrates as bioindicators and Hilsenhoff Family-Level Biotic Index as measurement of the indicators.

Two reaches (upstream, downstream) representing 2000 m of the stream were sampled. Sampling yielded 200 individuals representing 14 families and three orders/suborders. Collected taxa with highest sensitivity to pollution (lowest tolerance values) were Leuctridae (0), Rhyacophilidae (0), and Perlidae (1). Families with the highest tolerance values were Chironomidae (8), Caenidae (7), and Tabanidae (6). Chironomidae and Tabanidae were found at Reach 1 (upstream), particularly in stagnant, leech-infested pools. Collectively, Mapalyao Stream has a very good water condition, attributable to geomorphological characteristics of the stream.

INTRODUCTION

Nueva Vizcaya is considered a "watershed haven" because of its stream resources. These watersheds are from surrounding mountain ranges of Sierra Madre, Cordillera and Caraballo. The watersheds of the province are important to its people and other provinces because many of these converge to feed the Cagayan River system and the Pantabangan basin, among others. Locally, many communities are situated near or adjacent to these freshwater bodies as they see it as strategically ideal for abode and livelihood (Guinumtad, 2007).

In the town of Quezon, the Mapalyao Stream, located in barangay of Quezon, is the main source of irrigation and potable water. The barangay also benefits from the stream through its ecotourism operations. Further, it is home to the many people of the barangay and as such, many anthropogenic influences to the natural ecosystem are present, like picnic sites, livestock and vegetable farmlands, water impoundments and diversions and others. Farm lots adjacent to the stream are present as well. Because of these, the stream is susceptible to different types of pollution. Very few scientific studies, let alone monitoring activities are being conducted in the watershed to establish information whether pollution is a significant factor of degradation. It is feared that non-abatement of resultant pollution, including organic and inorganic, point- and non-point source, would render unfavorable conditions to many aquatic life therein. Pollution would then disrupt many ecosystem services, including those directly beneficial (*i.e.*, potable water) to people.

In application of ecological principles to policy making, there is a great need to obtain information as to the degree and extent of problem, so that actions can be made. This relates to assessment/monitoring of the stream.

In modernized and wealthy governments, physico-chemical and bacterial testing are used to provide pertinent stream pollution information. However, despite the supposed high level of technology, such kind of tests also has limits, as already described by Zimmerman (1993) and Manuel (2010; 2012). Expensive chemical assessment may miss a stream pollutant simply because the equipment used does not cover test for such substance. Also, since chemical testing is often descriptive of a particular period, results may only suggest that a stream is clean for a day or week, but it may not vouch for the rest of the year. For this, long-term monitoring can result to more frequent visit to the area of study, leading to more funding, manpower and effort.

Given the required manpower, finances, time and equipment, physico-chemical stream testing may not be feasible in far-flung areas in the Philippines. The pressing reality is that those same rural areas are where freshwater resources originate. Because of financial and logistical limitations, negligence would occur if valid scientific information is absent.

In the light of this scenario the researchers introduced the use of macroinvertebrates as biological indicators – organisms found in the study site known for their notable physiological and ecological characteristics. One water quality parameter that is highly related to survival of macroinvertebrates is dissolved oxygen (DO). DO is used by the organisms (compensating Biological Oxygen Demand, BOD) for metabolism and processing of organic material in the stream. When organic pollution occurs, DO is diverted to the chemical decomposition of allochtonous organic material. In essence, the water fails to supply macroinvertebrates' BOD. Macroinvertebrates fall within a wide gamut of pollution sensitivity. Collectively, their presence or absence thereof, reflect the general condition of habitats and ecosystems (Carter *et al.*, 2007). By looking into bioindicators, experts can ascertain whether organic pollution is indeed occurring or not. The strong scientific association between patterns in macroinvertebrate assemblages and current health of ecosystems can overcome limitations of non-biological water assessment methods.

The most commonly-used macroinvertebrates, or those species devoid of internal skeletons that can be identified with the unaided eye (often considered larger than 0.5mm) include arthropods, (crustaceans or arachnids), molluscs, as well as worms. Some of these organisms are called benthic macroinvertebrates because they thrive among the benthos. These include, among others, members of mayflies (Ephemeroptera), caddisflies (Trichoptera), dragonflies (Odonata), hellgrammites (Megaloptera) and beetles (Coleoptera).

The use of macroinvertebrates as bioindicators is being done in many parts of the world, but in the Philippines, only a handful of literatures exist in this topic. In fact, the Philippine government has no prescribed protocol for macroinvertebrate sampling.

To utilize macroinvertebrates as bioindicators, their sensitivity to pollution is usually quantified, that is, organisms are given their respective number. One of the simplest yet most comprehensive technique found by the researchers is the Family-Level Biotic Index, developed by American William Hilsenhoff (1988b). This technique, hereinafter referred to as HFBI, designates numerical values to describe the ability of macroinvertebrate taxonomic family to withstand pollution. The numbers, called "tolerance values", range from zero (0), for organisms being very intolerant, to ten (10), for organisms very tolerant of pollution or of presence of wastes.

As regard Hilsenhoff's designation of "tolerance values" to macroinvertebrates, a zero (0) value indicates that the water is of excellent quality. As value nears ten, water quality degrades in relative increments. The taxonomic family is at the core of tolerance values, but where a family or other taxon, such as order, is diverse that various lower taxa/ranks differ in tolerance, values are given accordingly.

Despite the fact that HFBI is a foreign technique, the taxonomic resolution (*i.e.*, order to family level) to which HFBI is founded makes it very ideal for the Philippine setting, because identifying organisms to their taxonomic families is quick and easy and does not need for very high level of expertise. Users of the HFBI may not worry that literatures on macroinvertebrate species in the country is sparse. Another advantage is that the knowledge and technique can be transferred to local people, so that they may be able to monitor the streams by themselves. Lastly, the technique would only require inexpensive, improvised equipment. Further, sampling for the HFBI is that the identification can be done quickly on site, as aided by taxonomic keys. This greatly cuts time and effort and eliminates laboratory preparations. The technique can be utilized by anyone, even without deep entomological background. In translation, this applied research method can be a viable tool for policy-makers in deriving economical, immediate and scientifically-sound information for their assessment and management strategies of important stream ecosystems.

As Mapalyao Stream is known to be the main artery of community, the researchers suggest that there may be changes in the water quality occurring there because of the proximity of human activity thereat. Thus, the researchers studied the ecological health (pollution levels) of Mapalyao Stream using macroinvertebrates as bioindicators, and the Hilsenhoff Family-Level Biotic Index as measurement of the indicators.

The general objective of the study was to determine the water quality of the Mapalyao Stream using macroinvertebrates as bioindicators and Hilsenhoff Family-Level Biotic Index as measurement of the indicators. The specific objectives were: 1) sample and identify macroinvertebrate families thriving in two reaches of Mapalyao Stream: upper part of the stream (away from human settlements) and lower part of the stream (adjacent to human settlements); 2) compute for the HFBI (upstream, downstream, whole) using the tolerance values obtained by the index to the macroinvertebrate families; and 3) observe biophysical present in the watershed area that can be attributed to the constitution or assemblage of macroinvertebrates and water quality.

MATERIALS AND METHODS

The stream is located at Barangay Mapalyao in Quezon, Nueva Viscaya. Sampling protocol in this study was developed by Manuel (2010) and Manuel *et al.,* (2012), which was patterned after the method devised by Hilsenhoff (1988b) and Zimmerman (1993). Two sections (upstream and downstream), each representing 1000-m reach were sampled. Upstream reach represented less-accessible areas thus more pristine while downstream section represented areas more-accessible to people, hence more organic pollution occur. This division is based on the notion that more anthropogenic disturbances and non-point source pollution is taking place in areas where people have better access to the stream and vice-versa (Manuel *et al.*, 2012). Starting point between sections is 500 meters.

In each stream section, six (6) stations, 150m apart, were established. Distance between sampling stations were measured at the middle of the section by odometer or by pacing method. Basic stream characteristics such as stream flow, average depth, and width were determined to serve as support observation in discussing the assemblage of macroinvertebrates in the area. There were other notable species and populations

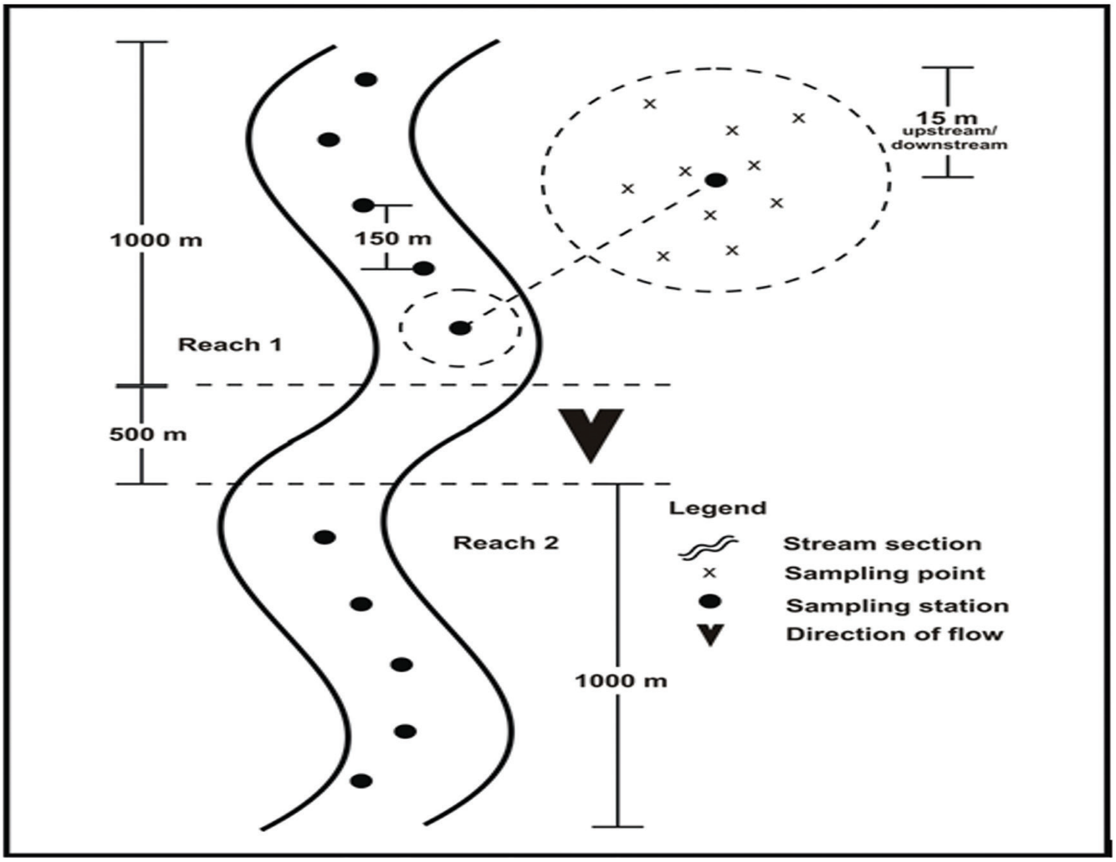

Figure 1. Schematic diagram of the sampling protocol performed at Mapalyao Stream (from Manuel *et al.*, 2012)

collected but were not included as well as the computation of their FHBI. However, for purposes of enriching discussion they were presented as well.

In each station, macroinvertebrates were randomly sampled from ten (10) sampling points falling within 15-meter radius (upstream and downstream and across the width of section) using 0.3m x 0.3m fabricated metal surber/kick net. The researchers ensured that sampling points represent at least one riffle, run, and pool. The researchers followed the recommendation of 1-min collection time per sampling point (Hilsenhoff, 1988). Thus, total collection time per sampling station was ten (10) minutes. Large stones and debris like leaves, twigs, and sticks and other material caught by the net were re-examined for overlooked organisms in the basin before being returned to the stream. All collected macroinvertebrates per sampling station was placed into individual plastic bottle and labeled accordingly. The collected macroinvertebrates were preserved using 70% ethyl alcohol.

To calculate the FBI stream reach, the researchers used Hilsenhoff's formula:

$$FBI = \frac{\sum [f(TV)]}{N}$$

Where:
FBI = Family Biotic Index
f = frequency of sampled macroinvertebrate taxon
TV = corresponding tolerance value for each taxon
N = total frequency sample

Table 1. Basic geomorphological data of Mapalyao Stream

Parameters	Reach 1	Reach 2
Average Depth	0.52 m in runs;	
Up to ~1.45m in certain pools	0.81 m; 2.37 m in some areas	
Stream flow / velocity	2.58 m/s	3.22 m/sec
Average Width	8.64 m	20.06 m
Stream Discharge	10.37 m^3/sec	27.48 m^3/sec
Riparian vegetation	Dense canopy cover give shade to the stream; big trees all over.	Mostly grasses
Other	small waterfalls; flat (pools) areas collect and trap water	Large boulders; wide pools as catchment of waterfall; many riffles and runs; waterfall area (pool) expands to 64 m

Figure 2. Heptageniidae (Order Ephemeroptera) specimen Photo by RP Manuel

The frequency of individuals per taxonomic family was multiplied by the tolerance value assigned by Hilsenhoff for that family; the products was summed and then divided by the total number of invertebrates in the sample. The resultant figure was compared to the Hilsenhoff's values for water quality using the family-level biotic index.

RESULTS AND DISCUSSION

Geomorphology of Mapalyao Stream

Basic geomorphological characteristics of the stream and its environs are presented in Table 1. The watershed area, which covers Mapalyao Stream, is generally adjacent to the barangay's residents. Lands converted for farming are located in proximity to the stream. Forested areas are located on the right side of the channels facing upstream. The stream is also characterized by huge boulders which arrest and agitate water. This feature may contribute to the aeration of water which is important for compensating for the Biological Oxygen Demand (BOD) of macroinvertebrates. Downstream (Reach 2) was noticeably bigger than the upstream section.

An interesting use of Mapalyao Stream is ecotourism. In fact, Mapalyao is one of the first locally-managed ecotourism destinations in Nueva Vizcaya. It is known to be frequented by people from other towns especially during summer. Like other streams in Nueva Vizcaya, people use the stream for irrigation, potable water and many others. During the collection of macroinvertebrates, the researchers noted the abundance of leeches (Class Hirudinea) in many parts of the stream, especially in higher reaches. These species has the highest tolerance value in Hilsenhoff scale. These were found in numerous pools upstream. During the collection, the researchers suspected that their abundance may be a reflection of oxygen-deficient environment, which in turn a sign of

Table 2. Assemblage of Macroinvertebrates at Reaches 1 and 2

Family / Order	Tolerance Value	Reach1 (Upstream)	Reach 2 (Downstream)	Total
Baetidae	4	7	0	7
Baetiscidae	3	2	0	2
Caenidae	7	0	1	1
Chironomidae	8	2	1	3
Chloroperlidae	1	0	1	1
Elmidae	4	9	8	17
Heptageniidae	4	51	53	104
Leuctridae	0	1	0	1
Perlidae	1	1	5	6
Philopotamidae	3	0	5	5
Psephanidae	4	34	2	36
Rhyacophilidae	0	0	1	1
Tabanidae	6	1	0	1
Taeniopterygidae	2	0	1	1
Trichoptera	3	2	0	2
Whirglig (Coleoptera)	4	6	3	9
Zygoptera	4	0	3	3
	TOTAL	**116**	**84**	**200**

non-point source organic pollution.

Assemblage of Macroinvertebrates and their Tolerance Values

Assemblage of macroinvertebrates in the stream reaches of Mapalyao is presented in Table 2. Sampling yielded a total 200 individuals representing 14 families and 3 orders/suborders. Dominant taxa were mayfly (Order Ephemeroptera) Family Heptageniidae and Psephanidae. These two families registered 104 (52.00%) and 36 (18%) individuals. Abundance of this family was reported by Manuel (2012) in the upper stream reaches of Amococan and Barobbob, in Bayombong, Nueva Viscaya and Nagsabaran, Diadi, Nueva Vizcaya. On the other hand, water pennies (Family Psehannidae) were reported in moderate quantities at Barobbob and Nagsabaran only. Family Psehanidae and Family Heptageniidae feed by scraping organic and other material (e.g., algae) on rocks and substrate in the stream. Both families had a tolerance value (TV) of 4 (moderate tolerance to pollution) in based on Hilsenhoff's scale.

Members of Order Coleoptera such as Family Elmidae and whirglig beetles registered 17 and 9 individuals. Like most beetles, these taxa are predatory in nature, signifying that the food base in the area, including other macroinvertebrates, is sufficient. Family Elmidae and whirglig beetles also have a tolerance value of 4.

Collected taxa with highest sensitivity to pollution (=lowest tolerance value) were Family Leuctridae (0), Family Rhyacophilidae (0) and Family Perlidae (1). Surprisingly, Family Rhyacophilidae and Family Perlidae were found in Reach 2, which is supposedly nearer to human settlements and tourism

Table 3. Computed Hilsenhoff Family-level Biotic Index for Mapalyao, 2013

Reach	HFBI	Descriptive Value
1	3.99	Very good
2	3.74	Very good
Whole	3.89	Very good

activity. Meanwhile, families with the highest tolerance values were Family Chironomidae (TV=8), Family Caenidae (7) and Family Tabanidae (6). Family Chironomidae and Family Tabanidae were found at Reach 1 (upstream), particularly in stagnant, leech-infested pools. Family Caenidae is one of only two Ephemeroptera families with highest TV (7). Family Chironomidae and Family Tabanidae both belong to Order Diptera (flies) which is the most pollution-tolerant order based on the Hilsenhoff scale.

Other important taxa identified at Mapalyao Stream were Family Hirudinea (Leeches; numerous), Family Dytiscidae (16 individuals) and Family Hydrachnidae (2 individuals at Reach 1). As mentioned, leeches were encountered frequently especially in stagnant higher channels. These feed as predator or parasite and have a very high tolerance to pollution. While not included in Hilsenhoff's list, Family Dytiscidae and Family Hydrachnidae have moderate sensitivity to pollution, as classified by West Virginia Department of Environmental Protection.

Hilsenhoff Family Biotic Index (HFBI) of the Stream

As aforesaid, Reach 1 represents the upper half of the sampling area, which covers the parts of the headwater section and that area of the stream where there are few human settlements. Most of the macroinvertebrates found thereat have a TV of 4. Reach 1 is found likely to have moderate organic pollution. This may be attributed to presence of farmlots at the Riparian zones of the upstream section. As such, open and converted lands therein may be the source of erosion and deposition of organic materials to the stream. The occurrence of pools especially during summer may also contribute to less aeration of water, leading to diminished dissolved oxygen which many macroinvertebrates need.

The lower section of Mapalyao's HFBI is slightly lower but still falls within the "very good" range. Albeit the vegetation is more open than channels upstream, downstream reaches are more inclined, leading to faster flow of water. This agitation somehow compensates for water exposure to sunlight temperatures and provides relatively more DO for organisms. Collectively, Mapalyao Stream has a very good (HFBI=3.89) water condition.

CONCLUSIONS AND RECOMMENDATIONS

Mapalyao Stream has a very good water quality, based on the macroinvertebrate assemblages and the computed HFBI. By "very good", however, means that there is presence of slight organic pollution. This perturbances to the water may be attributed to activities happening adjacent to the stream channels such as farming, land conversion, timber harvesting (leading to change in microclimate), and ecotourism. Interestingly, it is the upper channels of the stream that are relatively more polluted.

Nonetheless, certain biophysical features of stream like gradient-discharge function, substrate and remaining riparian forest cover are seen to compensate for anthropogenic disturbances in the stream. This resiliency is seen throughout the stream continuum and within that continuum certain processes upstream channels influence similar processes and constitution of organisms downstream. However, without proper regulations, these negative feedback mechanisms may fail, leading to further degradation of the ecosystem.

While HFBI is a valid measure of stream quality, the use of physic-chemical methods to measure water quality is recommended for future studies.

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