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Diversity and Functions of Benthic Macroinvertebrates in Relation to Water and Riparian Conditions in Riverine Channels of Eden and Dibibi, Quirino, Philippines

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ABSTRACT

Benthic macroinvertebrate diversity provides information on the quality of freshwater ecosystems. The dynamics of freshwater bodies and surrounding riparian zones in Eden and Dibibi were described using the ecology of macroinvertebrates. Various macroinvertebrate indices were used to calculate organic pollution levels. A total of 165 specimens were collected, representing five families, four orders/suborders, and three morphotypes. The two river channels have very low alpha diversities (H'Eden=1.43 and H'Dibibi=1.41). For both channels, dominance is distributed to about three taxa (1/DEden=2.90; 1/DDibibi=2.73). Hydropsychidae and Perlidae were the most abundant, indicating a plentiful supply of oxygenated water and perennial water flow. The Hilsenhoff Family Biotic Index (FBI) scale gives Hydropsychidae a TV of 4, indicating that it is somewhat tolerant to polluted water. Highly sensitive families include Perlidae TV=1; Tipulidae TV=3. Perlidae, Tipulidae, and Oligochaeta are also indicators of potential organic pollution. All physicochemical parameters are within "normal". The Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa and %EPT indices produced indicate that the sampled waters are "moderate" to "very good" condition. Due to the abundance of Hydropsychidae, Hilsenhoff FBI rated the sampled waters of Eden as "Excellent"; Dibibi was slightly lower in quality. Furthermore, the indices indicate the presence of pollution-causing elements, which can be linked to human presence and land uses. The geomorphology of the two river sections' riparian and lotic zones, including those of upriver, provide resilience against anthropogenic stresses. This is supported by measurements and observations of physicochemical parameters. Management decisions must take into account the enforcement of environmental functions that deter degradation and ensure river ecosystem's stability.

Keywords: Macroinvertebrates, Hilsenhoff FBI, EPT, Quirino

INTRODUCTION

Water is one of the most important renewable resources necessary for sustaining various life forms (Singh and Gupta, 2016). It is used in homes, in industries, in rearing livestock and in growing crops (Owa, 2014). The province of Quirino is divided into four major watersheds, each endowed with numerous rivers and creeks, alternate: that span 2,970 kilometers. The riverine systems are significant tributaries of the Cagayan River, the largest lotic body in the Philippines (maritime review.ph) and the Magat Dam, one of the largest dams in the country (https://bob.nia.gov.ph/Viewer/Magat). Aside from other human land uses, agriculture primarily takes advantage of water regimes in said area.

The Addalam River is the second-longest river system in the province, having a length of more than 825 kilometers. Because of the proximity of anthropogenic forces, the riverine sections of Eden and Dibibi in the municipality of Cabarroguis, have been susceptible to non-point source organic and other types of water pollution. Water pollution is "the presence in groundwater of toxic chemicals and biological agents that exceed what is naturally found in the water (www.environmentalpollutioncenters.org/water, n.d.). Such contaminations are usually the result of human activities, including "deforestation, construction of various infrastructures such as irrigational canals, dams, roads, and bridges, and even agricultural, and industrial and domestic activities" (Bashir et al., 2020). With the continuous pollution of river bodies, living organisms, including humans, have been seriously impacted (Owa, 2014). As ecosystems within a watershed are modified, lost, or degraded, the hydrology of river systems worsens, affecting water flow, quality, quantity, and even timing (Aglanu, 2014).

While scientific information is crucial in sound environmental management (Djenontin & Meadow, 2018), little is known about the river systems of the Quirino Province. Also, very few scientific studies, let alone monitoring activities, are being conducted in Eden and Dibibi sections, to establish whether pollution is a significant factor of degradation. This makes the areas susceptible to arbitrary management, or non-management thereof.

As a consequence, it is feared that non-abatement of resultant pollution, including organic and inorganic, point- and non-point sources, would result to unfavorable conditions for aquatic life therein. Pollution would eventually disrupt many ecosystem services, including those directly beneficial (i.e., potable water) to the local communities. The application of ecological principles to policy making, there is a great need to obtain information as to the degree and extent of the problem, so that actions can be made. This relates to the assessment/ monitoring of the stream.

High-end physicochemical and bacterial monitoring is supposed to be the top choice for gaining high-resolution, time-sensitive data for water pollution. However, these methods have some restrictions (Manuel 2014; Zimmerman 1993). Chemical assessments – as the name implies – are chemically sensitive; a reagent usually focuses only on a particular substance; hence a comprehensive (and more expensive) test would be required to cover a range of possible pollutants. Physicochemical testing also denotes a specific period, so tests must be done repeatedly to describe longer durations (EMB, 2008). As such, long-term physiochemical monitoring efforts depend on the availability of resources and finances. Such a thing may not be readily feasible in rural parts of the Philippines. An excellent alternative is the use of macroinvertebrates as biological indicators since they integrate information over more extended periods and represent responses of aquatic habitats to change (Naval-Perreira et al, 1996 cited in Eherek et al, 2014).

Various macroinvertebrate taxa are employed worldwide to measure water quality (i.e., presence of organic pollution) (Rizo-Patron et al., 2013; Flores and

Zafaralla, 2012; Zimmerman 1993; Hilsenhoff 1988, 1987 and 1982) water flow and regimes (Berhanu et al., 2015) and investigating ecosystem functions (Keeler et al., 2012). This is so because macroinvertebrate groups are known to have a particular sensitivity to pollution (or water oxygenation), perturbations in the riparian zones like erosion (Mesa 2014; Arnaiz et al., 2011), and vegetation (Rios et al., 2006); responses to temperature as induced by lack of surrounding vegetation, and dependency on /processing of autochthonous and allochthonous organic matter (Ferreira and Graca, 2006). Macroinvertebrates are also important element in various ecosystem functions (Nieto et al, 2017), thus their diversity, abundance and functions are reflections of the "health" of freshwater ecosystems (Archna et al, 2015; Stoyanova et al., 2014).

The solid scientific association among and between macroinvertebrate diversity and functions and ecosystems conditions can overcome, or supplement limitations of physicochemical water assessment methods. In addition, macroinvertebrates are easy to identify, representative of extended periods (e.g., one year) and require minimal resources to collect. Utilization of macroinvertebrates as biological indicators is therefore suitable for information-based management of freshwater ecosystems in the rural setting. This study takes full advantage of macroinvertebrates as bioindicators to reinforce the assessment of Eden and Dibibi's riverine-riparian zones, for use in future management initiatives.

OBJECTIVES OF THE STUDY

This paper presents the interrelationships between alpha (community) diversity and functions of macroinvertebrate assemblages and the ecosystem quality of the Addalam river, particularly Eden and Dibibi's river sections. For this, the researchers carried out the following: a sampling of macroinvertebrates, discussion of macroinvertebrates' diversity, functional feeding groups (FFGs) and tolerances to pollution, measurement of river condition/organic pollution levels using various macroinvertebrate metrics, and measurement and assessment of various riverine-riparian geomorphology and water physicochemical parameters.

MATERIALS AND METHODS

The study was conducted from January to May 2018. The study areas represent 500-m sections of Addalam River located in Eden and Dibibi's river sections. The sampling method was patterned after Hilsenhoff (1988) and

Zimmerman (1993). For each river section, two (2) sampling stations were sampled: upriver and downriver (Figure 1) distance between stations is 500.00m. For each station, ten (10) sampling points (riffle and runs) were randomly selected, where macroinvertebrates were collected from rocks and substrate. With 1-minute collection time per sampling point, the gathering of macroinvertebrate specimens was facilitated by 0.30m x 0.30m Surber net. Collected samples per river section were identified, sorted, and counted.

Alpha or community diversity was determined using Shannon-Weiner Index (H') and Simpson's Reciprocal Index (1/D). Interpretation of H' values was facilitated by the scale proposed by Fernando (1998). As a further guide, Magurran (1998) suggests that H' has normal values of 1.50-3.50, and rarely goes beyond 4.50. Meanwhile, as a dominance measure, 1/D is more convenient to interpret than Simpson's D because it readily presents the number of taxa dominant in the community, with the whole sample (Magurran, 1998). The phylogeny of macroinvertebrate taxa was also assessed to show relationships at higher taxonomic levels. The phylogeny tree was produced using the Interactive Tree of Life's online (www.itol.embl.de; http://phylot.biobyte.de) generator (Letunic and Bork, 2016).

Four indices were used to assess the presence of organic pollution in streams via macroinvertebrates: Hilsenhoff Family-Level Biotic Index (HFBI), Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa, %EPT, and EPT to Total%. HFBI is used herein as the primary indicator metric since it stresses tolerance values (TV) of various macroinvertebrate families. The other three were based on the presence of EPT orders because most families under these macroinvertebrate orders are known to be highly sensitive to organic pollution. EPT taxa index is a simple count of infraorder taxa, while %EPT and EPT to Total % are computed proportions (abundances) of individuals belonging to said orders. There were other notable species and populations encountered but were not included in the listing and actual computation of FHBI. However, for purposes of enriching discussion, they were presented here as well.

Using field instruments, the study team also performed measurements of the following water quality parameters: Dissolved oxygen (DO), Salinity, Total Dissolved Solids, pH, and Temperature Conductivity. References to quality were mainly inferred from Philippine standards (DENR AO 2016-8) and similar documents in other countries. With the assumption that river water is not used for human consumption, coliform content was not measured in this study. For simple comparisons, the most immediate major tributaries found in the sampling sites were also measured. Basic geomorphological characteristics of the riverine-riparian sections were also recorded. For riparian plants, paired quadrats measuring 20.00m x 20.00m were established alongside macroinvertebrate sampling stations (a total of 8 quadrats in Eden and Dibibi). Encountered species inside the quadrats were recorded, yielding presence-absence data.

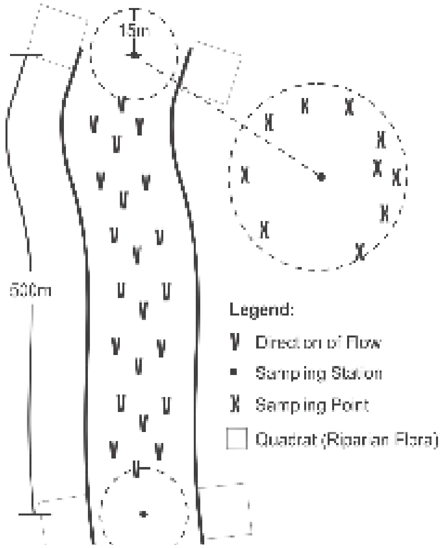


Figure 1. Schematic of the sampling protocol performed at Eden and Dibibi river sections.

RESULTS AND DISCUSSION

Macroinvertebrate diversity and tolerance values

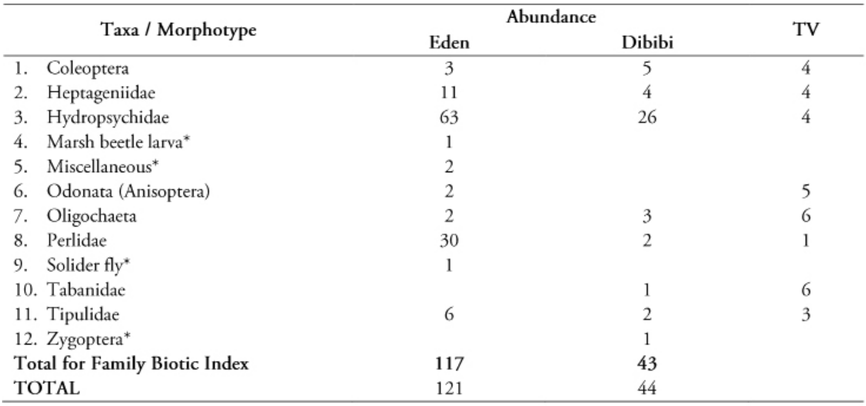
The assemblage of macroinvertebrates in the stream reaches of the study area is presented in Table 1. Sampling yielded a total of 165 individuals representing five families, four orders/suborders, and three morphotypes. Eleven of 12 identified taxa are arthropods (Figure 2). From the sampled sections, respective diversities are very low (H'_{Eden}=1.43 and H'_{Dibibi}=1.41). Dominance is distributed to about three taxa ($1/D_{\text{Eden}}$=2.90; $1/D_{\text{Dibibi}}$=2.73). Eden's assemblage is more abundant than Dibibi's, with a ratio of 11:4.

The dominant taxon for both streams was the caddisfly family Hydropsychidae (Order *Trichoptera*). This family registered in Eden and Dibibi at 63 (52.07%) and

26 (59.09%) individuals. Common stoneflies (*Perlidae*: *Plecoptera*) were abundant in Eden, with 30 sampled individuals. Other important macroinvertebrates identified in the two sites' aquatic and riparian zones are members of mollusk *Prosobranchia*, freshwater crab *Sundathelphusa* sp (*Decapoda*), freshwater prawn *Macrobrachium lar*, Robber fly (*Asilidae*), and some aquatic arachnids, dragonflies and damselflies.

Table 1

*Assemblage of Macroinvertebrates in Eden and Dibibi River Sections with their corresponding Hilsenhoff Family Biotic Index Tolerance Values (HFBI; after Zimmerman, 1993). Taxa/morphotypes with * is not included in the calculation of FBI*



Taxa / Morphotype	Abundance		TV
	Eden	Dibibi	
1. Coleoptera	3	5	4
2. Heptageniidae	11	4	4
3. Hydropsychidae	63	26	4
4. Marsh beetle larva*	1		
5. Miscellaneous*	2		
6. Odonata (Anisoptera)	2		5
7. Oligochaeta	2	3	6
8. Perlidae	30	2	1
9. Solider fly*	1		
10. Tabanidae		1	6
11. Tipulidae	6	2	3
12. Zygoptera*		1	
Total for Family Biotic Index	**117**	**43**	
TOTAL	121	44	

The constitution of macroinvertebrates in both Eden and Dibibi reflects the condition of the riverine ecosystem. *Hydropsychidae* and *Perlidae* are indicators of perennial water flow (epa.gov.ph). At the Order level, *Plecoptera* and *Ephemeroptera* are commonly found in fast-flowing bodies; thus, their presence denotes an abundant supply of oxygenated water in Eden and Dibibi sections of Addalam. This finding confirms Stoyanova et al, (2014) that EPT thrives in clean and well-oxygenated waters. However, the most dominant family, *Hydropsychidae*, has a TV of 4 on the Hilsenhoff Family Biotic Index scale. This means that it is somewhat tolerant on polluted water conditions. On the other hand, highly susceptible families (*Perlidae* TV=1; *Tipulidae* TV=3) are found scarce in the area. Thus, the combined presence of *Hydropsychidae*, *Perlidae*, and *Tipulidae* (plus Oligochaeta TV=6) indicates possible slight organic pollution in the two rivers. In other terms, thepresence of oxygen-limiting elements in the water and environs.

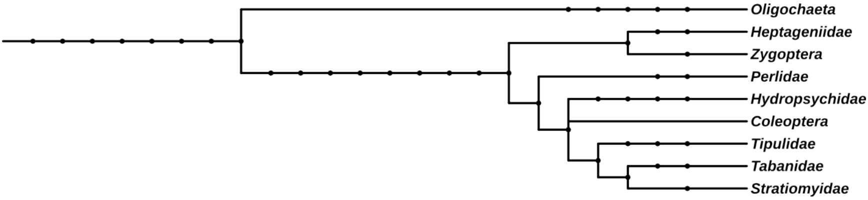


Figure 2. Phylogeny of identified taxa in Eden and Dibibi River Sections. Image generated by Letunic and Bork (2016) for Interactive Tree of Life (www.itol.embl.de).

Functional Feeding Groups

For both Eden and Dibibi, the most abundant feeding group is the filterers, with 52.07% and 59.09%, respectively. As the name implies, these macroinvertebrates are at the tail end of organic matter processing, sifting through debris and algae already processed in the headwaters by shredders and gatherers. The sampled sections of Eden and Dibibi represent the riverine parts of the Addalam, it is natural that the population of filterers in this part of the river continuum is at its largest.

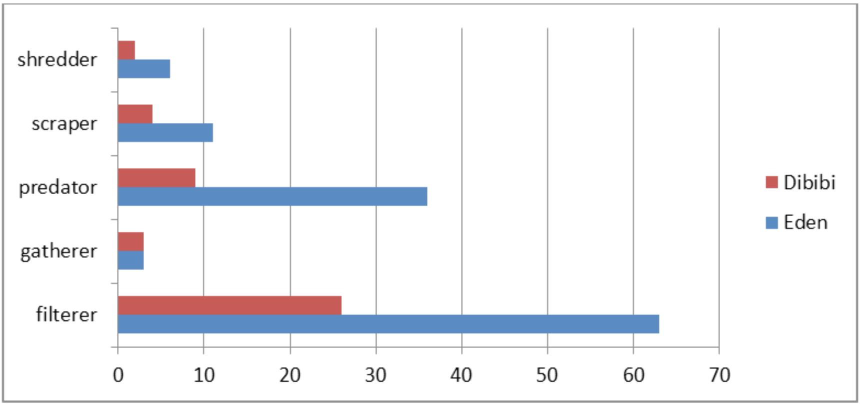


Figure 3. Abundance of various functional feeding groups of macroinvertebrates in Eden and Dibibi river sections.

The second-most abundant (macroinvertebrates) in the two sites were the predator group. Predatory larvae/nymph belongs to *Coleoptera*, *Odonata*

(Suborders *Anisoptera* and *Zygoptera*), *Tabanidae* (Order *Diptera*) and *Perlida*e (*Plecoptera*). They account for 29.75% of collected specimens in Eden and 20.45% in Dibibi. Because of their large numbers, it can be surmised that predators indicate a broad food base in the area.

On the other hand, the least represented functional feeding group in Eden were gatherers (2.48% of the total collection). Comprised of worms (*Oligochaeta*) and soldier fly larvae (*Stratiomyidae*), these organisms depend on allochthonous organic matter (e.g., leaves, twigs) pre-broken down by shredders and other collectors, especially those originated from headwater streams. In Eden, Oligochaetes were obtained in stagnant, peaty portions of the river. Since the sampled riverine sections drain higher water volumes than the headwaters, these places may not be the most suitable habitat for such FFG (which would require more agitated, but shallower riffle sections), hence their low abundance. Gatherers comprise 6.82% of the total assemblage in Dibibi.

Heptageniidae (*Ephemeroptera*) were observed in moderate numbers in Eden. As a "scraper," the nymphs of this mayfly family depend on periphyton and organic matter attached to the substrate (rocks). Being short-lived organism (with some species having a maximum lifespan of 3 days), mayflies require reproduction *en masse* as the primary survival strategy. Because of this, *Heptageniidae* can always be seen as dominant taxa, whenever observed in an area. It can be deduced that this family/FFG has the most comprehensive habitat range among all feeding groups.

In Dibibi, the least abundant FFG is the shredders (4.54%). Shredders were represented by the cranefly family *Tipulidae* (*Diptera*). While a default shredder, craneflies also are facultative predators, i.e., resort to carnivory in times of food scarcity.

Water condition values of Eden and Dibibi: relationship with present environs

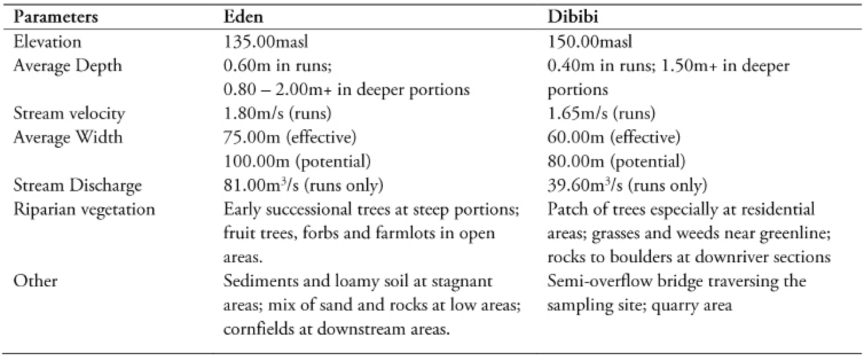
All physicochemical parameters fell within "normal" values to support aquatic life. Dissolved Oxygen (DO) and pH levels in both rivers (including tributaries) pass DENR (2016) effluent standards for all freshwater body classifications. Measured DO in Eden and Dibibi also correspond to "unimpaired" waters, as per In Taiwan Environmental Protection Agency (Taiwan-EPA; in Young et al, 2014) river pollution index standards. Moreover, Eden and Dibibi's TDS measurements are below USA Drinking Water Standard levels (1986) for "hard" water (i.e., not exceeding 500mg/L).

However, because the sampled sections are also some of the most accessible parts of the river system, it is highly likely that human presence has visually altered the condition of the area. Direct interventions in the riparian-river zones are the tending water buffaloes (carabaos), transportation by boat, tillage/conversion of riparian sections for agriculture and settlements, and fishing. As these factors readily contribute to sedimentation and organic pollution in the river, loading in upper reaches may also contribute to the condition in Eden and Dibibi.

River condition and a description of geomorphological characteristics and environs of the two river sections are presented in Table 2. Eden and Dibibi are accessible to the barangay's residents, facilitated by established roads and bridges (cemented and hanging). Lands converted for corn farming (the major crop in Quirino) are located near the rivers as well. The shallower parts of the sampled sections contain rocks and boulders which arrest and agitate the water. This feature contributes to the aeration of water which is important for compensating for the DO and Biological Oxygen Demand (BOD) of macroinvertebrates.

Table 2

Basic geomorphology of Eden and Dibibi river sections

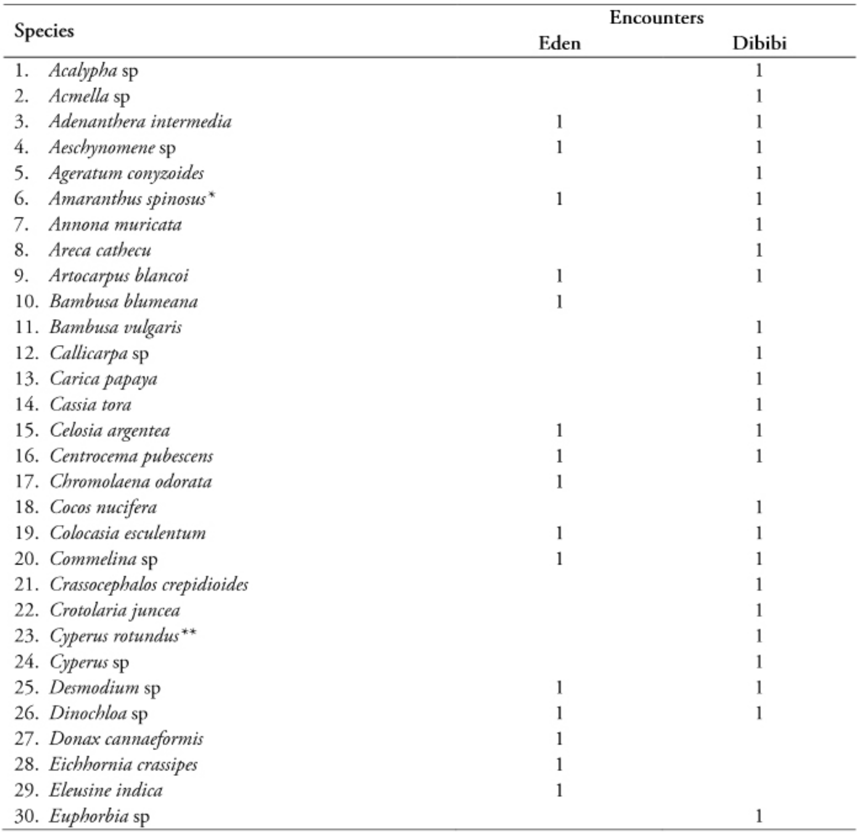


Parameters	Eden	Dibibi
Elevation	135.00masl	150.00masl
Average Depth	0.60m in runs; 0.80 – 2.00m+ in deeper portions	0.40m in runs; 1.50m+ in deeper portions
Stream velocity	1.80m/s (runs)	1.65m/s (runs)
Average Width	75.00m (effective) 100.00m (potential)	60.00m (effective) 80.00m (potential)
Stream Discharge	81.00m^3/s (runs only)	39.60m^3/s (runs only)
Riparian vegetation	Early successional trees at steep portions; fruit trees, forbs and farmlots in open areas.	Patch of trees especially at residential areas; grasses and weeds near greenline; rocks to boulders at downriver sections
Other	Sediments and loamy soil at stagnant areas; mix of sand and rocks at low areas; cornfields at downstream areas.	Semi-overflow bridge traversing the sampling site; quarry area

The riparian vegetation of the two areas is very sparse; the sampled sections are dominated by forbs and grasses (Table 3), rendering the area exposed to sun and wind. It is reasonable that the increased local/ambient temperature is due to its low elevation and lack of dense vegetation. Riparian vegetation is also crucial to invertebrate breeding and diet (Moraes et al., 2014; Seger et L.; Arnaiz et al., 2011); hence, the scarcity of plant cover (or openness of riparian zones) in the sampled areas affects the assemblage of macroinvertebrates that are supposed to be present in such part of the continuum. It is also common knowledge that increased water temperatures (due to the openness of the riparian zone) physically limit the amount of oxygen that the water can dissolve. Elevation (as a surrogate for atmospheric pressure) is also a known DO factor, still, because Eden and Dibibi are relatively close to sea level, elevation is considered not to have a crucial effect on the differences in DO levels.

Table 3

Identified plants along the riparian zones of Eden and Dibibi river sections



Species	**Encounters**	
	Eden	**Dibibi**
1. *Acalypha* sp		1
2. *Acmella* sp		1
3. *Adenanthera intermedia*	1	1
4. *Aeschynomene* sp	1	1
5. *Ageratum conyzoides*		1
6. *Amaranthus spinosus**	1	1
7. *Annona muricata*		1
8. *Areca cathecu*		1
9. *Artocarpus blancoi*	1	1
10. *Bambusa blumeana*	1	
11. *Bambusa vulgaris*		1
12. *Callicarpa* sp		1
13. *Carica papaya*		1
14. *Cassia tora*		1
15. *Celosia argentea*	1	1
16. *Centrocema pubescens*	1	1
17. *Chromolaena odorata*	1	
18. *Cocos nucifera*		1
19. *Colocasia esculentum*	1	1
20. *Commelina* sp	1	1
21. *Crassocephalos crepidioides*		1
22. *Crotolaria juncea*		1
23. *Cyperus rotundus***		1
24. *Cyperus* sp		1
25. *Desmodium* sp	1	1
26. *Dinochloa* sp	1	1
27. *Donax cannaeformis*	1	
28. *Eichhornia crassipes*	1	
29. *Eleusine indica*	1	
30. *Euphorbia* sp		1

Table 3 continued.

Species	Encounters	
	Eden	Dibibi
31. Fern vine	1	
32. *Ficus gul*	1	1
33. *Ficus nota*		1
34. *Ficus septica*	1	
35. *Ficus* sp	1	
36. *Ficus sp1 cf. ampelas*		1
37. *Fluggea* sp		1
38. *Gmelina arborea*	1	1
39. *Kleinhovia hospita*	1	
40. *Leucaena lecocephala*	1	1
41. *Macaranga tanarius*	1	1
42. *Mallotus ricinoides*	1	
43. *Melothria pendula*		1
44. *Mikania cordata*	1	1
45. *Milletia* sp		1
46. *Mimosa pudica*	1	1
47. *Mimosa* sp	1	
48. *Misc 3 (creeping fern)*		1
49. Miscellaneous 1 (ground orchid)		1
50. Miscellaneous 2 (forb with pink flowers)		1
51. *Momordica* sp		1
52. *Paspalum conjugatum*		1
53. *Passiflora foetida*		1
54. *Pennisetum purpureum*	1	1
55. *Persea americana*		1
56. *Physalis* sp		1
57. *Poaceae* sp		1
58. *Pongamia pinnata*	1	1
59. *Pterocarpus indicus*		1
60. *Rhaphidophora pinnata*	1	1
61. *Rottboellia* sp		1
62. *Saccharum spontaneum*	1	1
63. *Sandoricum koetjape*	1	1
64. *Semecarpus cuneiformis*		1
65. *Solanum* sp		1
66. *Stachytarpheta guyanensis*	1	1
67. *Stachytarpheta sp.*	1	
68. *Trema orientalis*	1	1
69. *Triumfetta rhomboidea*		1
70. *Urena lobata*	1	1
71. *Vigna* sp (Vegetable)		1
72. *Wedelia* sp	1	1
73. *Zingiberaceae* sp	1	
TOTAL	**38**	**60**

Species with * are world's worst weeds as reported by IRRI (Caton et al, 2010).

Dissolved oxygen of >5.00mg/L is needed for the full functioning of “elite” macroinvertebrates (i.e., pollution-sensitive) like members of Ephemeroptera, Plecoptera, and Trichoptera or EPT (Chadde, undated). Connoly et al., (2004) also reported that hypoxic conditions are lethal to macroinvertebrates. In terms of pH, however, these macroinvertebrate orders have a relatively “narrow” pH tolerance; in temperate environments, most aquatic life thrive in pH of 6.50-8.00 (Behar, 1997), but most EPT need water pH of 6.50-7.50 (Chadde, undated); mollusks prefer a pH 7.50-9.00 and fish, pH 6.50-8.50 (DENR 2016). With the measured physicochemical values in Eden and Dibibi’s waters, macroinvertebrates have sufficient DO, but in the threshold of pH preference. In translation, the inherent “structure” of the water limits the diversity of benthic invertebrates, especially EPT. This may be the direct effect of erosion-sedimentation from the riparian zones and upper channels, exposure to sunlight/temperature, intensive riverbed alteration, like dredging/quarrying, and many others.

pH can also be affected by TDS and temperature. Excessive TDS (>500mg/L) can make the water hyper alkaline, which may cause fish dehydration at the cellular level. On the other hand, water tends to become more acidic at warmer temperatures. With riparian zone openness as the cause of sunlight exposure and deposition/siltation, it can be deduced that the low density of vegetation in Eden and Dibibi’s riverbanks contributes to the properties of water thereat.

Compared to their respective and immediate tributaries, considerable differences in pH and TDS/Salinity/Conductivity were observed (Table 4). Both rivers have greater pH than their close tributaries (Dinatay, Cabitnungan). For Eden, TDS levels were higher in the main channel than in Dinatay which is a large stream with better forest cover but with more sediment at the Eden interface. This suggests that turbidity elements in the tributary have been loaded onto the main Eden channel. On the other hand, Dibibi’s TDS-Salinity-Conductivity values were lower compared to Cabitnungan. In this case, Cabitnungan (also a large stream) is more affected by human settlements. Thus the larger Dibibi may have “diluted” the potentially polluting discharges coming from its tributary. Dissolved oxygen flux was more observable in Dinatay-Eden than in Cabitnungan-Dibibi.

This said, the resulting Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa and %EPT indices list the two sampled waters in “moderate” to “very good” condition (Table 5). Meanwhile, since Hilsenhoff FBI is more sensitive to the abundances of more pollution-tolerant species, HFBI rates the sampled waters of Eden as “Excellent” due to the abundance of *Hydropsychidae*; Dibibi is slightly lower in quality. The water quality values are considerably high despite the low biological diversity information (i.e., H'). This observation reinforces Manuel's (2010) position that high diversity does not always equate to "excellent" ecological conditions.

Table 4

Basic physico-chemical measurements at Eden and Dibibi river sections

SECTION	pH	Temp. (°C)	TDS (ppm)	Salinity (ppm)	Cond. (μS/cm)	DO (mg/L)
Eden	8.345	29.95	94.50	70.50	140.50	8.36
Dinatay*	8.28	31.95	81.50	61.00	122.50	8.85
Dibibi	8.795	30.90	103.00	77.50	156.00	8.87
Cabitnungan**	8.32	30.40	120.5	90.50	180.00	8.97
MEAN	**8.435**	**30.8**	**99.875**	**74.875**	**149.75**	**8.76**

Table 5

Computed macroinvertebrate indices for assessing water quality

	Hilsenhoff FBI		EPT taxa		%EPT Index		EPT to Total %		Shannon-Weiner	
Section	**Numeric value**	**Description**	**Numeric value**	**Description**	**Numeric value**	**Description**	**Numeric value**	**Description**	**Numeric value**	**Description**
Eden	**3.12**	No apparent organic pollution (Excellent)	**3**	Moderate	**30.00%**	Very Good	**85.95%**	Good	**1.43**	Very low
Dibibi	**4.00**	Possible slight organic pollution (Very Good)	**3**	Moderate	**37.50%**	Very Good	**72.73%**	Good	**1.41**	Very low

CONCLUSIONS

As earlier stated, the macroinvertebrate diversity in Eden and Dibibi suggests that its waters are "clean," but there are also hints of oxygen-limiting (or pollution-causing) elements. These factors can be attributed to human presence and land uses in the two areas. Despite this, the inherent geomorphology of riparian and lotic zones of the two river sections, perhaps including that of upriver sections, are believed to provide resiliency against anthropogenic stresses. This thought is supported by measured and observed physicochemical parameters thereat.

RECOMMENDATIONS

Management decisions for Eden and Dibibi's riverine sections must consider enforcement of negative ecosystem feedback, i.e., environmental functions that deter failure or degradation of such ecosystems. Without proper conservation, protection, or rehabilitation efforts, these harmful feedback mechanisms (e.g., water re-oxygenation, erosion suppression) may fail, leading to further damage to the ecosystem and the services that first and foremost enticed people to settle in Eden and Dibibi.

Plate 1. Benthic macroinvertebrates collected in Eden and Dibibi channels of Addalam River, Quirino Province. A: **Freshwater Crab** (Decapoda); B: **Stonefly** (Perlidae); C: **Flatheaded Mayfly** (Heptageniidae); D: **Dragonfly Nymph** (Odonata); E: **Freeliving Caddisfly** (Rhyacophilidae); F: **Netspinning Caddisfly** (Hydropsychidae); G: **Crane Fly** (Tipulidae).

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