Communication

Monitoring of Neotropical Streams using Macroinvertebrate Communities: Evidence from Honduras

Stefano Fenoglio [1,2] and Alberto Doretto [2,3,*]

1   Department of Life Sciences and Systems Biology, University of Turin, Via Accademia Albertina, 13, 10123 Turin, Italy; stefano.fenoglio@unito.it
2   ALPSTREAM-Alpine Stream Research Center, 12030 Ostana, Italy
3   Department of Sciences and Technological Innovation, University of Piemonte Orientale Via T. Michel 11, 15121 Alessandria, Italy
*   Correspondence: alberto.doretto@uniupo.it

Abstract: Assessing the water quality by using biological indicators is a reliable and economically feasible way to promote environmental conservation in developing tropical countries. Here, we report one of the few examples of river biomonitoring in Honduras. In June 2005, benthic macroinvertebrates were collected from six sites in the Río Cangrejal basin. An adapted version of the Biological Monitoring Working Party index (BMWP) was used to assess the water quality because it is simple, consolidated, relatively easy to use, and needs a family-level identification. Moreover, two other community metrics were calculated, namely the total taxon richness and local contribution to beta diversity (LCBD). Differences in the biomonitoring and diversity metrics among sites and their correlations were statistically tested. Thirty-nine macroinvertebrate taxa were collected and, despite significant differences in the BMWP score, all sampling sites were classified in the high environmental quality class. A very strong and positive correlation between the BMPW and taxon richness was found, while LCBD did not vary significantly and did not correlate with the other metrics. Our results suggest that taxon richness could be used as a surrogate indicator to assess the water quality when consolidate biomonitoring methods are not available.

Keywords: biological indicators; BMWP; richness; LCBD; Río Cangrejal

1. Introduction

In the last decades, the biological monitoring of running water systems has become increasingly important and, in many countries, it has become an indispensable complement to traditional chemical–physical techniques in the evaluation of human impacts [1]. Benthic macroinvertebrates are widely used in biomonitoring due to their sensitivity to multiple changes in both the chemical characteristics of the water and the physical properties of the habitats [2–4]. Indeed, benthic macroinvertebrates have overwhelmed other taxonomic groups (e.g., microorganisms, algae and plants, amphibians, and fish) as biological indicators since the publication of the River Continuum Concept [5,6]. The relatively long length of macroinvertebrates' life cycles and their reduced mobility make the analysis of their community structure an effective tool to detect human pressures. Moreover, multiple community metrics might be selected depending on the type of human-mediated alteration, making the river biomonitoring more effective and stressor-specific [7].

The assessment of lotic system health is particularly important in developing tropical countries, where population and economic growth are threatening the exceptional regional biodiversity. Recently, many studies have underlined that biological biomonitoring methods may offer interesting possibilities of application in Neotropical streams [8,9]; may overcome logistic difficulties associated with traditional chemical–physical surveys; and appear advantageous from an economic point of view, providing synthetic information in a rapid way [10]. Besides, the collection and analysis of biological indicators, such as

benthic macroinvertebrates, requires moderate training, especially when organisms are identified by family. Although knowledge about the benthic macroinvertebrates of the Neotropics [11–16] and their use in biomonitoring [17,18] has increased in the last few decades, it is still scarce, and more extensive investigations are needed.

This study aimed to assess the water quality of Neotropical streams in the Río Cangrejal basin (Honduras), which is under growing pressure from ecotourism and white-water sports. In addition to the application of a monitoring index, the diversity and composition of benthic macroinvertebrate communities was analyzed with the aim of identifying the most biodiverse sites and supporting the best management and conservational strategies in the study area.

2. Materials and Methods

2.1. Area of Study

The study was conducted in the Río Cangrejal basin, on the northern coast of Honduras. The Río Cangrejal drains a large basin, with a drainage of 498 Km^2, characterized by the presence of mountains covered by rainforest. The most significant and important mountain of this area is Pico Bonito (2584 m a.s.l.), which has been classified as a national park since 1987. This area features a tropical rainforest climate (Af in the Köppen climate classification) with important rainfall throughout the year (annual mean = 3.5 m) and a precipitation peak in winter (October–February) [19]. A total of six sites, localized in the medium-upper part of the hydrographic network, were selected (Figure 1).
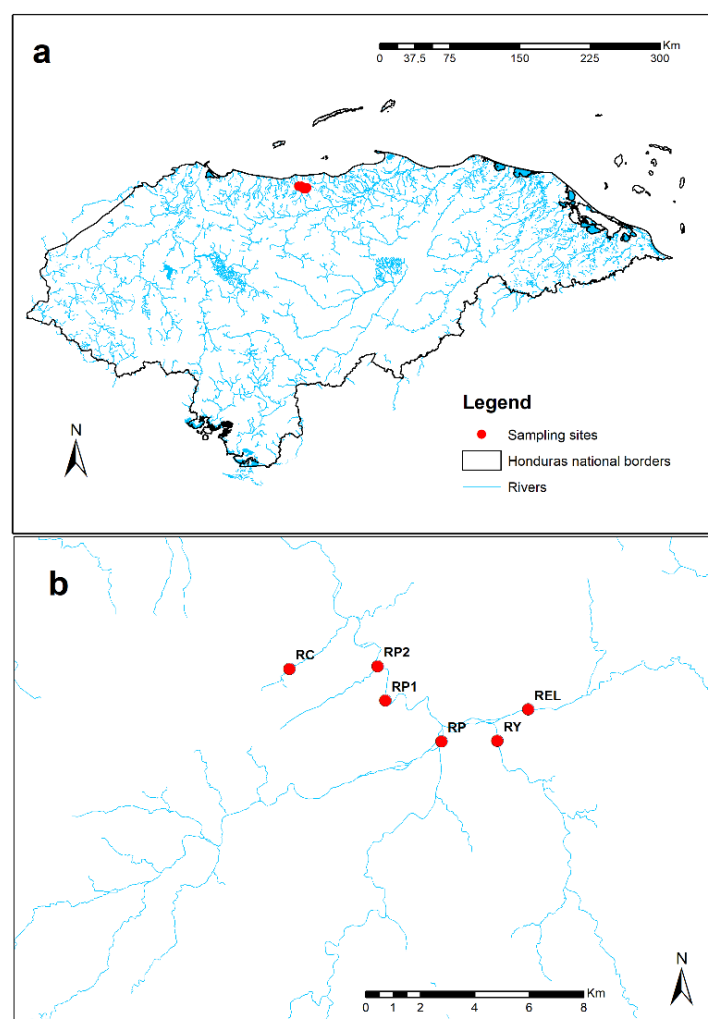

Figure 1. Study area (**a**) and geographical location of sampling sites (**b**): REP = Río El Padre, RY = Río Yaruca, RV = Río Viejo, P1 = Río Pital1, P2 = Río Pital2, RC = Río Cangrejal.

2.2. Data Collection

In June 2005, benthic macroinvertebrates were sampled from a single riffle area in each site according to the most representative microhabitats and using a dip-in net (250 μm mesh) [20]. The net was placed flush with the river bottom and benthic organisms were dislodged from the substrate immediately upstream from the net by washing the surface of cobbles with the hands or disturbing the substrate with feet. This operation was performed by the same operator, guaranteeing comparability among the samples and sites. Samples were fixed in ethanol 70° and subsequently sorted and identified in the laboratory with a compound scope (20/60 X) to the lowest possible level (genus or family).

2.3. Data Analysis

An adapted version of the Biological Monitoring Working Party (BMWP) index (see method details in [21,22]) was used to assess the water quality of the investigated sites, calculated at the family level. Specifically, scores for Neotropical taxa were corrected with those reported in the family-level biotic index [20]. This procedure was adopted because of the need for simple, proven and consolidated methods, applicable immediately and easy to use, with family-level identification. Moreover, this procedure allowed for overcoming the lack of available information on local benthic fauna ecology and was facilitated by the evident taxonomic affinities of local fauna with Palearctic and Nearctic faunas, at least at the family-level. A χ^2 test was used to statistically evaluate differences in the BMWP score among sites.

Total taxon richness and the local contribution to beta diversity (LCBD) were calculated for each site. The former corresponds to the total number of taxa, while the latter is a recently proposed measure of ecological uniqueness [23]: sampling sites hosting unique communities (i.e., taxonomically different form the other sites) are scored with high LCBD, thus, contribute to a greater extent to the total regional diversity [23]. Differences in the taxon richness and LCBD among sites were tested by using the χ^2 test. Moreover, the Pearson's correlation test was used to quantify the relation between the BMWP and the taxon richness and LCBD.

All analyses were performed with the software R [24], using the basic functions and the adespatial R package [23] for LCBD and significance of statistical testing was assessed at $p < 0.05$.

3. Results

A total of 39 taxa belonging to 12 orders were collected (Table 1). Diptera was the taxonomic group with the highest number of taxa, followed by Trichoptera, Ephemeroptera, Hemiptera, and Odonata.

Overall, all sites hosted rich communities of benthic macroinvertebrates with many representatives of the most sensitive taxa, such as EPT (Plecoptera, Ephemeroptera, and Trichoptera). BMWP score varied significantly among sites ($\chi^2 = 14.460$, $p = 0.013$): the lowest score was recorded in Río Viejo, while the highest score was observed in Río El Padre (Figure 2a). However, all sampling sites fall into the "high environmental quality class", because the BMWP score was always higher than 100 (mean = 131.5 ± 19.5 SD).

Total taxon richness did not vary significantly among sites ($\chi^2 = 5.138$, $p = 0.399$; Figure 2b). LCBD ranged from 0.147 and 0.222, but differences among sites were not significant ($\chi^2 = 0.023$, $p = 0.998$; Figure 2c).

BMWP was positively correlated ($r = 0.988$, $p < 0.001$) with total taxon richness (Figure 2d), but showed no linear association with LCBD ($r = -0.309$, $p = 0.552$; Figure 2e). Similarly, taxon richness and LCDB were also independent ($r = -0.384$, $p = 0.452$; Figure 2f).

Table 1. Presence/absence of the macroinvertebrate taxa in the six sites (REP = Río El Padre, RY = Río Yaruca, RV = Río Viejo, P1 = Río Pital1, P2 = Río Pital2, RC = Río Cangrejal).

| Taxon	REP	RY	RV	P1	P2	RC
Plecoptera						
Anacroneuria	+					
Ephemeroptera						
Baetodes	+	+	+	+		+
Camelobaetidius	+	+	+	+	+	+
Leptohyphes	+	+	+	+	+	+
Thraulodes	+	+	+	+	+	+
Euthyplocia	+	+		+		
Trichoptera						
Leptonema				+		+
Plectromacronema				+		
Smicridea					+	
Chimarra	+	+	+	+		+
Wormaldia	+	+				
Ecnomidae	+	+	+	+	+	+
Leptoceridae			+			
Lepidoptera						
Petrophila	+	+				+
Coleoptera						
Psephenus	+			+	+	+
Elmidae	+	+	+	+	+	+
Haliplidae				+		
Hemiptera						
Crhyphocricos	+	+		+		
Limnocoris	+					
Belostoma	+					
Gerridae	+	+	+	+		+
Rhagovelia	+	+	+	+	+	
Diptera						
Chironomidae	+	+	+	+	+	+
Simuliidae	+	+	+	+		
Sciomyzidae				+		
Limoniidae	+		+	+	+	+
Culicidae						+
Ceratopogonidae						+
Tabanidae	+					
Odonata Anisoptera						
Gomphidae	+		+	+		+
Libellulidae	+					+
Palaemnema	+					
Odonata Zygoptera						
Haeterina				+	+	
Argia	+	+		+	+	+
Megaloptera						
Corydalus	+	+	+	+	+	+
Decapoda						
Macrobrachium				+	+	+
Tricladida						
Planariidae	+	+	+	+	+	+
Gastropoda						
Lymnaeidae				+	+	+
Ancylidae	+	+	+		+	+
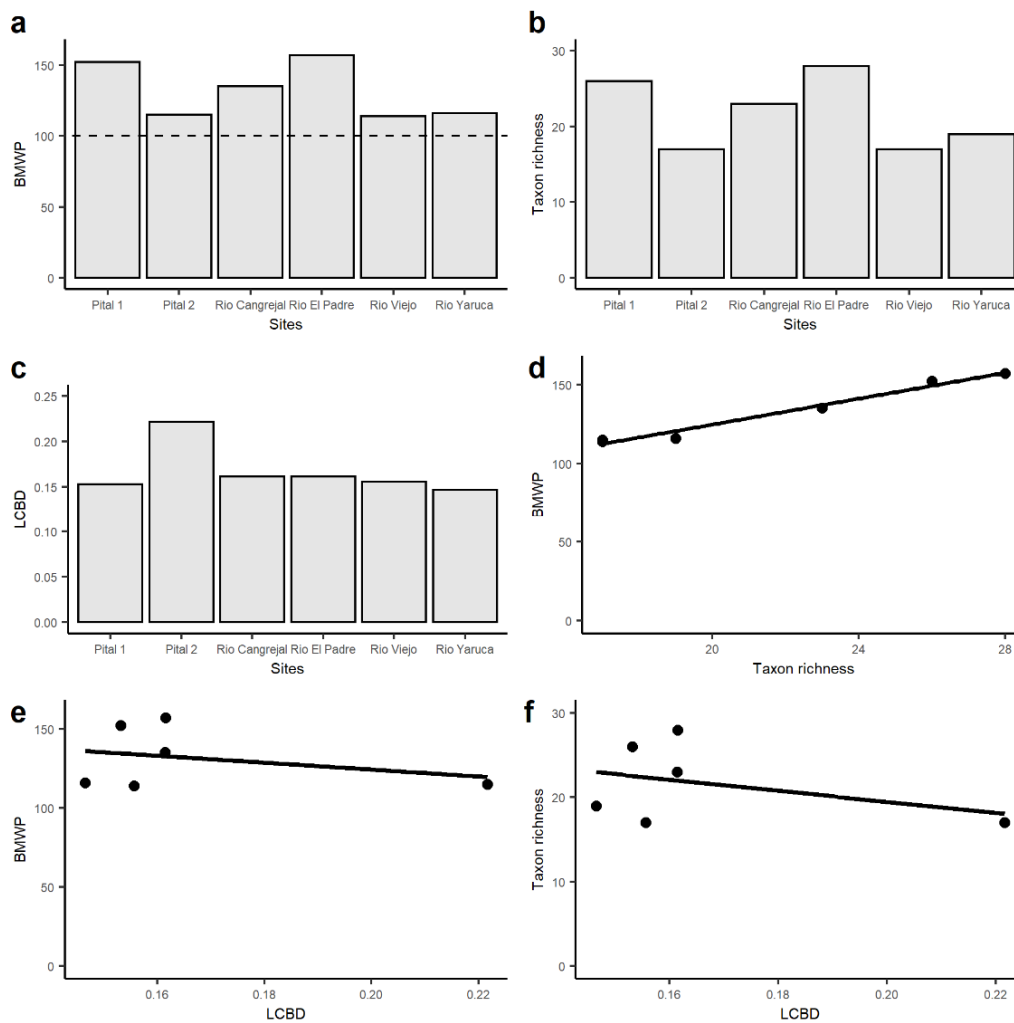
Figure 2. Gray bars represent the following: (**a**) BMWP score, (**b**) total taxon richness, and (**c**) LCBD in all sampling sites. The dashed horizontal line in figure (**a**) indicates the limit between the class I and class II water quality classes, according to the BMWP methodology [20]. (**d**) Correlation between the BMWP and taxon richness; (**e**) correlation between the BMWP and LCBD; (**f**) correlation between the taxon richness and LCBD.

4. Discussion

The development and implementation of effective biological methods for assessing water quality of lotic ecosystems in Honduras, and generally in Central America, is a topic of major importance, considering the growing environmental alteration that affects this region [25,26]. However, to our knowledge, only a few studies have been performed to date [9,27–29].

In this context, this study may represent an interesting benchmark. Although there were significant differences in the BMWP score among sites, our results demonstrated in a rapid and relatively economic way that the medium-upper part of the Río Cangrejal hydrographic network was in very good environmental conditions (i.e., class I according to the BMWP methodology). Moreover, we found a strong and positive correlation between this biomonitoring index and the total taxon richness. This finding assumes a great importance and provides useful applications for conservation strategies at local scale because it demonstrates that water quality is closely associated with biodiversity (i.e., taxon richness). In fact, Río Cangrejal is probably the best and most famous place for rafting and white-water sports in Central America. Thus, it is urgent to promote a sustainable use of running waters to accommodate both the demand for recreational tourism and the conservation of biodiversity. Taxon richness is a widely used diversity metric in ecological

studies on riverine communities [5,30,31] and, when consolidate biomonitoring methods are not available, could be successfully used as a surrogate indicator to assess the water quality [32,33]. Our results corroborate this conclusion and indicate that sites with the highest BMWP scores were also the richest ones.

By contrast, LCBD (i.e., a measure of the ecological uniqueness of the sampling sites) offered weak and less informative results in this study. Similar values of LCBD were observed among sites, with the exception of Pital2, and this indicator was scarcely correlated with either BMWP or taxon richness. These findings differed from those obtained in other studies [34,35]. For instance, Ruhí et al. [36] used LCBD to select protected sites in the Albarine River (France). The poor performance of LCBD in this study may be due to our sampling sites being located in a relatively small and near-pristine area, where differences among benthic macroinvertebrate communities were mainly driven by the gain/loss of taxa, rather than species turnover. This conclusion seems supported by our results on the variation in taxon richness among sites, that, albeit not significant, was higher than LCBD.

5. Conclusions

In Central American countries, the introduction and diffusion of biomonitoring could bring huge benefits, as it would allow quality control for an entire river network in a reliable and relatively inexpensive way. This study represents a first intent to use benthic macroinvertebrates as biological indicators for lotic ecosystems, in particular using the BMWP index, as well as taxon richness, as reliable and economic biomonitoring methodologies. These results can be the basis on which to implement an effective system of biomonitoring and preservation strategy in relation to various physical and chemical alterations in less-studied geographical areas, such as Honduras. Future goals include increasing the knowledge of the benthic invertebrate fauna taxonomy and ecology, creating taxonomic catalogues, dichotomous keys, reliable application methods, training courses, and reference collections. A major challenge is sensitizing local communities, public opinion, and policymakers about the benefits of better river health monitoring.

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