C. R. Biologies xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Comptes Rendus Biologies

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Biodiversity/Biodiversité

# Response of epilithic diatom communities to environmental gradients along an Ecuadorian Andean River

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ARTICLE INFO

*Article history:*
Received 16 January 2018
Accepted after revision 14 March 2018
Available online xxx

*Keywords:*
Eutrophication
Ecuadorian Andean Rivers
Diatom species richness
Diatom trophic values

ABSTRACT

Epilithic diatom communities are particularly suitable for the evaluation of freshwater quality. In Ecuador, however, no water quality index includes this biotic parameter. This work is the first attempt in the country to determine the composition of epilithic diatom communities associated with different degrees of eutrophication. This was accomplished by measuring physical, chemical and microbiological variables at five sampling sites along the Pita River, Ecuador, from August to December 2016. The results indicate a clear gradient of eutrophication from sampling sites P1 (good water) in the upper reaches to P5 (bad water) located in the lower reaches. Concerning diatom analyses, the results indicated a high diversity for tropical areas in terms of species richness, varying from $S = 34$ in headwaters to $S = 42$ downstream. Moreover, the results obtained suggest a lack of concordance with the trophic values given to some of the epilithic diatoms in the literature. There were also species that seem to be sensitive to downstream nutrient increases that were not considered as bioindicators in previous studies. We concluded that the trophic values of diatom species available in the scientific literature are not directly applicable to their sites in the Pita River. Hence, it is necessary to establish a trophic diatom index for the Andean region of Ecuador.

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## 1. Introduction

The majority of urban and rural hydrographic basins are exposed to domestic, farming, and industrial wastes, indicating that the consequences of such effects depend on a complex combination of factors, such as the volume of effluents and the discharge of the receiving water body [1]. Thus, efficient assessment tools capable of detecting the degree of pollution and the tolerance to its effects on the biota are required [2].

Traditional techniques based on physical, chemical and bacteriological characteristics are not sufficient to effectively assess freshwater bodies considering their multiple uses, as they are deficient in evaluating aesthetic, recreational, and ecological conditions [3]. For this reason, integrated quality analyses considering the biological aspects of the system, in addition to the traditional valuation methodologies, are necessary [4].

Among the bioindicator organisms used to evaluate the environmental conditions of lotic systems, epilithic diatoms species are recognized as indicators of organic pollution and eutrophication and have been recommended by studies in many countries as particularly appropriate for evaluating water quality [5,6]. Furthermore, studies of

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https://doi.org/10.1016/j.crvi.2018.03.008
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these communities provide a continuous record of environmental quality, uncovering changes that originate from both natural processes and human actions [7].

Environmental monitoring studies [4,8–10], show that epilithic diatom communities in lotic ecosystems are directly affected by the interaction among variables that characterize organic pollution and eutrophication, two phenomena that cannot be well separated in nature [11,12]. Thus, diatoms are considered to be key organisms for assessing the ecological quality of watercourses and have been used for this purpose for more than a century in several European countries [13,14]. In Latin America, the use of this group of organisms in water quality assessment received little attention until the end of the 20th century. In Argentina, the Pampean Diatom Index [11] is based on studies by Frenguelli that date from 1947. In Brazil, Lobo et al. [15] published the first description of a Brazilian saprobic system, characterizing three differential diatom groups: highly pollution-tolerant species, pollution-tolerant species and less pollution-tolerant species. In Lobo et al. [12], a new trophic water quality index (TWQI) for subtropical and temperate Brazilian lotic systems was developed that assigned trophic values of 1, 2.5, and 4 to species, corresponding to levels of low, medium, and high tolerance to eutrophication, respectively.

In Ecuador, a country of approximately 15 million inhabitants, there are few operative wastewater treatment plants; therefore, organic matter content and nutrient enrichment occur in most of the rivers, particularly in urban areas. This is the case of the Pita River, an Andean stream in the metropolitan area of the city of Quito. Thus, we carried out an ecological assessment in this stream based on epilithic diatom communities and water quality variables. Previous studies have described a marked downstream increase in organic matter content and nutrient enrichment in the Pita River [16,17]. Therefore, a marked downstream increase in eutrophication is expected from the river headwaters to lower populated zones. In this context, we aimed to test the hypothesis that diatom communities undergo changes in species composition along a downstream gradient of increasing eutrophication and organic pollution. Sensitive species at upstream reaches will be gradually replaced by more tolerant species. This will be the initial step to create for the first time in Ecuador a trophic index based on epilithic diatoms.

## 2. Materials and methods

### 2.1. Study area

The Pita River basin is located in the southern part of Pichincha province, approximately 20 km south of Quito, capital of Ecuador (Fig. 1). The highest part is located on the slopes of the Cotopaxi volcano (5897 m a.s.l.), and the lowest occurs at the confluence of the Pita and San Pedro Rivers (2440 m a.s.l.) [17]. It has an elongated shape in the south–north direction, with an extension of 100,823 hectares.

Altogether, five sampling stations were selected along the basin, and the following codes were given: stations P1 (GPS location: 785543; 9945002; 3,368 m a.s.l.) and P2 (GPS location: 786886; 9949659; 3,052 m a.s.l.) in the upper reaches, station P3 (GPS location; 787192; 9963951; 2558 m a.s.l.) in the intermediate lower reaches, and stations P4 (GPS location: 783151; 9966850; 2463 m a.s.l.) and P5 (GPS location: 782373; 9967924; 2,462 m a.s.l.) in the lower reaches (Fig. 1). Data were taken with a navigator GPS (WGS 84 UTM Zone 17 with 5 m of precision). The sampling design aimed to capture the variation among the different reaches of the hydrographical basin. All sampling stations were located in the municipality of Sangolquí. P1 and P2 are surrounded by paramo vegetation, meanwhile P3 is located in the pastures area P4 and P5 are located in farming and urban areas, respectively. Exhaustive information of the upper part of the Pita River basin could be found at Muñoz [18]. To visualize the stations on google maps a link is provided in Fig. 1.

### 2.2. Sampling and analysis of samples

Samples of epilithic diatoms and water from the Pita River were taken to evaluate the physical, chemical, and microbiological variables in August, October, and December 2016. The physical and chemical variables analyzed were water temperature, pH, turbidity, dissolved oxygen (DO) and conductivity, which were measured in the field with a HACH© Multiparameter analyzer, and biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen and phosphate, which were measured in the laboratory using the HACH method [19].

Epilithic diatoms were collected at the five sampling stations. The diatom samples were scrubbed off the upper surface of three stones that were 10 to 20 cm in diameter using a toothbrush and were fixed with formalin following the method described by Kobayasi and Mayama [20]. The samples were cleaned with sulfuric and hydrochloric acids and mounted on permanent slides with Pleurax® (Wako Pure Chemical Industries, Tokyo, Japan). To calculate the relative abundances of the species, all the organisms found along random transects across the prepared permanent slides were identified and counted, with a minimum of 600 valves, using a Leica DM750 light microscope. The species with a number of individuals above the mean (number of species divided by the total number of individuals) were considered abundant species, following the criterion proposed by Lobo and Leighton [21]. For species identification, the following taxonomic references were used: Lobo et al. [22,43], Metzelin and García-Rodríguez [23], Metzelin and Lange-Bertalot [24], Metzelin et al. [44] and Rumrich and Lange-Bertalot [25]. The permanent slides are stored in the Herbarium at the Department of Limnology, International University SEK, Quito, Ecuador.

### 2.3. Data analysis

For environmental analysis, the evaluation of water quality was conducted using the water quality index (WQI) adapted for south Brazilian lotic systems by Moretto et al. [26]. To calculate the WQI, the software IQAData was used

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