A STUDY OF BIODIVERSITY AND WATER QUALITY BY ANALYSING AQUATIC MACROINVERTEBRATES IN THE PASOCHOA WILDLIFE REFUGE, ECUADOR

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Abstract. The Province of Pichincha, Ecuador is home to the calderas and flanks of the Pasochoa volcano, where the Pasochoa Wildlife Refuge (RVSP for its Spanish acronym) is located. This area is one of the few places that conserves some of the most important remnants of the Andean native forest. This study seeks to determine the biodiversity and water quality of the Pasochoa Wildlife Refuge by studying its aquatic macroinvertebrates. The data for this work were obtained from five sampling points located between the caldera and outside the RVSP. This effort was carried out along the stream that descends from the Pasochoa volcano at an altitude of 3014 meters above sea level (masl) to 2667 masl. Water samples were also obtained for a physical-chemical analysis. Preliminarily, a total of 6149 invertebrates, corresponding to 3 phyla, 10 orders and 36 families, were captured as indicators of water quality. The most abundant phylum was Arthropoda, with 6130 individuals. Additionally, specimens of annelids and mollusks were recorded. The greatest abundance was recorded for the families of Elmidae (Coleoptera) and Leptoceridae (Trichoptera), with 2059 and 1071 individuals, respectively. According to the families that indicate water quality, it fluctuates between very good to regular in PMM-01, which is an area with anthropic influence.
Keywords: *environmental indicators, water quality, species richness, abundance, environmental quality*

Introduction

Modelling the environment and water resources are essential to improve and protect water quality (Eurie et al., 2015; Forio et al., 2016). Today, water monitoring has become particularly important due to the increasing human activity that often leads to water quality deterioration (Yillia et al., 2008; Holguin-Gonzalez et al., 2013; Kibena et al., 2014). Selecting the right indicators for monitoring has become essential and often the most challenging task of environmental studies and applied conservation science (Game et al., 2016). We have chosen macroinvertebrates for determining water quality considering that they are well-known indicators in environmental monitoring and assessment worldwide (Forio et al., 2016).

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The Pasochoa Wildlife Refuge (RVSP) is located in the caldera and in the flanks of the Pasochoa volcano, in the province of Pichincha, Ecuador. This area is one of the few places that conserves some of the most important remnants of the Andean native forest.

According to our bibliographic review, quantitative-type floristic investigations have been carried out within the protected area, such as those by Valencia and Jorgensen (1992), while other studies have consisted of rapid sampling where physical backups are not available. In terms of fauna, bird lists have been compiled by Sierra (1996), and the baseline list was recorded by Fundación Natura (1990). Studies referring to both terrestrial and aquatic insects are practically nonexistent for the sector. According to the map of vegetal coverage by the MAE (2013), the vegetal formation is a high-altitude evergreen mountain forest in the northern part of the Eastern Cordillera of the Andes. Its altitude range is from 3000 to 3700 masl, and the grassland of the moors ranges from 3400 to 4300 masl. The area has an average annual rainfall of 1200 mm, an average annual temperature of 10°C and a relative humidity that is almost higher than 80% (Valencia and Jørgensen, 1992).

In this study, aquatic macroinvertebrates were used as indicators of environmental quality. Aquatic macroinvertebrates have received much attention in studies regarding the ecosystems of running waters because they are transformers and integrators of allochthonous organic matter (leaves, seeds, branches, fallen trunks, etc.), the main inflows of energy to the fluvial systems and useful biological indicators.

Materials and methods

The Pasochoa Wildlife Refuge is located in the Province of Pichincha, Cantón Mejía, in the parish of Uyumbicho, Ecuador. It contains 520 hectares, which are covered mostly by Andean forest and, to a lesser extent, by herbaceous moorland. For the sampling points, the area of the caldera was prioritized because it is a pristine area, has been conserved and contains remnants of a mature forest. The second sampling point corresponded to the area outside the wildlife refuge where anthropic influence exists due to the presence of livestock and pastures. Then, the two areas were compared and evaluated. The data for this work were obtained from five sampling points along the stream that descends from the Pasochoa volcano from an altitude of 3014 to 2667 masl. The sampling points can be seen in *Figure 1* (López-López and Sedeño-Díaz, 2014).

The macroinvertebrates were collected through a “Surber” network in five sampling points (*Fig. 1*) along a 100 m-long transect according to the proposal of Roldán (2003) (Brito and Pinto, 2014). At each sampling point, we examined the riverbed of each body of water for a lapse of one minute to capture the existing macroinvertebrates, covering all possible microhabitats (riparian vegetation, sandy areas, rocky areas and algae). In addition, the ecological quality protocols for Andean rivers that were proposed by Encalada et al. (2011) were applied (Damanik-Ambarita, 2016; Carter, 2017; Mariadoss and Abril, 2015).

The samples were cleaned to later extract the macroinvertebrates and deposit them in correctly labeled plastic containers with 70% alcohol. Field work was executed following the rules and regulatory guidelines outlined by the Environment Ministry’s research permit.

To determine aquatic invertebrates, which were deposited in the aforementioned containers, the specimens were separated and identified at the family taxonomic level according to the protocols proposed by Encalada et al. (2011). To identify the

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invertebrates, we used the taxonomic keys of Fernández and Dominguez (2009). The invertebrate collections will be displayed in the Gustavo Orcés Natural History Museum at the Escuela Politécnica Nacional, under patent No. 04-2014-FAU- DPAP-MA (Knowl, 2016; Stancheva and Seath, 2016).

The analyses related to the abundance, diversity, and species accumulation curves were performed according to Colwell (2006) and Oksanen, 2015 using the EstimateS 8.2.0 programs and PAST (Paleontological Statistics version 1.12) according to Hammer et al. (2003).

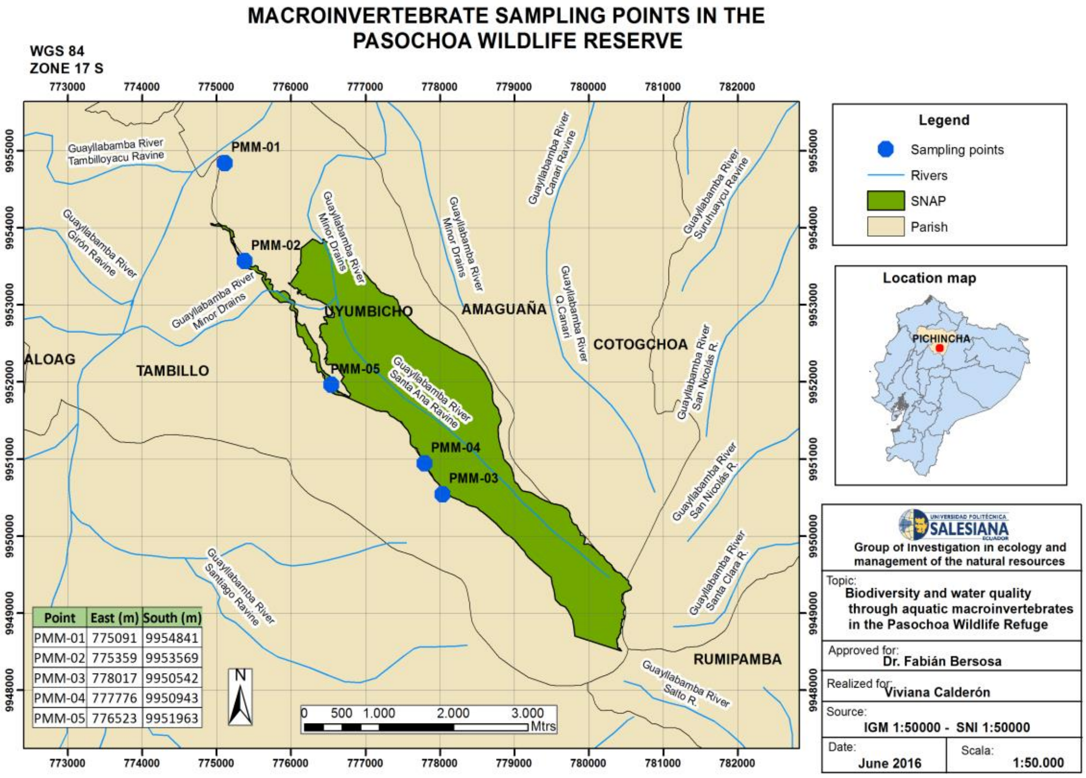

Figure 1. *Sampling points for macroinvertebrates in the Pasochoa Wildlife Reserve. "PPM-01" = Point 1; "PPM-02" = Point 2; "PPM-03" = Point 3; "PPM-04" = Point 4; "PPM-05" = Point 5; "Este" = East; "Sur" = South. Legends: "Puntos de muestro" = Sampling point, marked with blue dots; "Ríos" = Rivers, marked with green line; "Parroquias" = Parishes*

The analyzed parameters were divided into two groups. The first group is related to finding out the level of intromission of human effluents, such as gray and black waters, discharges from tourism or agriculture, and so on. Here, we measured the 5-day dissolved oxygen, Biochemical Oxygen Demand (BOD5), phosphorus, ammonia, nitrate and nitrite, the last three of which are indicators of pollution temporality (Cheeme, 2018). The second group of indicators focused on change in water quality due to human or natural causes. The indicators used were pH, calcium hardness, turbidity and total solids. The presence of calcium hardness, increased BOD5 and decreased dissolved oxygen could be the result of diffuse soil contamination from fertilizers (Schahrakane, 2018).

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Results

A total of 6149 invertebrates were captured, corresponding to 3 phyla, 10 orders and 36 families, that indicate the water quality. The most abundant phylum was Arthropoda, with 6130 specimens. Additionally, specimens of annelids and mollusks were recorded (*Table 1*).

The greatest abundance was recorded in the families of Elmidae (Coleoptera) and Leptoceridae (Trichoptera), with 2059 and 1071 individuals, respectively. The greatest abundance was recorded in Point 5.

Table 1. *Diversity and abundance*

Parameter	Point 1	Point 2	Point 3	Point 4	Point 5
Taxa_S	11	20	20	27	29
Individuals	197	253	465	2468	2766
Dominance_D	0.3141	0.1245	0.1764	0.2585	0.2303
Simpson_1-D	0.6859	0.8755	0.8236	0.7415	0.7697
Shannon_H	1383	2.35	1999	1792	1888

The determination of the quality of water in the sector by means of physical chemical parameters has not been done previously, but as regards the diversity in the present study, 3 phyla, 10 orders and 36 families were found in front of the study by Gallegos, 2013, which mentions 4, 13 and 34 respectively

Low values of dissolved oxygen were observed for all points, which are not due to temperature but to the existence of an organic load from three thousand meters high. This is corroborated by the BOD5 measurements that are accentuated in Point 4, where it reached 36 mg/l. With these levels of dissolved oxygen, fish cannot exist. From Point 2 onwards, there is a continuous presence of ammonia, which causes the depletion of dissolved oxygen and an increase in the nitrogen-bearing BOD5, which is oxidized slowly into nitrate and quickly into nitrite.

The increase in BOD5 and calcium hardness and the decrease in dissolved oxygen demonstrate the diffused intrusion of runoff water from crops with agrofertilizers.

The pH is basic, probably due to the type of riverbed in the upper part of the volcano, which decreases downstream. Turbidity increases as the water descends; the same is true for solids in the water, probably because of erosion and an increase in the organic load.

Current water quality does not present levels of eutrophication, but its decontamination is required for the water habitable by fish, and safe for human use. The results of the analyses, location and distance between the points are presented in *Table 2*.

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Table 2. *Results of the water quality analysis*

Parameter	Point 1	Point 2	Point 3	Point 4	Point 5
Altitude (masl)	3,014	2,995	2,864	2,718	2,667
Length from the previous point (m)	0	464	1,618	1,983	1,339
Dissolved oxygen (mg/l)	2.3	2.3	3	1	0.9
BOD5 (mg/l)	1.9	0.9	2.16	36	7.2
Total phosphorus (mg/l)	0.4	0.4	0.4	0.5	0.4
Ammonia (mg/l)	0	0.01	0.09	0.07	0.57
Nitrate (mg/l)	0	0	0	0	0
Nitrite (mg/l)	14	10	13	9	19
pH	8.35	8.82	8.5	8.1	7.41
Calcic hardness (mg/l)	0.38	0.63	1.09	0.79	1.3
Turbidity (NTU)	1.5	2.29	0.93	3	4.28
Total solids (mg/l)	0.06	0.06	0.07	0.08	0.1

Conclusions and recommendations

Values of BOD5 vary between 0.9-36 mgL^{-1} in our study that are comparable to other study (Naciph, 2016) findings (BOD5 vary between 5-40 mgL^{-1}) where San Pedro River was analysed. It is reassuring that the diversity and abundance values in our study are significantly higher than the values in Naciph's study where the same method (Encalada et al., 2011) was applied for specimens separation and for family taxonomic level identification. In our study 36 families were detected, while in Naciph's study only 12. This is due to the sad fact that San Pedro River is highly contaminated (FONAG, 2011) and can not be used for irrigation without pre-treatment (Naciph, 2016).

To aid reader understanding in the topic our preliminary study should be extended to other study areas, such as the lower part of the volcano, where areas of influence, such as cattle, urbanisation and plantations, exist.

According to the families that indicate the quality of water, the water quality fluctuates between very good to regular in Point 2, which is an area with anthropic influence. The current water quality does not present levels of eutrophication, but decontamination is required for the water to be safely used by humans.

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APPENDIX

Abundance of the different families within the sampling points

Order	Family	Point 1	Point 2	Point 3	Point 4	Point 5	Number of individuals
Oligochaeta	N.d	2	16	1			19
Amphipoda	Hyalellidae	3	50		30	31	114
Coleoptera	Dytiscidae		1		3	1	5
Diptera	Elmidae	1	6	80	1006	966	2059
	Ptilodactylidae		3	2	1	3	9
	Scirtidae	1	26	3	29	11	70
	Staphylinidae				6	3	9
	Blepharoceridae				2	4	6
	Ceratopogonidae	4	51	22	50	50	177
	Chironomidae	36	25	124	117	163	465
	Culicidae			1			1
	Dixidae					1	1
	Empididae		1				1
	Limoniidae		4		4	8	16
	Muscidae				1	5	6
	Psychodidae		1		4	6	11
	Simuliidae	83	29	76	30	16	234
	Tabanidae			5	41	35	81
	Tipulidae	2	14	25	678	368	1087

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Ephermeroptera	Baetidae	63	13	96	121	122	415
	Leptohyphidae	1		1	35	69	106
	Leptophlebiidae	1			1	1	3
Heteroptera	Veliidae		1				1
Hydracarina	N.d		2				2
Plecoptera	Perlidae		1	1	12	26	40
Trichoptera	Anomalopsychidae		5	2	19	28	54
	Glossosomatidae				1	3	4
	Helicopsychidae			2	9	7	18
	Hidropsychidae			5			5
	Hydrobiosidae			1	1		2
	Hydropsychidae				6	9	15
	Hydroptilidae			4		14	18
	Leptoceridae		2	13	256	800	1071
	Limnephilidae				1	11	12
	Odontoceridae			1			1
	Philopotamidae				4	4	8
Veneroidea	N.d		2				2
Basommatophora	Limnaeidae					1	1
Total:		197	253	465	2468	2766	6149

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