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Quality of the aquatic environment and diversity of benthic macroinvertebrates of high Andean wetlands of the Junín region, Peru

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ABSTRACT

The objective of this study was to evaluate the quality of the aquatic environment and diversity of benthic macroinvertebrates of high Andean wetlands in the Junín region, Peru, between March and December 2017. Samples of water and benthic macroinvertebrates were collected from 22 sampling sites during the rainy season and low water. The physical-chemical indicators of water quality determined in situ were: DO, DTS, EC, temperature and pH. The results obtained reveal that the physical-chemical and bacteriological indicators are within the environmental quality standards for water, except COD and BOD_5. Regarding the benthic macroinvertebrates, four phyla were identified, the most representative being the phylum Arthropoda in abundance and taxa richness. Therefore, according to the sampling period, highly significant differences were detected ($p < 0.01$) for conductivity, COD, temperature, nitrates and thermotolerant coliforms, and significant differences ($p < 0.05$) for DTS. According to the wetland, 100% of the indicators showed high significant differences. In addition, 70% of the indicators presented interaction according to sampling season and wetland. The greatest abundance and dominance were recorded in the Tragadero wetland and the greater richness, diversity and equitability of taxa in the Pomacocha wetland.

Introduction

High Andean wetlands are fragile – Multifunctional ecosystems with a high degree of environmental heterogeneity (Guswa et al., 2014). This complexity is favored by the diverse interactions and transitions between climate, geomorphology, precipitation, water flow and its river's systems (Alvial et al., 2012). However, the health of these ecosystems is affected by various anthropogenic pressures (Van Ael et al., 2015; Chapman et al., 2016) both in their structure and in the services they provide; groundwater recharge, water retention of flood, contributions of base flow, biogeochemical processing, improvement of water quality and wildlife habitat (Jackson et al., 2016).

The increasing deterioration that these ecosystems are experiencing due to pollution problems is leading to their degradation both globally and in basins (Quesnelle et al., 2015). At the global level, the extent of wetlands, especially in South Asia and South America, has fallen by 6% in just 14 years (from 1993 to 2007) due to the cumulative effects of economic development (Noble et al., 2011; Ball et al., 2013). These changes have generated in recent decades the need to evaluate and better manage the direct, indirect and potentially induced effects on wetlands (Burgin, 2010; Wohl et al., 2015).

Developed countries who are aware that the permanence and quality of water are factors that affect the functioning of ecosystems, have implemented water policies in their legislation (Liu et al., 2012). In Europe, Strategic Framework Directives such as the Water Framework, Basin and Marine Water Quality Directive have been implemented in 2000 (WFD, 2000/60/EC), 2006 (QBWD, 2006/7/EC) and 2008 (MSFD, 2008/56/EC), respectively (Petus et al., 2014). While in developing countries, water supply and treatment are the most important issues and account for the majority of investments in water management (Perrin et al., 2014). However, in practice, <20% of all wastewater effluents are treated before being discharged to water bodies (Alvarez-Mieles et al., 2013).

Peru is a country with a strategic location for water resources, but like many other countries, it faces problems of water availability due to the growth of population densification and pollution problems (Eda and Chen, 2010). The projections of future water

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shortages in the tropical Andes of the world are increasingly alarming. The models forecast water deficits for decades of the future in this part of the South American continent, where the recession of the glaciers is a great concern. However, conflicts have already arisen in some Peruvian river basins, not only because of the problem of water availability and the contraction of alpine-type wetlands (Bury et al., 2013; Bury et al., 2013; Bury et al., 2013) but also because of the great alterations that are causing the anthropogenic pollutants.

The biological evaluation of water quality has been implemented for many years complementing the physical-chemical indicators, with the benthic macroinvertebrates being the most frequently used groups, since they offer a range of responses to different degrees of environmental stress throughout the time (Nguyen et al., 2014; Sundermann et al., 2015; Pacioglu and Moldovan, 2016). The use of benthic macroinvertebrates to assess the ecological status of water bodies has become one of the main components of water-related legislation around the world (Couceiro et al., 2012; Lewin et al., 2014; Melo et al., 2015; MacEdo et al., 2016), generally through several indices, many of them are based on taxa richness, as the simplest and most common measure of biodiversity (Ramos-Merchante and Prenda, 2017).

Overall, the quality of the aquatic environment of freshwater wetlands has not received attention proportional to the wide distribution of this type of ecosystem. Further, at present, the response of benthic macroinvertebrates to different environmental stressors is a widespread practice for evaluating the quality of water and habitat. Hence, a more integrated knowledge of the various processes of wetlands is necessary to make judgments about the likely effects of a series of impacts. In this sense, the present study has as general objective, to evaluate the quality of the aquatic environment and diversity of benthic macroinvertebrates of high Andean wetlands of the Junín region, Peru, between March and December of 2017.

Materials and methods

Study area

The Mantaro river basin is located in the Central Andes of Peru, between latitudes: 10° 34′ S–13° 35′ S and longitudes: 73° 55′ W–76° 40′ W. The Pomacocha wetland is located in the area that goes to Comas at an altitude of 4543 m above sea level (18L 472578.8928E 8697395.1004N), Cuncancocha in the area that goes to the Nor Yauyos Cochas landscape reserve at 4503 m above sea level (18L 489222.4805E 8668292.9936N), Incacocha and Ñahuinpuquio located in the province of Chupaca at 4425 masl (18L 417879.0000E 8669608.0000N) and 3379 masl (18L 463170.9300E 8665411.6800N), respectively, and Tragadero located in the province of Jauja at 3471 masl (18L 441749.7040E 8698909.4474N). The vegetation in these ecosystems is very diversified herbaceous, both in temporary and permanent species, with erect and stunted growth, and very particular and specific morphological characteristics. The most representative families are Poaceae, Asteraceae, Cyperaceae, Plantaginaceae, Caryophyllaceae, Apiaceae, Geraniaceae, Ranunculaceae, Gentianaceae, Rosaceae, Isoetaceae, Polygonaceae, Fabaceae, Oxalidaceae and Juncaceae.

The productive activities in the high Andean wetlands are associated with the altitudinal floor. In the Puna, Jalca and Moor areas, the predominant activities are: cattle, sheep and camelid cattle raising, mining and fishing. As subsistence activity is the extraction of plants and peat as fuel, since a large part of the rural population depends on firewood for cooking their food. At lower altitudes, potato and other tuber crops and Andean cereals are grown. The water bodies of the Pomacocha, Incacocha and Cuncancocha wetlands are used for intensive cultivation of *Oncorhynchus mykiss*, Ñahuinpuquio for boat tourism and Tragadero for bird tourism. In these latter two wetlands, urban expansion in the surrounding area is predominant and therefore the generation of urban wastewater (Fig. 1).

Collection of water sample and physical-chemical and bacteriological analysis

Water samples and benthos were collected at 22 sampling sites, during the rainy season in the high Andes (January, February, March and April) and the dry season (May, June, July and August). The physical-chemical indicators determined in situ in each wetland were: dissolved oxygen (mg/l), total dissolved solids (mg/l), conductivity (μS/cm), temperature (°C) and pH. These determinations were made directly in the waters of each sampling site, using Hanna Instruments portable equipment. Also, water samples were collected at a depth of 20 cm in sterile glass jars; previously labeled, treated with a 1:1 hydrochloric acid solution and rinsed with distilled water, for bacteriological, nitrate, total phosphorus, COD and BOD_5 analyses. On-site determinations of physical-chemical indicators and collection of water samples were performed by quadrupling at each sampling site. The preservation and transport of water samples to the laboratory for further analysis were carried out according to the standard method (APHA/AWWA/WEF, 2012).

The determination of thermotolerant coliforms was performed using the method of the most probable number by the multiple tube dilution technique. The biological oxygen demand (BOD_5) was determined using the Respirometric method with the OxiDirect Lovibond equipment. Nitrates (mg/L) and phosphates (mg/L) were determined with the PC-MultiDirect photometer, according to the procedure accepted by the United States Environmental Protection Agency (USEPA, 1983).

Benthic macroinvertebrate collections

The collection of sediment for benthic macroinvertebrates was carried out at the sites defined by the Hydro-Bios Ekman-Birge dredge. One kilogram of sediment was collected from each sampling site. Next, 5% formaldehyde was added to each of the samples for preservation and subsequent identification in the laboratory. Taxonomic identification of benthic macroinvertebrates was performed at the family level through a trinocular stereomicroscope. Finally, the identified benthic macroinvertebrates were fixed with 70% alcohol and form part of the water macrofauna collection of the Water Research Laboratory (Huamantinco and Ortiz, 2010).

Analysis of data

In order to evaluate the quality of the aquatic environment with adequate efficiency, the surface water quality and the diversity of taxa of benthic macroinvertebrate communities were determined. To do this, multivariate statistical methods were used, such as multiple variance analysis (MANOVA), correlation analysis and cluster analysis (Everitt et al., 2011).

Multiple variance analysis

To detect the difference between physical-chemical indicators between wetlands, the generalized linear model was used by multiple variance analysis without interaction for electrical conductivity-EC, biochemical oxygen demand-BOD_5 and dissolved total solids-DTS; and with interaction for the variables pH, chemical oxygen demand-COD, dissolved oxygen-DO, temperature, nitrates and total phosphorus. The model was decided according to the significance or not of the interactions, being: