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Diversity of aquatic macroinvertebrates and water quality of the High Andean wetlands of Chalhuanca, Arequipa-Peru

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ABSTRACT Water quality is an issue of global concern because of the evident contamination of the sources of this resource. In recent decades the study of inland waters has been oriented towards the recovery and conservation of these ecosystems, in this sense abundant studies were carried out in lotic systems, and to a lesser extent in lentic systems and in a much more reduced way in high Andean wetlands. This work represents one of the few carried out in high Andean ecosystems, and lentic such as are the Chalhuanca bofedales. The high Andean wetlands of Chalhuanca provide important ecosystem services, among which stand out the water regulation, water reservoirs, and endemic species habitats. The aim was to assess water quality in the high Andean wetlands of Chalhuanca (Arequipa) using macroinvertebrate bioindicators. Samples were taken during the wet season (January) and dry season (June) in 2018; 2 sampling methods were used, Surber net for river and D-frame net for bofedal. Individuals were identified until genus in most cases through taxonomic guides. Biotic quality was determined using the BWMP/Bol, ABI and nPeBMWP indexes; physicochemical parameters were also evaluated in each study site. We found 6 phylum, 10 classes, 18 orders, 26 families and 33 taxa. According to biotic index, sampling sites presented water quality from critical or bad to acceptable. The physicochemical parameters were found in the range set by the ECAs of D.S.004-2017 MINAM, except the dissolved oxygen, which in the most study sites was lower than the established for water intended for conservation of the aquatic environment. Regarding diversity, it was found that it was greater in the dry season both in the river and in the bofedal, however, the abundance varied, finding greater abundance in bofedales in the wet season and greater abundance in the river in the dry season. The high Andean wetlands of Chalhuanca present a limited diversity of macroinvertebrates families and a regular water quality in most sampling sites.

KEY WORDS Water quality; pollution; wetlands; peatland; macroinvertebrates.

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INTRODUCTION

Bofedales are a type of high Andean wetland that in Peru are located at 3800 meters above sea level and are mainly in the southern and central zone of the country with an area of approximately 548 174 ha (0.42% of the national area) (Ministerio del Ambiente [MINAM], 2019). They are a kind of natural grassland with high forage potential and permanently moist soil (Asociación Integral de Ganaderos en Camelidos de los Andes Altos, 2001), which is located in the paramo, jalca and puna bioregions; associated with rivers, lagoons, streams, springs and meltwater (Convention Ramsar & Grupo de Contacto EHAA, 2008).

These ecosystems play an important role in the development of the Andean basins. Currently, three important types of environmental services offered by bofedales have been identified: the environmental service of providing water to the human communities living in their surroundings; the storage of water in the soil of bofedales acting as a large natural reservoir that regulates the flows of the hydrological cycle, reducing the negative consequences of variations; and finally the environmental service of storing carbon in the soil of bofedales (Quintero, 2010).

Water quality control in aquatic ecosystems has been performed for a long time by means of physicochemical analyses that only provide immediate water quality values and are therefore not sufficient to define the quality of the aquatic environment (Roldán, 1992). When the normal physicochemical values and biological parameters of water are exceeded, it can affect health and the environment (MINAM, 2010).

Nowadays there are bioindicators used as effective tools to measure the ecological quality of water bodies, among them the aquatic macroinvertebrates stand out because of the benefits of their use as integrative tools (Bonada et al., 2006). As mentioned by Forero & Reynoso (2013: 381): "*The integration of ecological, biotic and physicochemical indexes allows the determination of water quality in a more accurate and exact way, since it generates a more holistic approach to the state of water bodies*".

There is a variety of unimetric index for measuring the biological quality of wetlands, one of the most widely used is the Biological Monitoring Working Party (BMWP) developed in the United Kingdom (Hellawell, 1978), which has been adapted for each country in the American continent. The BMWP index has been disseminated as a simple, fast and low-cost method of assessing water quality using families of aquatic macroinvertebrates (Rosas et al., 2014).

Despite the importance of bofedales, now they are considered as ecosystems that are losing their ability to provide environmental services like drainage consequences, urbanization, pollution and different ways of intervention. The present study represents one of the few jobs worked in this kind of ecosystem in Peru, in addition to its importance of being head of the sub basin of Chili river from one of the main cities in southern Peru. The purpose of this study is to know about the aquatic macroinvertebrates diversity through ecological indexes and the water quality of the high Andean wetlands of Chalhuanca through BMWP, ABI indexes and physicochemical parameters, generating documented information about the current status of these wetlands in order to establish a baseline that will contribute to the monitoring, management and conservation of these important ecosystems.

MATERIAL AND METHODS

Study area

The town of Chalhuanca (15°43'2.51"S and 71°19'9.92"W) is located at 4 338 meters in Yanque district, Caylloma province, Arequipa, Peru; and is part of the buffer zone of the Salinas and Aguada Blanca National Reserve. In this zone we can find the bofedales that receive the same name from the town, which are related to the source of the Chalhuanca River that determines a big part of the hydrology of the area, crossing the pampas of the Chalhuanca population center, part of the Quilca River (Sumbay - Siguas) hydrographic basin (Mango, 2017).

Climatic and vegetation characteristics of the Chalhuanca wetlands

The weather is typical of dry puna in Peru, with an average annual temperature recorded in the area between 2012 to 2016 was 5.25 °C. on wet season

and 2.12 °C. on dry season, with precipitation values of 476.12 mm on wet season and 8.74 mm on dry season (Ramos, 2018). Months of highest precipitation are from January to March, constituting 65% of the annual total; the relative humidity of the area does not exceed 50% (Coaguila et al., 2010). The plant composition is typical of a bofedal for this locality, where the most representative species are *Distichia muscoides*, *Plantago rigida* and *Oxichloe andina* (Choque, 2017).

Sample design

The selection of the sampling sites was made on an area of 278 ha. A non-probabilistic sampling was used for convenience (Otzen & Manterola, 2017), establishing 8 sampling sites, 4 for the bofedales and 4 for the Chalhuanca river (Table 1). Sampling was done during wet (January) and dry (June) seasons of 2018.

Macroinvertebrate sampling

About bofedales, the proposed methodology in the manual of collection methods for biological communities was followed (Universidad Nacional Mayor de San Marcos & Museo de Historia Natural [UNMSM], 2014), where a D-net type network with a mesh opening of 500 µm was used, with two-meter sweep of the vegetation margin and another sweep in the middle of the water body, replications were made in underlying and similar water bodies in the area. For the river habitat, a Surber net (30 x 30 cm) with a mesh opening of 500 µm was used, which was placed on the bottom and against the current, the replicas were separated by a distance of 100 meters (UNMSM & Museo de Historia Natural 2014). Sampling was always started upstream.

A total of 45 samples in two seasons studied were obtained, 24 samples in the river and 21 in bofedales. From 24 river samples, 12 of them are from wet season and 12 of them from dry season. In bofedales, 21 samples were obtained, 12 from wet season and 9 from dry season (it was not possible to take samples from the B2 site this year because the water body suffered from drying out). Each sample was stored in 500 ml plastic bottles and preserved with 5% formaldehyde, recording data on habitat, date of sampling, collector, and later processed in the laboratory. The physicochemical parameters were recorded in situ prior to taking biological samples, always taking data in triplicate to minimize measurement error, using a multiparametric sensor called Hanna HI9829. The main variables measured were pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS) and temperature (T°).

Sample processing

Bofedal sample processing, the methodology recommended by Central Plains Center for BioAssessment (2005) was followed. The sample from each bottle was homogenized, placed in a 30 x 20 cm tray, a grid of 20 squares of equal dimension was introduced; then a sub-sample of 4 squares chosen at random (20 % of the sample) was extracted. The subsamples were examined using a stereo microscope; the values obtained were extrapolated to the total sample. Instead, river samples were reviewed in their entirety (100% of the sample).

For taxonomic identification of aquatic macroinvertebrates, the taxonomic keys of Domínguez & Fernández (2009), Merritt et al. (2008), Huamantinco & Ortiz (2010) and Thorp & Covich (2015) were used, trying to classify the organisms up to the most specific level possible.

Data analysis

Specific richness data were used, which is represented by the number of taxa found per sampling site. Abundance was determined as the number of individuals per taxon found at each sampling site

Site		Altitude (m asl)	Geographical coordinates	
Bofedal 1	B1	4350	15°41'40.71" South	71°18'38.32" West
River 1	R1	4350	15°41'40.09" South	71°18'40.20" West
Bofedal 2	B2	4345	15°42'31.85" South	71°18'54.71" West
River 2	R2	4342	15°42'31.73" South	71°18'51.57" West
Bofedal 3	B3	4328	15°43'58.96" South	71°19'51.34" West
River 3	R3	4328	15°44' 0.04" South	71°19'46.63" West
Bofedal 4	B4	4316	15°45'12.50" South	71°20'12.77" West
River 4	R4	4317	15°45'12.91" South	71°20'10.55" West

Table 1. Geographical location of sampling sites in the high Andean wetlands of Chalhuanca, Arequipa-Peru.

(Moreno, 2001). Diversity for each study season was calculated with the first order True Diversity index (1D) using the value of the Shannon-Wiener index with natural logarithm for transformation (Jost, 2006), because with this index the variation becomes more evident, since the results are given in number of effective species, besides improving their understanding, since the number of effective species allows the comparison of the magnitude of the difference in diversity of two or more communities (Moreno, 2001). The Dominance Index (D) and Pielou Equity (J') were determined (Moreno, 2001), also the similarity index based on the Bray Curtis distance using the UPGMA linkage method (Moreno, 2001). To calculate those indexes we used statistical packages SPSS 25 and Past 3.25 (Hammer et al., 2001).

Finally, Mann-Whitney U test was applied to determine if there are differences in the abundance distribution between wet and dry seasons; the analysis was applied separately for each type of habitat (bofedales and river).

Determination of water quality

Due to our study location, we used three adapted indexes for ecosystems located at more than 2,000 meters asl. These were BMWP/Bol (Ministerio del Medio Ambiente y Agua, 2011), ABI (Acosta, Ríos, Rieradevall & Prat, 2009) and nPeBMWP (Medina et al., 2010). Each sampling site was categorized based on the sum of the scores assigned for each index. The data of the physicochemical parameters obtained were evaluated for each season according to the national legal regulation of Peru, environmental quality standards (ECA)-category 4: water destined to the conservation of the aquatic environment (MINAM, 2017).

RESULTS

Macroinvertebrate richness and diversity

Abundance of Macroinvertebrates in the Chalhuanca wetlands was made up of 69,782 individuals for seasons and habitats evaluated, where it was represented by six phylum, ten classes, 18 orders, 26 families and 33 taxa (Table 2). For both habitats a total of 29 taxa were recorded on wet season and 31 on dry season. In bofedales 31 taxa were found and 29 taxa in the river. Regarding macroinvertebrates composition, 27 taxa were found to be shared in both habitats, including *Andesiops* Lugo-Ortiz & McCaffwerty, 1999, *Hydroptila* Dalman, 1819, *Cricotopus* van der Wulp, 1874, *Helobdella* Blanchard, 1896. Two taxa were presented exclusively for rivers, Muscidae and Claudioperla, and 4 genera were presented exclusively for bofedales: *Tropistermus* Solier, 1834, *Celina* Aubé, 1837, *Ischnura* Charpentier, 1840 and *Atopsyche* Banks, 1905.

In both seasons, the aquatic macroinvertebrate community was represented by the order Diptera with 5 families distributed in 10 taxa, followed by the orders Coleoptera and Trichoptera with 3 families each of them (Table 2).

The rank abundance curves (Fig. 1) show that in the bofedal, on wet season, the genus *Xiphimena* Cobb, 1913 is highly dominant followed by the family Lumbriculidae, while on dry season the Cyprididae and *Xiphimena* taxa were the most abundant. *Hydroptila* and *Hyalella* S.I. Smith, 1874 appear in the river on wet season as the most abundant, while on dry season, *Cricotopus* sp. 1 and *Cricotopus* sp. 2 are clearly the most abundant taxa, in all cases the other taxa show similar abundances.

In terms of richness, it was observed that all seasons presented greater richness on dry season, B3 site in bofedal and R4 site in river presented the highest values of richness (Fig. 2).

Ecological Indexes

Comparing the diversity between seasons, whether in bofedal or river, true diversity index shows the same pattern, more diversity on dry season than on wet season. It is observed that bofedal on dry season contains 2.36 times more effective species than on wet season, while the river during dry season contains 1.19 times more effective species than wet season (Table 3). In accordance with these results, in both seasons and habitats, where diversity is higher so does equity and conversely so does dominance.

The Bray Curtis index associated two groups, with a cut-off line of 40% similarity, one group consisting of the sites belonging to the bofedal and the other corresponding to study site on river, an expected result due to the differences in types of habitat (Fig. 3).

CLASS	ORDER	FAMILY	GENUS
Insecta	Diptera	Chironomidae	*Cricotopus* sp. 1
			Cricotopus sp. 2
			Alotanypus
			Clinotanypus
			Gymnotriochemus
			Pentaneura
		Simuliidae	*Simulium*
		Muscidae	*MuM1***
		Ephydridae	*EpM1*
		Ceratopogonidae	*CeM1*
	Coleoptera	Elmidae	*Neoelmis*
			Austrelmis
			Macrelmis
		Hydrophilidae	*Tropistermus**
		Dytiscidae	*Celina**
	Trichoptera	Limnephilidae	*Anomalocosmoecus*
		Hydroptilidae	*Hydroptila*
		Hidrobiosidae	*Atopsyche**
	Odonata	Coenagrionidae	*Ischnura**
	Ephemeroptera	Baetidae	*Andesiops*
	Plecoptera	Gripopterygidae	*Claudioperla***
	Hemiptera	Corixidae	*Corixini*
Arachnida	Acari	Limnesiidae	*LiM1*
	Oribatida	Limnozetidae	*Limnozetes*
Eumalacostraca	Amphipoda	Hyalellidae	*Hyalella*
Crustacea	Podocopida	Cypridídae	*CyM1*
Citellata	Lumbriculida	Lumbriculidae	*LuM1*
	Rhynchobdellida	Glossiphoniidae	*Helobdella*
Gastropoda	Basommatophora	Planorbidae	*Antillorbis*
Bivalvia	Veneroida	Sphaeriidae	*Pisidium*
Turbellaria	Tricladida	Dugesiidae	*Girardia*
Hydrozoa	Anthomedusae	Hydridae	*HyM1*
Adenophorea	Dorylaimida	Longidoridae	*Xiphinema*

Table 2. Taxonomic composition of aquatic macroinvertebrates recorded in the high Andean wetlands of Chalhuanca (* only in bofedal ** only in river).

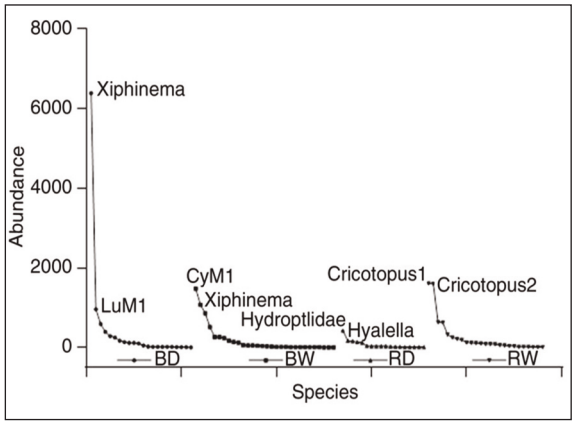

Figure 1. Range-abundance curves, relative of macroinvertebrates of the high Andean wetlands of Chalhuanca. B = bofedal; R = river; W = wet season; D = dry season.

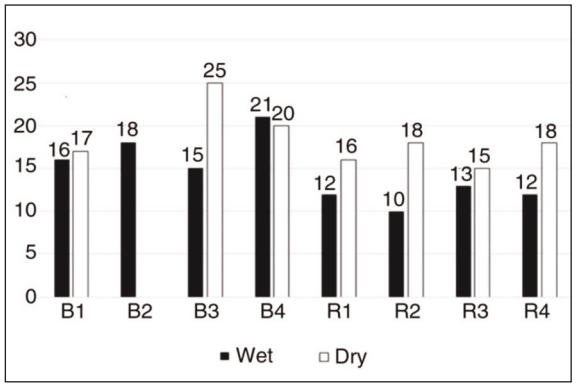

Figure 2. Macroinvertebrates richness at each sampling sites in the high Andean wetland of Chalhuanca.

Index	BW	BD	RW	RD
Taxa_S	22	30	19	25
Abundance	9620	5442	1646	6304
True diversity (^{1}D)	3.9749	9.3745	8.1825	9.7766
Equity (J')	0.4465	0.6579	0.714	0.7083
Dominance (D)	0.4576	0.1543	0.1704	0.1565

Table 3. Ecological index in the high Andean wetlands of Chalhuanca. B: bofedal, R: river, W: wet season, D: dry season.

Biological water quality with biotic indexes

In general, in bofedal and river, results for three biotic indexes, on wet and dry seasons, present a doubtful or regular biotic water quality, that is, of the 45 sampling sites, 35 of them present this condition, while of the remaining 10, 5 present water of critical or poor quality, and 5 of acceptable quality.

Bofedales. BMWP/Bol index, on wet season, categorized B4 site as water of acceptable quality and the rest of seasons as doubtful quality; on dry season, B3 site presented acceptable water quality and the rest of seasons doubtful quality. For nPeBMWP, on wet season, B4 site presented an acceptable quality and the rest of study sites presented regular quality; on dry season B3 site presented acceptable quality, and doubtful quality in the rest of seasons. The ABI index on wet season categorized B3 site as critical quality water and the rest of the study sites as doubtful quality, on dry season B3 site presented an acceptable quality and the rest of study sites are of doubtful quality (Table 4).

River. According to BMWP/Bol index, on wet and dry seasons, all study sites were of doubtful quality. For nPeBMWP index, on wet season, R1 and R2 sites presented poor quality and R3 and R4 sites regular quality; on dry season, all sites were of regular quality. For the ABI index, on wet season, R1 and R2 sites presented critical quality, while R3 and R4 sites presented doubtful quality; on dry season, all sites presented doubtful quality.

Physicochemical analysis

Values of physicochemical parameters are within the established ranges by the RCTs of D.S.004-2017 MINAM, except for dissolved oxygen, which in most of study sites was below the concentrations established in that same standard (Table 5). In general, the oxygen concentration on wet season was lower, almost in all seasons, while on dry season almost half of the concentrations were within the ECAs for Peru, where temperatures range are from 9.5 to 23.2 °C., being higher during the wet season than on dry season. On the other hand, pH values were between 6.0 and 8.4, both recorded on wet season. For electrical conductivity the highest value was 63 µS/cm and the lowest was 20 µS/cm both recorded on dry season. About total dissolved solids, the lowest value was on dry season with 10.5 ppm and the highest on wet season with 37.7 ppm.

In both habitats the Mann-Whitney U-test for independent samples showed that the distribution of macroinvertebrates abundances between seasons is significantly different (U= $p < 0.001$).

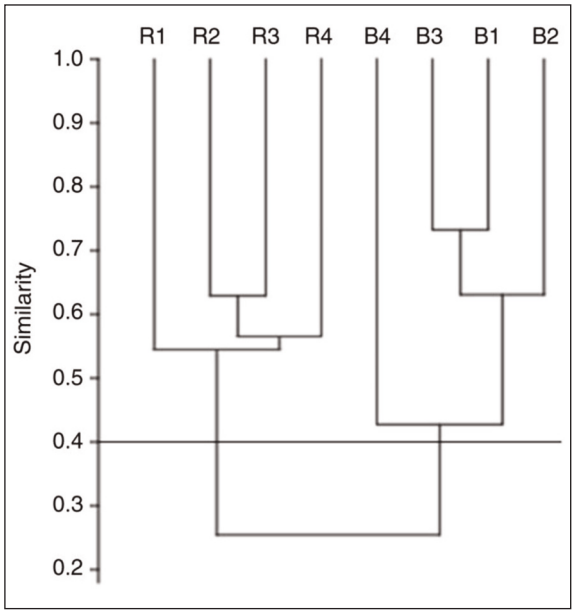

Figure 3. Bray-Curtis similarity dendrogram with the UPGMA (linkage method) of the Chalhuanca wetland sampling sites.

DISCUSSION

The taxonomic richness found (28 families and 33 taxa) can be compared to high Andean environments above 3,000 meters, as both are similar (Jacobsen & Marín, 2008; Custodio & Chanamé, 2016), however, compared to lower altitude environments it is much lower (Meza, Días & Walteros, 2012; Salcedo, Artica & Andrea., 2013). Jacobsen & Marín (2008) report a low richness of macroinvertebrates families above 4,000 meters asl as does Acosta (2009) who describes that a greater number of macroinvertebrates taxa prefer bodies of water between 2,500 and 3,000 meters asl, so the altitude at which Chalhuanca is located (4,338 meters asl) could be a limitation for the settlement of macroinvertebrates communities.

However, Jacobsen & Marín (2008) explain that the low diversity in the Altiplano cannot be explained only by the higher altitude, it is also due to the ecological conditions of the high Andean wetlands. In this sense, Toro et al. (2002) describe many causes of water quality degradation, such as contamination by organic matter, the presence of persistent inorganic pollutants and anthropic intervention, which were observed in the sampling sites being strong and permanent used in sheep grazing that generates a higher concentration of organic matter (faeces) in the water bodies.

According to Rivera (2004), the establishment of macroinvertebrates communities is linked to the type of substrate, where the substrate with vegetation contains the greatest diversity of macroinvertebrates, followed by the rocky substrate, while the sandy bottoms shelter few species with low abundances by species, this coincided with what we found in our work. The R4 site, whose river had a substrate, was richer than the other river study sites. In the case of the bofedal, all of them presented a greater abundance than the river. This could be due to the presence of vegetation in their substrate, which determines the existence of a greater diversity of macroinvertebrates.

Diversity and abundance of macroinvertebrates

The greatest diversity was found on dry season, which coincides with the results found by Custodio & Chanamé (2016) in the central highlands of Peru at 3,440 meters asl, while in regards to the abundance, in bofedales it was greater in the wet season and in the river it was greater in the dry season. This variation in abundance in both ecosystems is due to their typology, the bofedal being a lentic system and the river a lotic system. Giacometti & Bersosa (2006) and Motta et al. (2017) mention that in river the reduction of water that occurs in the dry season facilitates the establishment of macroinvertebrate communities. This is because the drag of individuals caused by the rains is reduced, while in bofedales the opposite occurs because the decrease in the water in their water wells causes their desiccation, as well as the restriction of space and food which leads to the decreased abundance.

The Mann-Whitney U test in both types of habitats, the bofedal and the river, showed that the distribution of abundances is not the same between the two seasons studied. In bofedales, this variation is evident by the greater dominance on wet season compared to dry season, given the high abundance of the family Longidoridae (phytoectoparasites found in the soil). This family could have been dominant due to the dragging of sediments and the removal of soil by water runoff that occurs in the rainy season (Pérez et al., 2013).

This is supported by Flecker & Feifarek (1994) who mention that high levels of water in the rainy

Site	Season	BMWP/Bol		ABI		nPeBMWP	
		Score	Quality	Score	Quality	Score	Quality
B1	Wet	50	Doubtful	44	Doubtful	43	Regular
	Dry	54	Doubtful	43	Doubtful	55	Regular
B2	Wet	58	Doubtful	49	Doubtful	48	Regular
B3	Wet	37	Doubtful	33	Critical	37	Regular
	Dry	71	Aceptable	61	Aceptable	65	Aceptable
B4	Wet	66	Aceptable	59	Doubtful	63	Aceptable
	Dry	60	Doubtful	53	Doubtful	57	Regular
R1	Wet	37	Doubtful	29	Critical	29	Bad
	Dry	48	Doubtful	43	Doubtful	47	Regular
R2	Wet	40	Doubtful	28	Critical	28	Bad
	Dry	59	Doubtful	47	Doubtful	46	Regular
R3	Wet	48	Doubtful	39	Doubtful	39	Regular
	Dry	36	Doubtfu	36	Doubtful	40	Regular
R4	Wet	51	Doubtfu	49	Doubtful	44	Regular
	Dry	49	Doubtful	42	Doubtful	46	Regular

Table 4. Water quality values for the biotic indexes: BMWP/Bol, ABI and nPeBMWP.

Sites	Temperature		pH		EC [µS/cm]		D.O.[ppm]		TDS [ppm]	
	W	D	W	D	W	D	W	D	W	D
B1	13.3	10	6	7.6	60	56	3.8*	6.6	29.7	28
B2	18.6	-	8.4	-	42	-	4.0*	-	21.3	-
B3	21.3	18.2	7.9	7.6	40	26	5.4	3.5*	37.7	11.5
B4	23.2	11.7	7.9	7.6	55	20	2.8*	4.1*	28.7	10.5
R1	9.5	5.7	6	7.4	52	63	3.7*	5.4	26	31.5
R2	12.7	11.6	7.6	7.6	50	50	3.8*	5.1	25	25
R3	14.5	12.6	7.3	7.9	49	50	3.3*	4.7*	24.3	25
R4	16	13.1	7.3	7.5	49	50	3.2*	4.5*	24.7	25
(ECA)s Values	Δ 3		6.5 a 9.0		1000		≥ 5		-	

Table 5. Physical-chemical variables of the high Andean wetlands of Chalhuanca. W: wet season, D: dry season. (*)Values below the permissible limit established in the national environmental water quality standards (ECA)s Supreme 2017 MINAM.

season condition a low density in macroinvertebrate communities and low levels corresponding to the dry season allow the recovery of macroinvertebrate communities; and coincides with the findings of Molina et al. (2008) in their study carried out in a high Andean river in the Royal Mountain Range of Bolivia.

Family Gripopterygidae is only in the river is due to its low temperature requirements, presence of fallen stones or branches and areas with a good state of conservation (Domínguez & Fernández, 2009). This family was recorded at R4 and R2 sites, which had the above-mentioned characteristics, but with very few individuals, a result that could be related to habitat alteration by pollution.

Family Dytiscidae is an exclusive family for bofedales, which is generally found in lentic environments, and in lotic water bodies they are more frequently observed in backwaters, where current velocity is low or null (Domínguez & Fernández, 2009), these conditions may have limited the presence of this family to bofedales.

Some organisms such as *Cricotopus*, *Andesiops*, and *Hydroptila* were found in all eight sites, because they are organisms that occupy a wide spectrum of environmental conditions, (eurithophics) (Domínguez & Fernández, 2009; Acosta, 2009).

Water Quality

According to the results of the BMWP/Bol, ABI and nPeBMWP indexes 77.78 % of the study sites have water of doubtful or regular quality. Comparing both seasons with the BMWP index, the water quality in most of them was the same, this coincides with the study carried out by Zamora et al. (1995) in the Genil basin, finding that there was no variability between the different seasons of the year, despite the fact that a common criticism is that the use of biotic indexes shows a dependency related to the seasons of the year.

Authors such as Toro et al. (2002) and Mancilla et al. (2009) refer to the influence of physicochemical factors on the aquatic macroinvertebrates community, emphasizing that water temperature and oxygen availability are determining factors in the distribution of these organisms. In our study we found greater richness on dry season which presented a higher concentration of dissolved oxygen and lower temperature compared to wet season, coinciding with the study of Meza et al. (2012) in the upper sub-basin of the Chinchiná River.

According to Rivera (2004) the concentration of dissolved oxygen is generally high and constant in Andean rivers, so this is not usually a limiting factor. However, in the high Andean wetlands of Chalhuanca, most of the study sites (73%) presented values that were lower than those required for the category destined to the conservation of the aquatic environment, established in the ECAs for Peru - 2017 (MINAM, 2017).

The low concentration of dissolved oxygen could be related to the accumulation of sheep faecal remains, since dissolved oxygen is strongly related to the concentration of organic matter according to Forero (2017).

In conclusion, the high Andean wetland of Chalhuanca presents a limited diversity of macroinvertebrates families, regular water quality above the BMWP, nPeBMWP and ABI indexes, and is home to a low fluvial fauna composed of aquatic organisms, which should be given greater attention as indicators of the ecological state of these ecosystems. It is recommended to perform monthly studies throughout all climatic periods, for a better understanding of the functioning of the community structure of aquatic macroinvertebrates of Chalhuanca. In addition, it is suggested that pollution tolerance studies be conducted on the families Limnesiidae and Limnozetidae of the class Arachnida, for which no scores were found in the index used, making an accurate evaluation of the ecological status difficult.

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