

## Aquatic macroinvertebrates (Animalia: Invertebrata) of the area of influence of El Quimbo Hydroelectric Station, Huila, Colombia\*

Rubén Darío Valbuena-Villareal<sup>1</sup> & Diana María Gualtero-Leal<sup>2</sup>

### Abstract

**Objective.** To carry out an analysis of the hydrobiological communities of macroinvertebrates of the discharge flows of El Quimbo hydroelectric plant, Huila, Colombia. **Scope.** To make a contribution to knowledge about the aquatic macroinvertebrate species in the upper basin of the Magdalena river. **Methodology.** Aquatic invertebrates were collected at six sampling stations using Surber traps at 10 sites along a 100 m linear transect. **Main results.** A total of 36,490 specimens belonging to 11 classes, 26 orders, 79 families and 168 taxa were collected. The class Insecta presented the highest values with nine orders (34.62%), 55 families (69.62%) and 137 taxa (81.55%). The assessment of the water quality in the study area showed that all the stations have good waters quality for the BMWP index, and all the stations have questionable water quality for the ASPT index. The analysis of similarity between the sampling stations found great similarity between all the sampling stations, except MGE4, possibly due to the influence of the treated wastewater that falls into the river a few meters upstream. **Conclusions.** This document makes a significant contribution to the knowledge of the aquatic macroinvertebrate communities for the study area. However, it is known, that the different phases of the hydroelectric project affect these communities in different degrees, which will be the subject in future studies.

**Key words:** Diversity, bioindicators, BMWP/Col index, aquatic macroinvertebrates.


## Macroinvertebrados acuáticos (Animalia: Invertebrata) del área de influencia de la estación Hidroeléctrica El Quimbo, Huila, Colombia

### Resumen


**Objetivo.** Realizar un análisis de las comunidades hidrobiológicas de macroinvertebrados de los caudales de descarga de la hidroeléctrica El Quimbo, Huila, Colombia. **Alcance.** Realizar un aporte al conocimiento sobre las especies de macroinvertebrados acuáticos de la cuenca alta del río Magdalena. **Metodología.** Los invertebrados acuáticos fueron recolectados en seis estaciones de muestreo mediante el uso de trampas Surber en 10 sitios a lo largo de un transecto lineal de 100 m. **Principales resultados.** Se colectaron 36.490 especímenes pertenecientes a 11 clases, 26 órdenes, 79 familias y 168 taxones. La clase Insecta presentó los mayores valores con nueve órdenes (34,62%), 55 familias (69,62%) y 137 taxones (81,55%). La evaluación de la calidad del agua en la zona de estudio tuvo como resultado que para el índice BMWP, todas

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<sup>1</sup> Ph.D. Docente Universidad Surcolombiana, Programa Itico y pesquero del alto Magdalena, Grupo de Investigación GINACUA. E-mail: rubendarío@usco.edu.co

 orcid.org/0000-0002-3244-7742 **Google Scholar**

<sup>2</sup> MsC. Profesional Ambiental, Central Hidroeléctrica El Quimbo Enel-Emgesa. E-mail: dgualtero@enel.com

 orcid.org/0000-0002-2329-6153 **Google Scholar**

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las estaciones presentan aguas de buena calidad, y para el índice ASPT, todas las estaciones presentan aguas de dudosa calidad. El análisis de similitud entre las estaciones de muestreo encontró gran similitud entre todas las estaciones de muestreo, excepto MGE4, posiblemente debido a la influencia de las aguas residuales tratadas que caen al río pocos metros aguas arriba.

**Conclusiones.** El presente documento realiza un relevante aporte al conocimiento de las comunidades de macroinvertebrados acuáticos para la zona de estudio, sin embargo, se sabe que las diferentes fases del proyecto hidroeléctrico afectan estas comunidades en diferentes medidas, lo cual se asumirá en futuros manuscritos.

**Palabras clave:** Diversidad, bioindicadores, índice BMWP/Col, macroinvertebrados acuáticos.

## Introduction

The Quimbo hydroelectric station has a reservoir of 8,250 hectares on the Magdalena river. It has an installed capacity of 400 MW, with an average generation of 2,216 GW-h/year, which corresponds to 4% of the national energy demand (Emgesa, 2018). It is located in the south of the department of Huila in the jurisdiction of the municipalities of Gigante, El Agrado, Garzón, Paicol, Teslia and Altamira. Due to its proximity to the Betania hydroelectric, almost 30 km, The Quimbo optimizes the cost/benefit due to the fact that the Betania-El Quimbo, complex supplies 8% of the national demand (Ingetec, 2008). The Quimbo and Betania reservoirs are located in the equatorial zone, with a maximum operation level between 520 and 720 masl, making them warm tropical lakes (Hutchinson, 1957; Roldán & Ramírez, 2008). This type of artificial aquatic systems are susceptible to the eutrophication process, which could affect the quality of the aquatic environment, modifying the macroinvertebrate community composition and could also bring secondary problems such as bad smells, equipment corrosion, decreased in dissolved oxygen, metal re-suspension, ammonia accumulation and fish death, among others; although this process is natural and can last thousands of years, certain human activities can accelerate it to a few years (Camargo & Alonso, 2007; Ruíz, 2017; Salas & Martino, 2001).

On the other hand, the physical and chemical characteristics of lotic systems is home to a series of organisms grouped in communities, which play important roles in trophic networks as producers (periphyton), consumers of first, second or third order (zooplankton, fish, macroinvertebrates, benthos) and in the decomposition processes (bacterial microbiota, fungi, some macroinvertebrates, among others) (Hutchinson, 1957; Needham & Needham, 1978; Roldán & Ramírez, 2008). Macroinvertebrates are relatively large animals, not less than 0.5 mm or at least visible to the human eye, although they usually have sizes greater than 3 mm (Alba-Tercedor, 1996). This community is mainly of arthropods, such as crustaceans, arachnids and insects, the latter group being the most abundant and best represented in taxonomic groups,

and especially in their immature forms (larvae, naiades and nymphs). In addition, oligochaetes, hirudineas and molluscs can also be found (Roldán & Ramírez, 2008). Although the community is associated with the rocky or muddy bottoms of water sources, some are found on aquatic plants, and others close to the water surface (Merritt & Cummins, 1996; Pratt, 1992; Ramírez & Viña, 1998).

Obviously, hydrobiological communities can be affected by changes in water quality and/or hydrological dynamics, in such a way that some of them can be used as bioindicators of the environment quality. However, they must have requirements such as being abundant, easy to collect and manipulate, being sensitive to environmental changes and habitat disturbances, have a stable taxonomy and a relatively well-known biology, among others (Bonada et al., 2006; Jacobsen, 2008b; Prat et al., 2008; Villalobos-Moreno, 2017; Villalobos-Moreno & Salazar, 2020). The objective of this study was to analyse the aquatic macroinvertebrate community in the area of influence at the Quimbo hydroelectric station, and to establish possible changes between the monitoring stations.

## Materials and methods

**Study area.** The Quimbo dam is located in the south of the department of Huila, between the Central and Oriental mountain ranges, in the upper basin of the Magdalena river. This part of the river runs from the Colombian Massif to 1,300 m before the confluence between the Magdalena and Páez rivers, between the geographical coordinates  $1^{\circ}30'N$  -  $76^{\circ}35'W$  and  $2^{\circ}30'N$  -  $75^{\circ}35'W$ , and together they form a complex along with the Betania reservoir, which is known as cascade dams (Emgesa, 2018). For the sampling, six stations were established, located from the dam wall of the Quimbo reservoir, to the beginning of the tail of the Betania reservoir (Figs. 1 and 2).

- **Station I (RP):** Lotic system located on the Páez river near the point of confluence with the Magdalena river ( $2^{\circ}27'25.66''N$ ;  $75^{\circ}34'22.87''W$ ), area of jurisdiction of the Gigante municipality, Huila, 300 m below the bridge leading to the Domingo Arias site. It is characterized by having a medium slope with some erosion, arboreal and shrubby vegetation on both banks. The river bed is rocky, with sandy and rocky beaches nearby. The waters appearance is cloudy, yellowish in colour, without offensive smells, no iridescence or floating material. On average, at this site the river is 70 m wide and 2 m deep, values that vary according to the time of year. No agricultural, livestock or housing activities were detected.
- **Station II (MGE1):** Lotic system waters under of the Quimbo reservoir, located in the Magdalena river waters underneath the reservoir discharge ( $2^{\circ}27'25.56''N$ ;  $75^{\circ}34'11.69''W$ ; 595 masl), area of jurisdiction of the Gigante municipality, Huila. It is characterized by having a medium slope with some erosion, arboreal

and herbaceous vegetation on both banks; rocky bed, sandy substrate with sandy and rocky beaches nearby. The appearance of the water is cloudy, brown, without offensive odours or iridescence, with a moderate presence of leaf litter and particulate matter. On average, at this place the river is 48 m wide and 1.7 m deep, values that vary according to the season of year.

- **Station III (MGE2):** Lotic system waters under of the Quimbo reservoir, located on the Magdalena river near the point of confluence with the Paez river ( $2^{\circ}27'46.43''\text{N}$ ;  $75^{\circ}34'2.07''\text{W}$ ; 589 masl), area of jurisdiction of the Gigante municipality, Huila, near to the current road bridge that connects the municipalities of Tesalia and Gigante. It is characterized by a low slope, the right bank with little vegetation and the left with some arboreal and shrubby vegetation. Rocky bed, sandy substrate with sandy and rocky beaches nearby. The appearance of the water is semi-cloudy, brown in color, without offensive odours or iridescence, with a moderate presence of leaf litter and particulate matter. At this site the river is 150 m wide and 2.5 m deep, values that vary according to the season of year.
- **Station IV (MGE3):** Lotic system waters under the confluence of Paez and Magdalena rivers ( $2^{\circ}29'40.54''\text{N}$ ;  $75^{\circ}33'29.84''\text{W}$ ; 576 masl), area of jurisdiction of the Gigante municipality, Huila. It is characterized by a low slope, the right bank has herbaceous, arboreal and shrubby vegetation, as well as rocky beaches, the road to the municipality of Gigante and some cattle farms, while on the left bank the area is mountainous and with rocky slope. The river bed is sandy and substrate is rocky. The appearance of the water is semi-cloudy, brown in colour, without offensive odours and with moderate presence of surface white foam. On average, this point of the river is 88 m wide and 2.5 m deep, and they vary according to the time of year.
- **Station V (RM-PSE):** Lotic system located on the Magdalena river waters underneath the Quimbo reservoir, in the Puerto Seco farmhouse ( $2^{\circ}30'5.44''\text{N}$ ;  $75^{\circ}32'35.12''\text{W}$ ; 574 masl), area of the jurisdiction of the Gigante municipality, Huila. It is characterized by having a low slope, on both banks arboreal and shrubby vegetation can be seen, rocky beach and livestock, agricultural and industrial activities. The river bed is rocky-sandy. The appearance of the water is semi-cloudy, brown in colour, without offensive odours or floating matter. On average, at this point the river is 180 m wide and 2 m deep, values that vary according to the season of year.
- **Station VI (MGE):** Lotic system waters underneath the Quimbo reservoir, relatively near to the Betania reservoir ( $2^{\circ}31'37.60''\text{N}$ ;  $75^{\circ}32'15.80''\text{W}$ ; 564 masl), area of the jurisdiction of the Gigante municipality, Huila, waters underneath the Puerto Seco farmhouse, next to Las Vueltas limnographic station. It is characterized

by having a low slope, on both banks there is arboreous and shrubby vegetation, rocky beach on the right and a mountainous area on the left, as well as certain agricultural and livestock activities. The river bed is sandy and the substrate is rocky. The appearance of the water is semi-cloudy, brown in colour, without offensive smells or iridescence, or floating matter. At this point the river is 200 m wide and 2 m deep, values that vary according to the season of year.

**Sampling methods.** Monthly, aquatic macroinvertebrate samplings were made at each station, between April 2011 and December 2017. The biological samples were collected using a Surber net of 30 cm x 30 cm with a 560- $\mu$ m net hole, located upstream and into of the different environments: stream, basin and threshold. Ten sites were demarcated along a 100 m longitudinal transect, at each station, and quantitative sampling using the Surber trap was carried out for 5 minutes. The trap area is equivalent to 0.09 m<sup>2</sup> so that in each station, an equivalent total area of 0.9 m<sup>2</sup> is obtained and density is calculated with this value. The collected specimens were preserved in plastic bottles with 70% ethanol (Barajas et al., 2004; Pinheiro et al., 2004; Roldán & Ramírez, 2008). With the material collected, population parameters were set like abundance, determined by the total number of specimens/station/week, and density like the number of specimens/m<sup>2</sup>. Taxonomic identifications were made in laboratory conditions with the keys and descriptions of Domínguez et al. (2006), Domínguez & Fernández (2009), Posada & Roldán (2003), Roldán (1996) and Springer (2006). Most of the samples was deposited in the Entomological Collection of University del Tolima.

**Evaluation of water quality.** To evaluate the water quality, the method BMWP (Biological Monitoring Working Party) was applied. This method was adapted by Roldán (2003) for the Colombian territory: BMWP/Col. It uses aquatic macroinvertebrates as bioindicators, in terms of the presence-absence of a taxon, and assigns them a score ranging from 1 to 10 (Table 1), which was established according to the previously showed sensitivity for each group (Roldán, 2003, 2016). It is important to highlight that the method gives each family a score corresponding to the most resistant species. The result of the BMWP index corresponds to the sum of the scores and reflects the minimum value of ecological quality of the studied site, as shown in Table 2 (Cammaerts et al., 2008; Roldán, 2003, 2016). As the BMWP index is dependent on the sampling effort, the ASPT index (Average Score per Taxon) was calculated dividing the value of the BMWP index by the number of taxa collected; in this way, the ASPT index translates the lower limit average from sensitivity to contamination on the part of the taxa of a group, to a value of environmental contamination, independent of the sampling effort (Cammaerts et al., 2008).

**Comparison between sampling stations.** To establish possible differences between the sampling stations in the area of influence at the Quimbo hydroelectric, the inventories

of taxa reported for each station were compared. With the list of species, an abundance matrix was organized, and grouping analyses were made to identify any pattern of similarity between the localities. The Jaccard index was used to establish the similarity between the stations and the single linkage technique to create the dendrogram (Ludwig and Reynolds, 1988; Magurran, 1988). For the respective calculations and graphs, the program Past3 version 4.02 was used (Hammer, 2020).

## Results and discussion

36,490 individuals belonging to the aquatic macroinvertebrate community were collected. They were organized into 11 classes, 26 orders, 79 families and 168 taxa (Fig. 3, Table 3). The class Insecta was the best represented in the samplings, both in terms of abundance and taxonomic groups, as it usually happens (Jacobsen, 2008a). This class presented nine orders (34.62%), 55 families (69.62%) and 137 taxa (81.55%). The best represented orders in the sampling area were Diptera with 21,172 specimens (33.35%), 13 families and 31 taxa, Ephemeroptera with 5,769 specimens (15.81%), 20 families and 20 taxa, Hemiptera with 4,196 specimens (11.5%), 9 families and 17 taxa, and Trichoptera with 2,267 specimens (6.21%), 7 families and 20 taxa. These four orders represent about 67% of all the biological material collected, 62.03% of the total families and 52.38% of the taxa recorded for the study area.

***Evaluation of water quality.*** To evaluate the water quality, the method BMWP/Col (Biological Monitoring Working Party/adapted for Colombia) (Roldán, 2003) was used. The results showed that all the sampling stations have very clean water, which means good water quality (Table 4). In general, a high richness of species was observed in all sampling stations. The calculated BMWP index show a relatively well-preserved environment, although this index is dependent on the sampling effort. For this reason, the ASPT index was calculated (Cammaerts *et al.*, 2008), whose result shows that all stations have an environmental pollution value between 5.52 and 6.19, which means doubtful quality water (Table 4).

***Some observations.*** In general, the order Ephemeroptera are considered indicators of good water quality, because they inhabit clean and flowing waters, with a good oxygen level, although some species can survive a certain degree of contamination. They are found at the bottom of water sources, in rocks, trunks, leaves or submerged vegetation, and constitute an important part of the diet of various species of fish (De la Lanza *et al.*, 2000; Flowers & De la Rosa, 2010). With respect to the order Odonata, they are skilled predators usually inhabiting slow-flowing water sources with abundant aquatic vegetation (Ramírez, 2010). The order Plecoptera order is a small and little studied group in South America, with only two known families; they take refuge in trunks, branches, leaves and stones of fast and well-oxygenated waters, that is why they are considered very clean waters indicators (De la Lanza *et al.*, 2000; Roldán, 1996)



The order Neuroptera is a group of large predators that inhabits clean waters and takes refuge under rocks, woods or plants submerged; they are among the largest macroinvertebrates, very striking for their long and strong jaws (Alba-Tercedor, 1996; De la Lanza *et al.*, 2000; Roldán, 1996). The order Hemiptera present in the neotropics two large groups of aquatic insects: the Nepomorpha, truly aquatic and the Gerromorpha that are subaquatic; they inhabit backwaters of rivers and streams, as well as lakes and swamps (Escobar, 2005); they are aquatic and terrestrial predators that, even, the largest species can feed on small fish (De la Lanza *et al.*, 2000); the families Gerridae and Veliidae were found in high densities near the banks of aquatic systems with the presence of riparian vegetation and forests, as described by Hilsenhoff (2001) and Pacheco *et al.* (2014). The Coleoptera order is one of the most extensive and complex, and the study of aquatic coleoptera is still scarce; they present aquatic and semi-aquatic specimens, both in lentic and lotic systems, with some families indicating good water quality, and others having the capacity for withstanding much broader parameters (Alba-Tercedor, 1996; De la Lanza *et al.*, 2000; Roldán, 1996).

With respect to the order Trichoptera, most inhabit clean, well-oxygenated, flowing waters, and are characterized because in their larval phase they make a sort of refuge with various materials and with varied shapes, which are of great taxonomic value (Roldán, 1996); some groups feed on plant material found on rocks, while others are predators (De la Lanza *et al.*, 2000; Motta *et al.*, 2016). The order Diptera is a complex, abundant and widely distributed group; it has groups in almost all the existing aquatic environments, including on the sea coasts; some families, like Simuliidae, inhabit very clean waters, while others, such as Tipulidae and Chironomidae, are found in contaminated waters (Alba-Tercedor, 1996; De la Lanza *et al.*, 2000; Motta *et al.*, 2016; Roldán, 1996). The Chironomidae were one of the most dominant groups, along with other groups such as Simuliidae, typical organisms from well-oxygenated flowing waters; to these groups is added the family Baetidae, made up of individuals of great importance in the trophic chains of rivers and streams, collected in stony substrate habitats, as described by Flowers & De la Rosa (2010) and Domínguez *et al.* (2009).

***Comparison between sampling sites.*** The comparison between the taxon inventories of the sampling stations in the area of influence at the Quimbo hydroelectric power station, allowed to observe a clear relationship between all the stations, except RM-PSE. Two groups MGE1-MGE2-MGE3 with 66% of similarity and MGE5-RP are clearly formed (Fig. 4). The evident difference between these groups and the MGE4 station could be explained by the dynamics of the riparian communities that discharge waste into the river that could cause changes in the fauna of aquatic macroinvertebrates of said sampling station. This fact should be subsequently proved using a more detailed analysis including available physicochemical and microbiological data.

## Conclusions

This document is a contribution to the knowledge of aquatic macroinvertebrates in the area of influence at the Quimbo reservoir where there is great abundance and richness of species that allow to establish, according to the BMWP index, that waters are classified as very clean, while using the ASPT index, it was established that the water is moderately contaminated. The difference between the two results is explained from the dependence on the BMWP index to the sampling effort, which for the present study was seven years. The presence of large populations of groups indicating good water quality, such as the families of the orders Trichoptera, Ephemeroptera, Plecoptera, among others, contrasts with the large populations of macroinvertebrates indicating the presence of contaminated or highly contaminated waters, such as the class Clitellata or the family Chironomidae.

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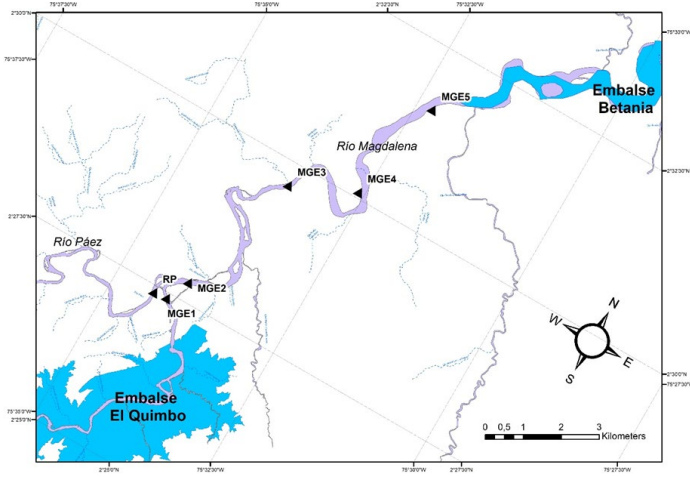
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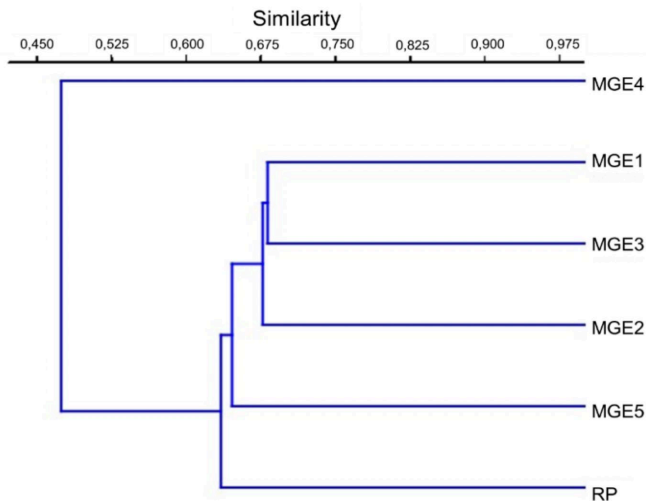
**Figure 1.** Location of the study area and the sampling station at the Quimbo Hydroelectric Power Station. Source: Google maps.



**Figure 2.** Sampling station in the area of influence at the Quimbo Hydroelectric Power Station. Source: Authors' photographs.



**Figure 3.** Some specimens from the area of influence at the Quimbo. A: *Ammicola* sp.; B: *Helobdella* sp.; C: Hygrobatidae; D: *Macrobrachium* sp.; E: *Traverella* sp.; F: *Leptobryes* sp.; G: *Camelobaetidis* sp.; H: *Anacroneuria* sp.; I: *Limnocoris* sp.; J: *Hexacylloepus* sp.; K: *Phanocerus* sp.; L: *Marilia* sp.; M: *Nectopsyche* sp.; N: *Anatolica* sp.; O: *Chironomus* sp.; P: Tanyponidae 1. Source: Authors' photographs.








**Figure 4.** Similarity of sampling sites. Jaccard index; correlation coefficient: 0.928. Source: Authors' elaboration.

**Table 1.** Score given to each family of aquatic macroinvertebrates based on the ecological sensitivity established for the BMWP index

Family	Score
Anomalopsychidae, Aphelocheiridae, Athericidae, Atriplectididae, Beraeidae, Blephariceridae, Brachycentridae, Calamoceratidae, Capniidae, Chloroperlidae, Chordodidae, Goeridae, Gomphidae, Heptageniidae, Hydridae, Lampyridae, Lepidostomatidae, Leuctridae, Lymnessiidae, Molannidae, Odontoceridae, Oligoneuriidae, Perlidae, Perlodidae, Phryganeidae, Polythoridae, Potamanthidae, Psephenidae, Ptilodactylidae, Sericostomatidae, Siphonuridae, Taeniopterygidae	10
Ampullariidae, Dytiscidae, Ephemeraeidae, Euthyplociidae, Gyrinidae, Hydrobiosidae, Leptophlebiidae, Philopotamidae, Polycentropodidae, Xiphocentronidae	9
Amnicolidae (=Hydrobiidae), Astacidae, Cordulegasteridae, Corduliidae, Gerridae, Gomphidae, Hebridae, Helicopsychidae, Macroveliidae (=Hebroidea), Leptoceridae, Lestidae, Palaemonidae, Pleidae, Pseudothelpusidae, Psychomyiidae, Saldidae, Simuliidae, Tateidae, Thiaridae, Veliidae	8
Baetidae, Caenidae, Calopterygidae, Coenagrionidae, Corixidae, Dixidae, Dryopidae, Ecnomidae, Ephemerellidae, Glossosomatidae, Hyalellidae, Hydroptilidae, Hydropsychidae, Leptohiphidae, Limnephilidae, Naucoridae, Nemouridae, Notonectidae, Planaridae, Psychodidae, Prosoptomatidae, Rhyacophilidae, Scirtidae,	7
Aeshnidae, Ancylidae, Atyidae, Corophiidae, Corydalidae, Elmidae, Gammaridae, Libellulidae, Limnichidae, Lutrochidae, Megapodagrionidae, Neritidae, Platycnemididae, Sialidae, Staphylinidae, Unionidae, Viviparidae,	6
Belostomatidae, Clambidae, Crambidae, Dendrocoelidae, Dugesidae, Gelastocoridae, Helophoridae, Hydrochidae, Mesoveliidae, Nepidae, Planariidae, Planorbidae, Polymitarcidae, Pyralidae, Tabanidae, Thiaridae	5
Anthomyidae, Curculionidae, Chrysomelidae, Dolichopodidae, Empididae, Haliplidae, Hidracarina, Hydraenidae, Hydrometridae, Stratiomyidae, Limoniidae, Lymnaeidae, Noteridae, Piscicolidae, Rhagionidae, Sphaeriidae	4
Asellidae, Bithyniidae, Bythinellidae, Ceratopogonidae, Cochliopidae (=Hydrobiidae), Cyclobdellidae, Erpobdellidae, Glossiphoniidae, Helodidae, Hirudidae, Hydrophilidae, Hygrobatidae (with Arrenuridae, Hydrachnidae, Pionidae), Ostracoda (+ Cypridae), Physidae, Planorbidae, Sphaeridae, Tipulidae, Valvatidae	3
Chironomidae, Culicidae, Chaoboridae, Ephydriidae, Muscidae, Sciomyzidae, Thaumaleidae	2
Oligochaeta (incluye: Haplotaxidae, Lumbriculidae, Naididae, Tubificidae), Syrphidae	1

Source: Adapted from Cammaerts *et al.* (2008) and Roldán (2003).

**Table 2.** Classification of waters in accordance with BMWP and ASPT indexes

Class	Quality	BMWP Index	ASPT Index	Meaning	Colour
I	Good	> 150	> 9 - 10	Very clean waters	
		101 - 120	> 8 - 9	Unpolluted waters	
II	Acceptable	61 - 100	> 6.5 - 8	Effects of contamination are evident	
III	Questionable	36 - 60	> 4.5 - 6.5	Moderately polluted waters	
IV	Critical	16 - 35	> 3 - 4.5	Heavily polluted waters	
V	Very critical	<15	1 - 3	Severely polluted waters	

Source: Authors' elaboration

**Table 3.** Aquatic macroinvertebrates in the area of influence at the Quimbo reservoir

Class	Order	Family	Taxa (gen-sp)	Ab.
<b>PHYLUM NEMATOMORPHA</b> Vejdovsky, 1886				
<b>Gordioida</b>	<b>Chordodea</b>	Chordodidae	<i>Chordodes</i> sp.	3
<b>PHYLUM PLATYHELMINTHES</b> Minot, 1876				
<b>Turbellaria</b>	<b>Tricladida</b>	Dugesiidae	<i>Dugesia</i> sp.	9
<b>PHYLUM ANNELIDA</b> Minot, 1876				
<b>Clitellata</b>	<b>Rhynchobdellida</b>	Glossiphoniidae	<i>Helobdella</i> sp.	6
			<i>Placobdella</i> sp.	4
	<b>Oligochaeta</b>	Tubificidae	<i>Tubifex</i> sp.	18
	<b>Lumbriculida</b>	Lumbriculidae	Lumbriculidae 1	7
			Lumbriculidae 2	7
	<b>Haplotaxida</b>	Naididae	Naididae 1	509
			Naididae 2	95
Haplotaxidae		Haplotaxidae 1	92	
	Haplotaxidae 2	253		
<b>PHYLUM MOLLUSCA</b> Linnaeus, 1758				
<b>Gastropoda</b>	<b>Littorinimorpha</b>	Amnicolidae	<i>Amnicola</i> sp.	11
		Tateidae	<i>Potamopyrgus</i> sp.	2
		Cochliopidae	<i>Heleobia</i> sp.	7
	<b>Caenogastropoda</b>	Thiaridae	<i>Melanoides</i> sp.	2
	<b>Basommatophora</b>	Planorbidae	<i>Helisoma</i> sp.	1
			<i>Uncancylus</i> sp.	107
		Physidae	<i>Physa</i> sp.	137
<b>Bivalvia</b>	<b>Veneroida</b>	Sphaeriidae	<i>Eupera</i> sp.	2
<b>PHYLUM ARTHROPODA</b> Latreille, 1829				
<b>Arachnida</b>	<b>Trombidiformes</b>	Arrenuridae	Arrenuridae 1	1
		Hygrobatidae	Hygrobatidae 1	76
		Pionidae	Pionidae 1	31
	<b>Actinedida</b>	Hydrachnidae	Hydrachnidae 1	82
<b>Branchiopoda</b>	<b>Diplostraca</b>	Cyzicidae	<i>Cyzicus</i> sp.	47
<b>Ostracoda</b>	<b>Podocopida</b>	Cyprididae	Cyprididae 1	17
<b>Malacostraca</b>	<b>Decapoda</b>	Palaemonidae	<i>Macrobrachium</i> sp.	149
	<b>Amphipoda</b>	Hyalellidae	<i>Hyalella</i> sp.	1
<b>Entognatha</b>	<b>Collembola</b>	Isotomidae	Isotomidae 1	1
			Isotomidae 2	265
		Entomobryidae	Entomobryidae 1	2
Entomobryidae 2	29			

Class	Order	Family	Taxa (gen-sp)	Ab.
<b>PHYLUM ARTHROPODA</b> Latreille, 1829				
<b>Insecta</b>	<b>Ephemeroptera</b>	Baetidae	<i>Americabaetis</i> sp.	21
			<i>Apobaetis</i> sp.	4
			<i>Baetis</i> sp.	55
			<i>Baetodes</i> sp.	765
			<i>Callibaetis</i> sp.	12
			<i>Camelobaetidius</i> sp.	1,637
			<i>Dactylobaetis</i> sp.	23
			<i>Mayobaetis</i> sp.	6
			<i>Moribaetis</i> sp.	2
			<i>Nanomis</i> sp.	10
		<i>Paracloeodes</i> sp.	4	
		Caenidae	<i>Caenis</i> sp.	6
		Leptohyphidae	<i>Leptohyphes</i> sp.	824
			<i>Tricorythodes</i> sp.	248
	<i>Vacupernius</i> sp.		8	
	<i>Traverella</i> sp.		1,885	
	<i>Allenhyphes</i> sp.		8	
	Leptophlebiidae	<i>Thraulodes</i> sp.	240	
		<i>Farrodes</i> sp.	5	
	Oligoneuriidae	<i>Lachlania</i> sp.	6	
	Gomphidae	<i>Progomphus</i> sp.	6	
	<b>Odonata</b>	Libellulidae	<i>Dythemis</i> sp.	3
			<i>Macrobrachium</i> sp.	2
			<i>Brechmorhoga</i> sp.	1
		Coenagrionidae	<i>Argia</i> sp.	14
	<b>Plecoptera</b>	Perlidae	<i>Anacroneuria</i> sp.	152
		Hebridae	<i>Hebrus</i> sp.	125
		Mesoveliidae	<i>Mesovelia</i> sp.	29
		Macroveliidae	<i>Macrobrachium</i> sp.	2
		Vellidae	<i>Rhagovelia</i> sp.	3,841
			<i>Microvelia</i> sp.	9
		<b>Hemiptera</b>	Gerridae	<i>Rheumatobates</i> sp.
<i>Trepobates</i> sp.				54
<i>Eurygerris</i> sp.				7
<i>Telmatometra</i> sp.				2
Belostomatidae	<i>Belostoma</i> sp.	1		
Gelastocoridae	<i>Gelastocoris</i> sp.	1		
	<i>Nerthra</i> sp.	4		
Corixidae	<i>Tenagobia</i> sp.	71		
Naucoridae	<i>Limnocoris</i> sp.	15		
	<i>Ambrysus</i> sp.	6		
	<i>Pelocoris</i> sp.	3		
	<i>Cryphocricos</i> sp.	1		



Class	Order	Family	Taxa (gen-sp)	Ab.
<b>PHYLUM ARTHROPODA</b> Latreille, 1829				
Insecta	Coleoptera	Carabidae	<i>Dyschirius</i> sp.	4
		Dytiscidae	<i>Dytiscius</i> sp.	2
			<i>Neobidessus</i> sp.	3
		Hydraenidae	<i>Hydraena</i> sp.	1
		Hydrophilidae	<i>Berosus</i> sp.	12
			<i>Derallus</i> sp.	1
			<i>Enochrus</i> sp.	3
			<i>Helochares</i> sp.	1
			<i>Hemiosus</i> sp.	4
			<i>Hydrobius</i> sp.	1
			<i>Hydrochara</i> sp.	1
			<i>Hydrochus</i> sp.	6
			<i>Hydrophilus</i> sp.	1
			<i>Tropisternus</i> sp.	70
		Staphylinidae	<i>Bledius</i> sp.	4
			<i>Pontamalota</i> sp.	13
		Scarabaeidae	<i>Ataenius</i> sp.	11
		Scirtidae	<i>Elodes</i> sp.	1
			<i>Scirtes</i> sp.	2
		Elmidae	<i>Austrolimnius</i> sp.	2
			<i>Cylloepus</i> sp.	50
			<i>Disersus</i> sp.	1
			<i>Gyrelmis</i> sp.	1
			<i>Heterelmis</i> sp.	456
			<i>Hexacylloepus</i> sp.	19
			<i>Huleechius</i> sp.	2
			<i>Macrelmis</i> sp.	56
			<i>Microcylloepus</i> sp.	40
			<i>Neelmis</i> sp.	8
			<i>Phanocerus</i> sp.	14
			<i>Pseudodisersus</i> sp.	4
			<i>Stenelmis</i> sp.	8
Dryopidae	<i>Pelonomus</i> sp.		5	
Lutrochidae	<i>Lutrochus</i> sp.		15	
Limnichidae	<i>Eulimnichus</i> sp.		7	
Psephenidae	<i>Psephenus</i> sp.	8		
Ptilodactylidae	<i>Anchyteis</i> sp. <i>Anchytarsus</i> sp.	4		
	<i>Ptilodactyla</i> sp.	14		
Chrysomelidae	<i>Donacia</i> sp.	3		
	<i>Corydalus</i> sp.	52		
<b>Neuroptera</b>				

Class	Order	Family	Taxa (gen-sp)	Ab.	
<b>PHYLUM ARTHROPODA</b> Latreille, 1829					
<b>Insecta</b>	<b>Trichoptera</b>	Hydropsychidae	<i>Leptonema</i> sp.	29	
			<i>Macrostemum</i> sp.	11	
			<i>Smicridea</i> sp.	1,918	
		Polycentropodidae	<i>Polypectropus</i> sp.	1	
			<i>Cyrnellus</i> sp.	2	
		Glossosomatidae	<i>Culoptila</i> sp.	48	
			<i>Protoptila</i> sp.	1	
		Hydroptilidae	<i>Hydroptila</i> sp.	20	
			<i>Leucotrichia</i> sp.	17	
			<i>Neotrichia</i> sp.	13	
			<i>Ochrotrichia</i> sp.	12	
			<i>Oxyethira</i> sp.	3	
			Hydrobiosidae	<i>Atopsyche</i> sp.	10
			Odontoceridae	<i>Marilia</i> sp.	9
		Leptoceridae	<i>Atanatolica</i> sp.	26	
			<i>Grumichella</i> sp.	9	
			<i>Nectopsyche</i> sp. 1	108	
			<i>Nectopsyche</i> sp. 2	18	
			<i>Nectopsyche</i> sp. 3	7	
		<b>Lepidoptera</b>	Pyralidae	<i>Oecetis</i> sp.	5
	Pyralidae		Pyralidae 1	2	
	<b>Diptera</b>	Crambidae	<i>Petrophila</i> sp.	8	
			<i>Hexatoma</i> sp.	10	
		Tipulidae	<i>Limonia</i> sp.	7	
			<i>Molophilus</i> sp.	42	
			<i>Tipula</i> sp.	11	
		Psychodidae	<i>Maruina</i> sp.	16	
			<i>Pericoma</i> sp.	1	
			<i>Psychoda</i> sp.	1	
		Ceratopogonidae	<i>Alluaudomyia</i> sp.	153	
			<i>Atrichopogon</i> sp.	17	
			<i>Bezzia</i> sp.	5	
			<i>Ceratopogon</i> sp.	119	
			<i>Culicoides</i> sp.	696	
		Chaoboridae	<i>Probezzia</i> sp.	18	
			<i>Stilobezzia</i> sp.	9	
			<i>Chaoborus</i> sp.	2	
			<i>Chironomus</i> sp.	9,200	
			<i>Corynoneura</i> sp.	6,740	
	Tanypodinae 1		208		
<i>Uranotaenia</i> sp.	1				
Culicidae	<i>Aedeomyia</i> sp.		1		
	<i>Culex</i> sp.		4		
Simuliidae	<i>Simullum</i> sp.		3,723		
Blephariceridae	<i>Limonicola</i> sp.	10			
Stratiomyidae	<i>Odontomyia</i> sp.	2			
Tabanidae	<i>Tabanus</i> sp.	27			
Empididae	<i>Hemerodromia</i> sp.	41			
	<i>Aphrosylus</i> sp.	39			
Dolichopodidae	<i>Raphium</i> sp.	8			
	<i>Rhagovelia</i> sp.	40			
Muscidae	<i>Limnophora</i> sp.	12			
	<i>Lispe</i> sp.	9			

Source: Authors' elaboration

**Table 4.** Summary of the analysis of water quality using the BMWP/Col and ASPT indexes

	<b>MG7</b>	<b>MGE1</b>	<b>MGE2</b>	<b>MGE3</b>	<b>MGE4</b>	<b>RM PSE</b>
BMWP	326	311	292	307	265	192
Class	I	I	I	I	I	I
Quality	Good	Good	Good	Good	Good	Good
Meaning	Very clean	Very clean	Very clean	Very clean	Very clean	Very clean
Colour						
ASPT	5.93	5.87	5.84	5.90	5.52	6.19
Class	III	III	III	III	III	III
Quality	Questionable	Questionable	Questionable	Questionable	Questionable	Questionable
Meaning	Moderately contaminated	Moderately contaminated	Moderately contaminated	Moderately contaminated	Moderately contaminated	Moderately contaminated
Colour						

Source: Authors' elaboration