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Full Length Research Paper

River quality analysis using environmental indicators: a case study in the Cunas river watershed, Peru

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Water pollution is one of the biggest environmental problems, not only by the rapid growth of urban centers, but also for wastewater discharge untreated into rivers. The aim was to analyze the water quality of rivers through environmental indicators. To do this, sampling three sectors defined on the cot river. The pressures exerted by human activities on water quality and biodiversity of benthic macroinvertebrates through the BOD_5 load to provide wastewater were evaluated. The quality of the river water was evaluated through INSF. The results showed strong anthropic pressure on the quality of the river with loads of BOD_5 of 23.70 kg / day from the wastewater from the fish activity, 391.64 kg / day of livestock and 418.48 Kg / day of urban activity. Physical indicators-chemical and bacteriological showed significant differences for conductivity, temperature and total dissolved solids. Four phyla, seven classes, 12 orders and 26 families of benthic macroinvertebrates were identified. It is concluded that discharges of wastewater from livestock and urban activities are significant human pressures on the quality of the river. Physical indicators-chemical and bacteriological quality of certain water, according to sector and time of sampling, are in the range of environmental quality standards. Wealth, abundance and diversity of benthic macroinvertebrates, by sector and sampling time showed significant differences.

Keywords: water quality, benthic macroinvertebrates, biodiversity, environmental indicators.

INTRODUCTION

Rivers are dynamic and multifunctional systems with a high degree of environmental heterogeneity. This complexity is favored by various interactions and transitions between climate, geomorphology, precipitation, water flow and river systems (Gómez et al., 2012; Guevara, 2014). However, the quality of these ecosystems is affected by various anthropogenic pressures (Van et al., 2015) in both its structure and the services they provide (Ormerod et al., 2010; Acosta et al., 2009).

The increasing deterioration that these ecosystems are experiencing both biodiversity and the quality of its waters

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is leading to their degradation both globally and watershed (Cordova et al., 2009; Ferreira et al., 2011; Rizo et al., 2013). These changes have stimulated in recent decades the development of biotic indices to assess the effect of human interventions on these ecosystems (González et al., 2013), highlighting those that rely on the use of benthic macroinvertebrates.

Benthic macroinvertebrates are organisms that occupy a habitat with certain environmental conditions (Guerrero et al., 2003). Changes in these conditions will be reflected in the structure of macroinvertebrate communities (Bonada et al., 2006), because these organisms respond to environmental faster than other biomarker changes; which can exhibit obvious answers when it is late from the point of view of managing wáter shed conservation (Wolfran et al., 2012).

The use of benthic macroinvertebrates to assess the ecological status of water bodies has become one of the main components of the legislation related to water worldwide (Moya et al., 2011; Pond et al., 2013). These bodies have proven to be good indicators of the quality of the aquatic environment (Gabriels et al., 2010), as they provide a measurable response to various disturbances of the medium.

Knowledge of the composition and structure of benthic macroinvertebrate communities in the rivers of the Andes of Central Peru is low compared to other riverine ecosystems in other Andean regions (Acosta, 2009). This lack of knowledge creates a high degree of uncertainty and not to apply a monitoring of the ecological state of the river from bioindicators such as benthic macroinvertebrates. In this context, the aim of the research was to analyze the state of biodiversity of benthic macroinvertebrates in the Cunas River by environmental indicators.

MATERIAL AND METHODS

Study area

The research was conducted in the Cunas River, located in the central highlands of Peru, in the Mantaro River hydrographic watershed. Its main course describes the shape of the letter S, with route direction West-East route. The river flow varies according to the time of the year. In the rainy season, the flow reaches 152.95 m^3/s and in the dry season 2.57 m^3/s (Local Water Authority -ALA, 2012). Concepción and Chupaca were the provinces included in the study.

Three sampling sectors were definedin Cunas River according to their area representativeness in terms of anthropic activity influence. Sector onewas located in the town of San Blas-Conception at 3440 masl (18L 455952E8670268S), the sector two in Huarisca at 3315masl (18L 471711E8667535S) and sector three in La Perla at 3229 masl (18L 470205E8667164S), the last two ones in the province of Chupaca.

Samples were synchronous for the determination of physico-chemical, bacteriological indicators and benthic macro invertebrates biodiversity in the rainy and dry seasons, considered in the investigation.

Anthropic pressures records on Cunas River macro invertebrate bio diversity

Anthropic pressures identification on Cunas River macroinvertebrate biodiversity was done previous river stretch course that the study included and the human activities records and their respective pressure sources that could affect water volumes. Then, the pressure magnitude was determined. To do this, the waste wáter discharged into the river flow was calculated, according to anthropic activity and to collect wastewater samples for the biological oxygen demand determination.

The pressure exerted by nitrogen and phosphorus contributions derived from agrochemicals use appreciation was done from nitrates and phosphates indicators determined int he Cunas River water in the three sampling areas.

Water physic-chemical analysis

Water samples were collected in the opposite direction to the flowing flow from the river surface.The identified indicators in sit were: dissolve doxygen (DO), total dissolved solids (TDS), temperature (°C), pH and turbidity (FTU). The determinations were made directly inthe Cunas River water, in each sample sector using portable Hanna Instruments (HI 991301 Micro processor pH /temperature, HI 9835 Micro processor Conductivity/TDS and HI9146 Micro processor dissolved oxygen). Previously, teams were calibrated in the respective sampling field.

Biological oxygen demand (BOD_5) was determined using the respirometric method with the equipment SOxi Direct Lovibond. Nitrates and phosphate were determined with the PC-Multi Direct photometer according to the procedure approved by the Agency for Environmental Protection of the USA, Hach Company (2000).

Benthic macroinvertebrate community analysis

In each sampling sector a 10m stretch of river was defined. Samples were collected using a Surber sampler with a square frame of 30 x30cm side (area 0.09m^2) anda 250 µm wire netting opening. Sampling was done by placing the wire netting cross current and removing the substrate upstream from themanga (Jáimez et al., 2002). Each simple consisted of 10 replicates which were preserved in alcohol at 70%.

Table 1: Pressure on the aquatic environmentand Cunas River benthic macroinvertebrate biodiversity, according to anthropic activity
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Anthropic Activity	Pressure	
	Source	**Indicator**
Fish farming	Bypass flow	Water flow captured
	Wastewater discharge	DBO_5 load contributed by wastewater
Farm	Bypass flow	Water flow captured
	Fertilizer and pesticide consumption	Nitrogen and phosphorus contribution
		Pesticide contribution
	Marginal strip occupation	Occupied stretch marginal area percentage
Livestock (working, camal)	Bypass flow	Water flow captured
	Wastewater discharge	DBO_5 load contributed by wastewater
Urban	Wastewater discharge	DBO_5 load contributed by wastewater
	Marginal strip occupation	Occupied area percentage
Hidroelectric	Bypass flow	Water flow captured
	Natural riverbade disruption	Fluvial habitat fragmentation

The taxa taxonomic identification was at a family level. To do this, different benthic macroinvertebrate taxonomic keys were used (Alvaetal, 2005; Alvarez, 2005; Andrei Takeand Ortiz, 2010; Narcis and Acosta, 2011; Gomezetal, 2012, Gonzales, 2013).

Data Analysis

Wastewater discharged into the river DBO_5, data normality was evaluated, the water physicochemical and bacteriological indicators, and biodiversity indicators normality data was evaluated with Anderson-Darling, Ryan-Joiner, Shapiro-Wilk, Jarque Bera and Kolmogorov-Smirnov statists of Minitab 16, SPSS 21 and PAST 2.17 software.

One way or factor ANOVA parametrics were used with the SPSS 21 program to physico-chemical and bacteriological indicators with normal distribution and Kruskal-Wallis ANOVA parametrics with the Minitab 16 program which did not show normal distribution, to detect significant differences ($p<.05$) in the two period sand three sampling areas. Water quality is determined by the index of the National Sanitation Foundation (INSF) in each sampling area.

Benthic macroinvertebrate community Simpson-Gini and Shannon-Wiener Taxa richness, abundance and diversity qualifiers were evaluated using the program PAST 2.17. To detect significant differences ($p<.05$) in the two periods and three sampling sectors, a factor ANOVA parametric was used with SPSS 21 program. When significant differences ($p<.05$) were detected, a Tukey posthoc test was performed to establish multiple comparisons between each time and sampling sector.

The most influential taxa determination in the Cunas River benthic macroinvertebrate community composition was done by similarity percentage analysis (SIMPER). Previously, the benthic macroinvertebrate abundance was transformed (X Log +1). This analysis was performed with the PAST2.17 program.

Finally, Pearson correlations were conducted to analyze the relationship among the abundance, richness and benthic macroinvertebrate diversity and Cunas River water quality. These correlations were performed with the SPSS 21 program.

RESULTS

Anthropic pressures on benthic macroinvertebrate biodiversity

Cunas River water in its downstream course Cunas waters below is derived through channels for fish production, agricultural areas irrigation, livestock use and electricity generation.They also receive wastewater discharges from fish farming, livestock, urban and water discharges after its turbinating in Huarisca Hydroelectric Plant. Other pressures that have been detected are the natural course disruption and river defenses on both river edges.

The river marginal stretch occupation for agricultura and dispersed human settlement is another significant pressure on the aquatic environment and the benthic macroinvertebrate communities that has been observed. The occupied marginal stretch area percentage for agricultura and urbanization is 13.92% (7.04 Ha) and 0.24% (0.12 Ha), respectively. This natural physical barrier loss disrupts the dynamics between the river and river vegetation and it favors the agrochemical and fertilizer excess to the water river, affecting its chemical characteristics and biota composition.

Inthe Cunas River lower part, water catchment for washing clothes and carrot has been detected, becoming as another important pressure for this part of the river for the supply of chemicals and detergents which receives water from the river (Table 1).

Significant anthropic pressures on the aquatic environment and Cunas River macroinvertebrate biodiversity infants were obtained prior pressure appreciation. DBO_5 fishing farming wastewater concentration ranged between 7.14 and 8.12 mg/L with a mean of 7.70 mg/L, a standard deviation of 0.50mg/L.DBO_5 livestock activity wastewater concentration fluctuated between 722 and 1069 mg/L with a mean of 869 mg/L.DBO_5 urban activity wastewater concentration fluctuates between 387 and 486 mg/L with an average of 428.3mg/L, a standard deviation of 51.5mg/L.

The fishing farming activity that is developed in Cunas River is subsistence and average discharge wastewater into river is 35.47 L/s with a DBO_5 load of 23.70 kg/day. Livestock activity makes an average contribution of 4.68 L/s of wastewater with a DBO_5 load of 391.64 kg/day and urban activity makes an average contribution of 11.30 L/s of wastewater with DBO_5 load of 418.48 kg/day.

The difference in DBO_5 load these anthropic activities contribute to the riveris mainly due to the concentration of DBO_5 each type of wastewater has. Thus, the water product from fish farming had an average DBO_5 concentration of 7.70mg/L, which is among the ranges of the environmental quality standards-EQS for high land river water (<10 mg/L). Wastewater from livestock activity had a DBO_5 average concentration of 869mg/L. This result excedes maximum permissible limits-MPL effluent for Peruvian Law surface water (50 mg/L).Wastewater from urban activity showed a DBO_5 average concentration of 428.3mg/L. This result excedes the effluent MPL for discharges into wáter (100 mg/L).

Pressures exerted by of nitrogen and phosphorus inputs derived from agrochemical application inputs, are related to the location of crops respect to the river, its type and chemicals, were detected, in small parcels, some occupying the marginal border and others very close to it. However, agricultural practices in this river stretch were considered not significant because nitrates and phosphates in water concentrations were below the EQS for highland river water.

Physico-chemical and bacteriological water indicators

Water pH presented variations in the evaluation section of the river, with average ranging from 7.17 in the San Blas sector in the rainy season to 7.97 in La Perla sector during the dry season. However, these variations are within the natural range for aquatic life. This same behavior showed electrical conductivity, with a salt content which is within the normal amount for aquatic life and other uses.

Turbidity values were higher in the rainy season, reaching a maximum value of 19 FTU in LaPerla sector. The DBO_5 mean ranged from 4.83 mg/L in San Blas sector during the rainy season to 11.12 mg/L in the Perla sector in the dry season. The lowest dissolved oxygen concentrations were recorded in La Perla sector, in the two sampling periods.

The variation in water temperatura did not show significant changes, although a slight increase was observed in La Perla sectorin the dry season. The total dissolved solid mean ranged from 102.67 mg/L in San Blas sector in the rainy season to 395.33mg/L in the La Perla, dry season. This increase would be due to the wastewater discharge which is discharged directly into the river without a previous treatment, mainly in the Huarisca and La Perla sectors.

Phosphates presented means ranged from 0.003mg/L in San Blas sector at 0.079 mg/L in the La Perla sector, both in the rainy season. Phosphates increased downstream as soon there are wastewater discharges and detergent contribution. While, nitrates had very low concentrations in the three sampling sectors.

Thermotolerant coli form concentration ranged from 39NMP/100ml in San Blas sector, rainy season 1100NMP /100ml in the LaPerla sectorin the dry season. The thermotolerant coli form concentration increase inthis sector would be due to the municipal wastewater which is discharged directly into the river without a previous treatment.

Table 2 shows Kruskal-Wallis ANOVA results for Cunas River water physic-chemical and bacteriological indicators, considering the time and the sampling area. Depending on the sampling time, only significant differences ($p<.05$) for conductivity, temperature and total dissolved solids were detected. However, according to the sampling sector, the indicators which showed significant differences in most of them corresponded to the simpled areas during the rainy season. While in the simple d areas in the dry season, the indicators showed significant differences in 50% of them.

Cunas River water quality results obtained from physico-chemical and bacteriological indicators, according to the Index of the National Sanitation Foundation (INSF) rated to San Blas sector water volumes as good quality water with an average of 76.91ICA-NSF for the rainy season and 72.40 for the dry season. While for Huarisca and La Perla sectors, this index rated the water volumes as average quality water. In Huarisca, the ICA-NSF averages were 70.08 and 66.27, for both the rainy and dry seasons. In La Perla sector the INSF averages were 61.07 and 58.47, for the rainy and dry season respectively.

Benthic macroinvertebrate biodiversity

Four phyla, seven classes,12 orders and 26 families of benthic macroinvertebrates were identified in the Cunas River during the rainy and dry seasons, in San Blas, Huarisca and La Perla areas. The Arthropoda phylum

Table 2: Cunas River water physicochemical and bacteriological Kruskal-Wallis indicators variance analysis according to time and sampling sector.

Bacteriological and physicochemical indicators	Sampling time			Sampling sector					
				A			B		
	H	p	Sig.	H	p	Sig.	H	p	Sig.
pH	3.44	.064	n.s	1.76	.416	n.s	0.42	.810	n.s
Conductivity	12.79	.000	*	0.20	.905	n.s	0.62	.733	n.s
Turbidity	3.44	.064	n.s	7.20	.027	*	6.49	.039	*
DBO_5	0.86	.354	n.s	7.20	.027	*	7.20	.027	*
Dissolved oxigen	0.01	.930	n.s	6.49	.039	*	7.20	.027	*
Temperature	12.79	.000	*	2.87	.239	n.s	2.07	.356	n.s
Dissolved total solids	11.56	.001	*	6.49	.039	*	2.96	.228	n.s
Phosphates	0.56	.453	n.s	6.07	.048	*	7.20	.027	*
Nitrates	0.38	.536	n.s	7.20	.027	*	5.60	.061	n.s
Thermotolerant Coliforms	0.78	.377	n.s	7.20	.027	*	7.20	.027	*

A = Sampled San Blas, Huarisca y La Perla sectors in rainy season (p<.05)
B = Sampled San Blas, Huarisca y La Perla sectors in dry season
H = Kruskal-Wallis Testing statistic

was the most representative in abundance and taxa richness. Being the Insecta type the most distinctive with 76.92% of the total phylum taxa (Table 3a). The highest numberbenthic macroinvertebrate taxa number occurred in the dry season (26) and the lowest in the rainy season (24).

The Diptera order had the highest individual abundance, both in the dry season and rainy seasons (71.8 and 74.3%, respectively), followed by the Ephemeroptera order (19.7and 17.8%, respectively). Coleoptera species reached their greatest abundance in the dry season (5.20%), followed by the order Trichoptera (3.36%) during the rainy season. Hemiptera was the order which had the lowest Insecta type abundance, in both sampling periods (0.2% in the dry season and 0.04% in rain).

The Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa number decreased downstream, being replaced by the Diptera order taxa, which most of them are the most tolerant to contamination by organic matter. However, the taxa composition for taxonomic orders showed little variation in the two sampling periods.

In San Blas Sector abundance (logX+1) showed variations, with means ranging from 3.00 during the rainy season to 3.64 in the dry season. Taxa richness mean (S) was higher in the dry season. The Simpson diversity index mean (1-D) did not change between the two periods. However, the Shannon-Wiener diversity index mean (H') was higher in the dry season. Similar behavior was observed in Huarisca sector. In La Perla, biodiversity indicator mean recorded in the dry season was markedly higher than the indicator mean recorded in the rainy season (Table 3b).

The results of ANOVA of a factor of abundance, richness and diversity of Shannon-Wiener showed significant differences (p=.000) at the level of significance of 5%, depending on the time and area sampling.

The Cunas River benthic macroinvertebrate community composition results which were analyzed using similarity percentage (SIMPER), showed that the Diptera and Ephemeroptera orders contributed more in the differentiation of these communities. The highest contribution percentages were presented by the Diptera (46.05%) and Ephemeroptera (37.87%) orders, contributing with 83.92% of the taxa total. At family level, in the rainy season, the highest percentage of the contribution was made by Chironomidae individuals (47.65%), followed by those of Leptophlebiidae (19.89%%) and Simuliidae (16.17%), contributing with 83.71% of total families registered. Furthermore, the analysis defined the Chironomidae family as the most dominant in La Perla.

The family that contributed the most to the dissimilarity in abundance and species composition between sampling areas during the dry season, was the Chironomidae family with an average of 717 individuals and 54.39% of contribution, followed by Simuliidae, Leptophlebiidae families and Baetidae *families* (Table 4).

The resultsof the Pearson coefficient linear correlation coefficient between the benthic macroinvertebrate richness and water quality index INSF, showed a very high correlation, both in the dry season (0.987) as in the rain season (0.976). Similar behavior shows the correlation

Table 3a: Collected benthic macroinvertebrate taxa in Cunas River, in rainy and dry seasons.

Phylum	Type	Order	Family
Platyhelmintes	Turbellaria	Tricladida	Dugesiidae
Annelida	Oligochaeta	Tubificida	Tubificidae
	Hirudinea	Glossiphoniiformes	Glossiphoniidae
Mollusca	Gastropoda	Basommatofora	Lymnaeidae
Arthropoda	Crustacea	Amphipoda	Hyalellidae
	Arachnoidea	Acari	Hydrachnidiidae
	Insecta	Ephemeroptera	Baetidade
			Leptophlebiidae
		Plecoptera	Perlidae
			Gripopterygidae
		Trichoptera	Hydropsychidae
			Hydrobiosidae
			Hydroptylidae
			Leptoceridae
			Limnephilidae
		Coleoptera	Elmidae
			Hydrophilidae
			Hydraenidae
			Scirtidae

Table 3b: Descriptive statistics of biodiversity indicators Cunas benthic macroinvertebrate the river, according to area and time of sampling.

Area sampling	Period	Descriptive statistical	Biodiversity indicators			
			Abundancia (logX+1)	Richness(S)	Simpson index (1-D)	Shannon-Wiener index(H')
San Blas	Rain	Minimum	2.71	5.00	0.62	1.16
		Maximum	3.16	13.00	0.79	1.79
		Average	3.00	8.20	0.71	1.53
		DE	0.15	2.44	0.60	0.24
	Dry season	Minimum	3.54	11.00	0.64	1.32
		Maximum	3.75	19.00	0.84	2.22
		Average	3.64	13.80	0.71	1.66
		DE	0.07	2.15	0.58	0.25
Huarisca	Rain	Minimum	2.15	3	0.37	0.65
		Maximum	2.91	6	0.77	1.59
		Average	2.62	4.40	0.53	1.04
		DE	0.21	1.17	0.16	0.34
	Dry season	Minimum	3.31	9	0.33	0.81
		Maximum	3.77	12	0.67	1.51
		Average	3.58	10.60	0.46	1.07
		DE	0.15	0.97	0.10	0.20
La Perla	Rain	Minimum	2.36	1	0.00	0.00
		Maximum	3.35	3	0.29	1.29
		Average	3.05	2.10	0.10	0.32
		DE	0.32	0.88	0.10	0.18
	Dry season	Minimum	3.80	7	0.17	0.40
		Maximum	4.12	11	0.66	1.27
		Average	3.96	8.30	0.44	0.92
		DE	0.10	1.57	0.14	0.25

Table 4: Cunas River benthic macroinvertebrate family abundance mean and contribution percentage, indry season, according to SIMPER analysis.

Taxa	Av. dissim.	Contrib. %	Cumulative %	Abund mean San Blas	Abund mean Huarisca	Abund mean La Perla
Chironomidae	38.00	54.39	54.39	11.90	292	717
Simuliidae	9.13	13.08	67.47	159	38.8	10.50
Leptophlebiidae	8.58	12.29	79.76	135	2.70	0
Baetidade	6.74	9.65	89.41	56	22.20	136
Elmidae	2.26	3.24	92.65	24.50	13.30	48
Tipulidae	0.84	1.21	93.86	9.50	13.60	9.90
Leptoceridae	0.54	0.78	96.64	8.20	0.70	0
Hydropsychidae	0.52	0.75	95.39	7.70	1.40	0.60
Empididae	0.39	0.55	95.94	2.50	3.90	2.40
Gripopterygidae	0.36	0.52	96.47	5.30	0.70	0.40
Tubificidae	0.33	0.47	96.94	2.70	2.20	3.00
Psychodidae	0.26	0.38	97.32	2.00	0.60	2.60
Ceratopogonidae	0.22	0.32	97.64	1.50	0.50	3.00
Lymnaeidae	0.22	0.31	97.95	0.70	0.40	3.50
Perlidae	0.21	0.30	98.26	3.20	0.40	0
Hydraenidae	0.21	0.29	98.55	1.90	0.30	1.40
Hydrobiosidae	0.18	0.27	98.82	2.50	0.60	0
Naucoridae	0.16	0.23	99.05	0.50	0.20	2.80
Dugesiidae	0.12	0.17	99.22	0.80	1.20	0.70
Hydroptylidae	0.12	0.17	99.39	1.50	0.50	0.20
Scirtidae	0.11	0.15	99.54	1.10	0.40	0.40
Limnephilidae	0.10	0.15	99.69	0.70	0.30	1.00
Hydrophilidae	0.07	0.11	99.80	1.00	0.30	0
Hydrachnidiidae	0.07	0.10	99.90	0.80	0.50	0
Glossiphoniidae	0.03	0.05	99.95	0.40	0.20	0
Hyalellidae	0.03	0.04	100	0.50	0	0

between diversity and water quality index (0.922 at drought, 1,000 in rain).

DISCUSSION

Anthropic pressures on benthic macro invertebrate biodiversity

Anthropic pressures both at global as watershed scales are exerting strong pressure on the aquatic environment and the biological communities that inhabit it, adversely affecting water quality and the structure and functioning of these communities, as well.

The results show that the Cunas River has been enduring various pressures, since the diverting flow to wastewater discharge coming from fishing, livestock and urban activities (direct pressures). However, the pressure that fish production exerts in this river stretch is low, since DBO_5 water concentration is between maximum permissible limits for effluents whose fate is surface water and even itis in the range of environmental quality standards for highland water rivers.

The pressures exerted by waste water discharge from the livestock and urban activities are significant. Waste water DBO_5 concentration from livestock origin excedes effluent maximum permissible limits for surface water. The same behavior have urban wastewater DBO_5 concentrations, they municipal maximum permissible limits effluent for surface water.

The results show thatwater discharges product of these activities do not have a previous treatment before its disposal. These pressures are leading to reduced water quality and quality degradation especially in the last riverstretch (La Perla sector).

The livestock and urban activity continuous development without environmental criteria is leading to excessive organic pollutants loads emission (discharges directly into the river). Causing processes that impoverish and reduce the aquatic ecosystem growing ability to eliminate this disposal (Alonso and Camargo, 2005), which threatens the food supply sustainability and biodiversity.

The riparian vegetation removal of in a great part of the river is another of the detected pressures. This type of pressure reduces the water column thermal stability, increases the sediment and aquatic macrophytes frequency and facilitates the pollutant entry into water volumes (Scalley and Aide, 2003). Among the most important consequences of this pressure is water quality deterioration, biodiversity reduction (Corbacho, 2003; Cordova et al., 2009; Ferreira et al., 2011) due to habitat destruction of many aquatic insect fauna adult stages (Egler, 2012).

Other authors have said that benthic macroinvertebrate communities are severely affected by lack of shelters (González et al., 2013) compared to hydraulic stress exerted floods (Bonada et al, 2006; Munn et al, 2009.). However, other factors that would be contributing to the composition and benthic macroinvertebrate community structure (Rizo et al., 2013), the temperature, since these organisms do not only respond quickly to anthropic disturbance but also to the natural ones (small increases in temperature).

Durance and Ormerod (2007) studied the effects of climate change on the macroinvertebrate fauna in upland rivers of the North-Atlantic for a period of 25 years. They argue that macroinvertebrate abundance could decrease in 21% for each increase of 1°C.However, if the temperatura increases in 3°C, between 5 and 12% would be atextinction risk.

Inthis context, the temperatura increase of about 1°C in the Mantaro River basin, in the last decade, reveals another of the pressures that Cunas River benthic macroinvertebrate biodiversity has been supporting. This temperature trend is influencing the Earth climate system and leading to climate change whose effects threaten these organisms biodiversity, specifically.

Water physic-chemical and bacteriological indicators

The water pH results recorded during the two sampling periods are among the EQS ranks for highland riverwater, referred to the category three (vegetal watering and animal beverages) and category four (aquatic environment conservation), with alkalinity tendency.

The water pH tendency towards alkalinity would be related to the soil conditions where the course goes, to farming activity (Perezand Rodriguez, 2008), and wastewater discharges that are made directly to the river river bed (Cordova et al., 2009). Another factor equally important factor that would be contributing to the wáter pH variation would be the photosynthetic activity (CO_2) that occurs during the day (Molina et al., 2008).

Dissolved oxygen is undoubtedly the most important disolved gas in natural water. This gas together with temperature determine the benthic macro invertebrate family richness and distribution patterns (Guerrero et al., 2003). Dissolved oxygen values obtained in two out of the three sampling sectors reflect oxygen relatively good levels. However, the oxygen amount also depends on the river bed characteristics, water turbulence, and chemical and biological processes.

DBO_5 low values in San Blas sector show the small amount of organic matter in its water. However, in La Perla, DBO_5 values reveal organic pollution, because they are beyond the ECA water for highland water river.

The temperature is a limiting factor for most aquatic organisms and in fact it is a constant that has great importance in the various phenomen a development that take place in the water, because it determines the physical properties, richness and macroinvertebrate family distribution (Bustamante et al., 2008).

Data from the three sampling sectors basically reflect uniform temperature, even though higher in La Perla sector, where lowflow and scarce vegetation cover, due to riparian vegetation removal, determine high environmental temperatures, and therefore they impact in water temperature. However, the obtained results according to time are significant, which would explain the existent variability.

Phosphorus isone of the limiting factors in algae and aquatic plants growth, so their concentrations determination allows to detect water bodies eutrophication problems (Rivera et al., 2008). The obtained phosphate value sin the three sampling sectors do not exceed the environmental quality standards (0.5 mg/L) for the aquatic environment conservation.

The thermotolerant coliform values, water body fecal pollution indicators, exceed the environmental quality standards thresholds for highland water rivers, category three. Highlighting livestock and urban origin wastewater discharge untreated to the river, since the presence of these bacteria in water reveals fecal contamination.

Bacterial contamination from wastewater and animal waste is one of the major causes of illness and human death. The consequences for health cause 12,000 million dollar a year economic cost (Shuval, 2003). This untreated waste does not only cause negative impacts onpeople's health but also inaquatic ecosystems and their biodiversity.

Regarding sampling sectors both in the rainyand dry seasons, the turbidity, DBO_5, dissolved oxygen, phosphates and thermotolerant coliform results showed significant differences. However, these differences were more evident in La Perla sector, in lower flow time, probably caused by anthropic activity increase and at the lower dilution capacity that the river presents in this time (Morais et al., 2004). While these same indicators, according to the sampling season, did not showed significant differences.

Considering wáter quality índices are tolos that provide a more accurate ecological stateand biological environment state perspective (Pagot., 2003; Gonzales et al, 2013), the obtained results by physicochemical and bacteriological indicators have been integrated through the NSF water quality index. This index ranks San Blas water as good water quality, which indicates that the threat degree by anthropic type exogenous factors (organic pollution) is lower. Aquatic environment conditions are close to the natural ones.

La Perla and Huarisca sampling sector water quality measured through INSF qualifies as medium quality wáter and indicates that organic and biological threat degree pollution is moderate. However, water volumes in the La Perla sector show a certain tendency to qualify as poor water quality.

Benthic macroinvertebrates biodiversity

The obtained results show that the most abundant benthic macroinvertebrates correspond toInsecta type individuals. Diptera order has the most abundantand this order most representative family is Chironomidae. This family spectrum distribution extends to all zoogeographical regions including Antarctica (Rivera et al., 2008).

The Chironomidae individual lowest abundance recorded in San Blas sector confirms the high oxygenation level that water volumes have. Similarly, the greater abundance of these individuals recorded in the La Perla, confirmsits low water oxygenation level. The results coincide with Ferrington (2008) who noted that Chironomidae abundance increases when there are low oxygen levels.

Miserendino, et al. (2012) also confirms the obtained results in La Perla sector, he refers the macroinvertebrate density decrease is related to the waterand food quality decrease, with breathing mechanisms interference and other physiological and morphological characteristics.

Another important family due to its abundance in San Blassector is Simuliidae. This family is characterized for living in oligotrophic, clean, well-oxygenated water. Other found dipterous that were recorded correspond to the Ceratopogonidae, Tipulidae, Empididae, and Psychodidae families.

The greatest individual abundance of the Ephemeroptera order occurred in San Blas. Results are corroborated by Rivera et al.(2008) and Colla and Salas (2013) who report that most of this order species have low tolerance to pollution. They prefer to live in places with good oxygenation, in stone and sand substrates. The family with most abundance was Baetidae, this family individuals can tolerate certain degree of pollution (Romero et al, 2006; Baptista et al, 2006.). This explains Baetidae abundance recorded in La Perla sector.

Theorder Trichopterais an important of benthic community component and aquatic ecosystem food chain base (Rivera et al., 2008). The greatest Trichoptera order abundance was recorded in San Blas sector, where water quality is good. The most representative family for its abundance is Hydrosychidae. These results are corroborated by Acosta (2009) and Rodriguez et al.(2011), who point out that trichopteros are clean water indicators and their abundance increases with altitude increase.

The Coleopteraorder is the tax on that has colonized all kinds of aquatic biotopes. Most families preferstanding water with abundant vegetation. Conversely, the Elmidae family prefers running and good quality water (Valladolid et al., 2006). This family is the most abundant and the best distributed in this order.

The Plecoptera order ranked fifth in terms of abundance. This group of insects, Perlidae, and Gripopterygidae families, are restricted to the sector San Blas. Results are agreed by Molina et al. (2008), who reports that this order individuals are the most demanding in the macroinvertebrate group in terms of water quality.

Other benthic macroinvertebrates, such as the phyla Mollusca, Annelida and Platyhelmintes were the lowest abundance recorded in the three sampling areas.

Benthic macroinvertebrate biodiversity indicators according to sampling time and sector, have significant differences. These results agree with Verdonschot's (2006) and Chaves et al. (2008), who report that in areas with warm weather, seasonality plays a very important role in the macroinvertebrate community structure.

The structure of these communities follows an expecteds patial pattern because the Ephemeroptera, Plecoptera and Trichoptera abundance is higher in the more altitude sampling sector (San Blas). While Mollusca, Annelida and Platyhelmintes taxa individuals follow the opposite pattern (Sanchez et al, 2007; Rodriguez and Turizo, 2011).

Overall, the benthic macroinvertebrate greatest abundance is recorded in the lowest altitude sector (La Perla). This increaseis determined by the high abundance that the Diptera order, especially the Chironomidae family, considered as the resistant and resilient taxon against anthropic pressures such as urbanizationand native vegetation replacement for pastures and crops, which are leading tobiological community impoverishment and therefore they are altering the ecosystem (Maroneze et al., 2011).

In San Blas sector, benthic macroinvertebrate richness and diversity of showed higher values than in Huarisca and La Perla sectors, showing significant differences in both the rainy and dry seasons.

The spacial pattern that the benthic macroinvertebrate taxa number follows in the Cunas River is highly dependent on the water quality because as it has a high correlation between benthic macroinvertebrate community taxonomic richness and water quality. Similar behavioris recorded for diversity and water quality.

Sensitive taxa to riseas Chironomidae, considered as tolerant to water quality deterioration, it increases in the dry season, which would be mainly related to water quality in La Perla sector, as it was described in other studies (Chaves et al, 2008;. Colla, 2013).

Cunas River benthic macroinvertebrate bio diversity current state is no more than the human intervention past trends result. Nowadays, the largest population growth (dispersed human settlements along the river) is leading togreater pressures on these organism communities. Therefore, if human intervention current trends on benthic macroinvertebrate biodiversity along the course evaluated river continue being under production process development conditions that have negative impacts on these organisms biodiversity, it is likely to irreversible changes in composition and structure.

Finally, result analysis reveals that in San Blas sector, the anthropic activity impacton benthic macroinvertebrate impact is compatible, which means it does not require corrective measure implementation. In Huarisca sector, biota good state recovery takes some time, so it is advisable to corrective measure implementation. Meanwhile, in La Perla sector, whose impact is severe requires corrective measure introduction for its recovery which lead to bring to acceptable levels the ecological and chemical states of Cunas River water to achieve these organism biodiversity conservation and sustainable use.

Riparian areas are animal and plant species home. It is the last defense line for the water quality and biological community protection. Besides, it exerts astrong influence on the diversity organization and associated community dynamics associated with aquatic and terrestrial ecosystems.

In response to the detected anthropic pressure, riparian vegetation removal (the river marginals trip occupation), we propose to recover this defense line with native species so that we can provide better conditions for the aquatic insect fauna reproduction and protect the aquatic resource.

The reparian repopulation must be limited to the river marginals trip width to avoid conflicts of the residents who own their land bordering the river. Furthermore, zone residents must be involved to ensure project success.

The responsible ones to carry out the mitigation and adaptation measures proposed by Dirección Regional de Agricultura, the Cunas River bordering town municipalities, Regional Government and civil society.

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