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Physicochemical and biological characterization of the Roble river, Upper Cauca, western Colombia

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Abstract: Caracterización fisicoquímica y biológica del río Roble, Alto Cauca, occidente de Colombia. Para determinar las diferencias diarias y estaciónales, así como la productividad y el estado trófico del río Roble, un afluente de la Vieja, alto Cauca al occidente de Colombia, tomamos muestras de fitoplancton, zooplancton, peces y macroinvertebrados y registramos variables físico-químicas (oxígeno disuelto, porcentaje de saturación de oxígeno, pH, conductividad, humedad relativa, temperaturas ambiente, del agua, máximas y mínimas, ancho, profundidad, velocidad de la corriente, sustrato, CO_2, DQO, DBO_5, dureza total, dureza calcica y durezas magnesicas, sólidos totales, disueltos y suspendidos, alcalinidad , acidez, cloruros y turbidez) durante sequía y lluvias. La mayoría de las variables físico-químicas tales como la humedad relativa, oxígeno disuelto y porcentaje de saturación de oxígeno mostraron bajos coeficientes de variación, a excepción de déficit de oxígeno. El índice de diversidad de Shannon-Wiener, Equidad y Dominancia fueron bajos alrededor de 0.5. Registramos ocho órdenes, 28 familias y 58 géneros de macroinvertebrados, tres divisiones, cinco órdenes y 45 géneros de fitoplancton, dos divisiones y seis géneros de zooplancton y 19 especies de peces. El río Roble presentó un estado trófico heterotrófico-alóctono y es oligotrófico con tendencia a la eutroficación.

Key words: Estado trófico, limnología, bioindicadores, quebrada, metabolismo.

Resumen: To determine dial and seasonal differences as well as productivity and the trophic status of the lower Roble river, a tributary of the Vieja and upper Cauca rivers of west Colombia, we sampled phytoplankton, zooplankton, fish and macroinvertebrates and recorded physicochemical variables (dissolved oxygen, percent oxygen saturation, pH, conductivity, relative humidity, temperatures environmental, water, maximum and minimum, width, depth, current velocity, substrate, CO_2, COD, BOD, total hardness, calcium and magnesium, total solids , dissolved and suspended, alkalinity, acidity, chlorine and turbidity) during the wet and dry seasons. Most physicochemical variables such as relative humidity, dissolved oxygen and percent oxygen saturation showed low coefficients of variation, except for oxygen deficit. The Shannon-Wiener diversity index, equity and dominance had low values around 0.5. We recorded eight orders, 28 families and 58 genera of macroinvertebrates, three divisions, five orders and 45 genera of phytoplankton, two divisions and six genera of zooplankton and 19 species of fishes. This river has an allochthonous-heterotrophic trophic state and productivity is oligotrophic but with a tendency to eutrophication.

Palabras clave: Trophic state, limnology, bioindicators, stream, metabolism.

INTRODUCTION

Limnological studies show that most water bodies today are impacted by human activities. In the Neotropics, significant degradation of aquatic resources occurs because of agriculture and residual water from households (Román-Valencia *et al*., 2005). Limnological analyses are usually carried out to determine baseline vales for physical and chemical characteristics of water bodies and how these correlate with the associated biological communities. It has been shown that each type of aquatic ecosystem is usually associated with a particular community of organisms (Lampert & Sommer, 1997, Wetzel & Likens, 2000; Roldan & Ramirez, 2008). Biological aspects of aquatic ecosystems have become increasingly important in monitoring their health because physicochemical variables only provide a snapshot in time of water quality, but do not represent how the ecosystem changes over time (Alba-Tercedor, 1996). The living elements of these systems, such as macroinvertebrates, fish, phytoplankton and zooplankton are witnesses to the environmental degradation of surface waters where they live. (Caicedo & Palacio, 1998). As such, changes in the abundance and structure of their communities, when compared within hydrological systems of similar characteristics, act as biological indicators of aquatic ecosystem overall health.

In the Neotropics, natural dramatic altitudinal and seasonal differences have been documented for physical and chemical parameters of continental waters (rivers, streams, lakes) (Sierra *et al.*, 2004). But constantly increasing anthropogenic impacts are rapidly overshadowing naturally occurring variations in freshwater ecosystems. The objective of this study provide baseline data on the aquatic ecosystem health of the lower Roble river, Vieja river drainage, upper Cauca, Colombia. By measuring both physicochemical and biological variables we provide a comparison point for future studies.

MATERIALS AND METHODS

Study area. The Roble river is located in the Colombian department of Quindío, and includes the Quimbaya and Montenegro municipalities (N 4° 40' 74''- W 75° 53' 64''), at an elevation of about 1100 m.a.s.l. The vegetation in this region is represented by the families of Asteraceae, Zingiberaceae, Mirtaceae, Curcurbitaceae, Cyperaceae, Heliconeacea, Piperaceae, Marantaceae, Amarantaceae, Moraceae, Cecropiaceae, Leguminosae, Melastometaceae and Poaceae; and is dominated by bamboo *Guadua angustifolia* and ferns (Pteridophyta). This type of vegetation is characteristic of premontane humid forests. Water color is brown, and the substrate is a mix of stones and sand. In some places of lower velocity of water flow, organic detritus accumulates.

Sampling and laboratory analyses. Samples were collected from 29 February - 2 March and from 17- 19 April 2008. Average multi-annual precipitation (1985-2005) was determined from pluviometric data from the Maracay meteorological station (N 4° 36'-W 75° 44', 1402 m.a.s.l.). dissolved oxygen, percentage of oxygen saturation and water temperature were recorded with a digital oxymeter OXI196-microprocessor; pH with a potentiometer PIN POINT-BNC, conductivity with conductimeter (Hanna H198842); relative humidity, ambient temperature, maximum and minimum temperature with a digital thermohygrometer (Fisher Scientific W5160H); width and depth with a decameter and flexometer respectively and current velocity was measured by timing a floating ball in to travel one meter.

Water samples were analyzed in the water laboratory of Quindío University for total hardness, calcium and magnesium hardness, total solids, dissolved and suspended solids, alkalinity, acidity, chlorine and turbidity using the methods described in APHA (1998) and Wetzel & Linkens (2000). Phytoplankton and zooplankton were collected in one liter bottles, preserved in situ with 4 %-formaldehyde, stained with lugol and later transported to the Biology Laboratory of Quindío University for identification by using taxonomic keys Lackey (1956), Kudo (1966), Bicudo & Bicudo (1970), Uhlerkovich & Schmidt (1974), Needham & Needham (1978). Phytoplankton and zooplankton density was determined using the drop technique and expressed as ind/ml. Macroinvertebrates were collected with the use of hand nets, surber nets, triangular nets (D-net) and entomological forceps (direct capture), and were preserved in 70%-alcohol and transported to the laboratory for identification to genus with taxonomic keys: Rodriguez *et al.* (1992), Roldan (1996), Wetzel & Linkens (2000), and Posada-García & Roldan-Pérez (2003). Fishes were collected with different kinds of nets following methodology of García-Alzate *et al.* (2007). When possible, identification was done in situ but samples that couldn't be determined in the field visually were preserved in 10%-formaldehyde and taken to the Ichthyology Laboratory at Quindío University where they were identified using taxonomic keys for this area (Román-Valencia 1995, 2003; Ruiz-Calderon & Román-Valencia 2006; Román-Valencia & Ruiz-Calderon 2007; García-Alzate & Román-Valencia 2008).

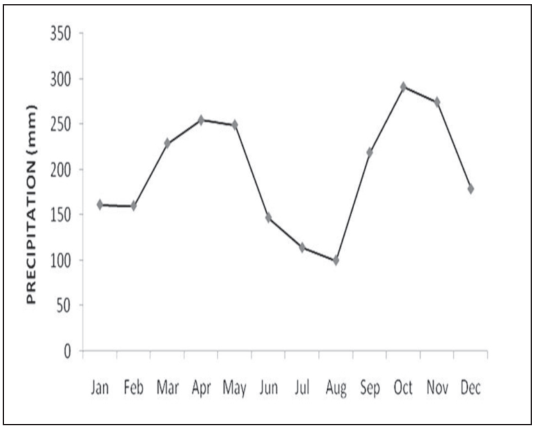

Fig. 1. Pluviometric data of station Quimbaya, Maracay, Department of Quindío, Colombia. This data are on average precipitation between 1985 and 2005 for station Maracay.

Metabolism. Ecosystem metabolism (Wetzel & Likens, 2000) was calculated by collecting water samples at regular intervals during 40 hours and determining dissolved oxygen, percent oxygen saturation, pH and conductivity in transparent and dark bottles.

Data analysis. For pluviometric data the multi-annual monthly analysis was made with averages from 1985 to 2005 from the Maracay station. Analysis of variance (ANOVA) was cal-

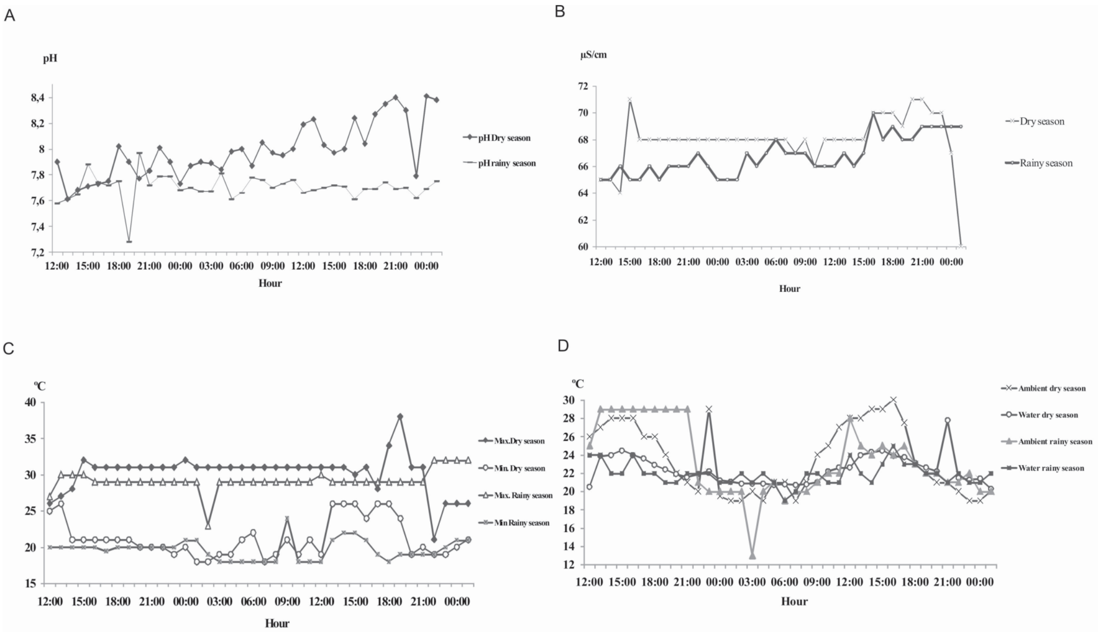

Fig. 2. Comparison of nictemeral compartment, of physicochemical variables in Roble river , Upper Cauca Colombia; (A.) pH, in dry and rainy season; (B.) conductivity in dry and rainy season; (C.) Maximal and minimal temperature in dry and rainy season; (D.) Water temperature and ambient temperature in dry and rain.

culated with 95% significance for comparison of physicochemical variables between seasons and hours. Also the coefficient of variation (CV) was calculated as an average of relative dispersion that indicates the relationship between the standard deviation and the average, and range (maximum and minimum values) by using the statistic package Stat graphics Plus 5.1. Index of water quality was calculated following Viña & Ramirez (1998). Dissolved oxygen was corrected for altitude (Roldan, 1992). Oxygen deficit was calculated comparing values of dissolved oxygen from the river with those of the transparent and dark bottles between season (Wetzel & Likens, 2000). Relative and absolute abundance were calculated from biological variables such as the Shannon-Wiener index of diversity (H’), Margalef (M), Simpson dominance (D) and Pielou equity (E) using Divers under Windows program (Pérez & Sola, 1993) with index of logarithm in base 10. The BMWP index for macroinvertebrates modified for Colombia was calculated (BMWP/Col; Roldan, 2003).

RESULTS

Physicochemical variables. Twenty years of records from the Maracay station, Quimbaya municipality, show an annual bimodal rainfall distribution with peaks in April-May, and October-November. Our sampling times thus include both the dry and rainy seasons (Fig. 1).

Physicochemical parameters showed significant differences between seasons, except for minimum temperature ($F=1.95$, $p= 0.512$). Dial variation for most physical and chemical variables didn’t show significant differences except conductivity in the rainy season ($F= 3.47$, $p= 0.001$). Maximum and minimum temperature both noticeably decreased at night (Fig. 2c), ANOVA showed that significant differences exist between maximum and minimum temperatures for the different seasons ($F=24.47$, $p=0.000$). Coefficients of variation (% CV) of maximum and minimum temperature for dry and rainy season were generally low (Table 1).

The pH values (Fig. 2a) differed significantly between seasons ($F=1.79$; $p=0.032$) but for the dial cycle it varied little (3.27 % CV in dry and 2.77 % CV in rainy season), generally pH values were close to neutral. Conductivity also showed a low coefficient of variation (3.08 % CV in rainy and 2.18 % C.V in dry season), and the mode was the same for both seasons (67 μs/cm). Nevertheless, ANOVA showed that significant differences did exist between seasons ($F= 5.32$; $p=0.000$), with atypical values in the dry season, whereas for the rainy season records were more homogeneous with little noticeable variation (Fig. 2c). Average water temperature was 22.32 ºC; the dry season coefficient of variation was low (6.94 % C.V), and the rainy season average was lower (21.86 ºC) with the same as coefficient of varia-

TABLE 1. Physicochemical variables of the Roble river, Upper Cauca, Colombia. ***C.V*** = Coefficient of variation.

VARIABLES	DRY SEASON		RAINY SEASON	
	VALUE	C.V (%)	VALUE	C.V (%)
Altitude (m.a.s.l)	1100			
Water temperature (ºC)	20.3 – 24.5 (22.32 ± 1.54)	6.94	19-24 (21.86 ± 1.13)	1.10
Ambient temperature (ºC)	19 – 29 (23.682 ± 3.64)	15.4	13-29 (22.95 ± 3.77)	5.20
Oxygen saturation (%)	39.6 – 107 (69.28 ± 20.30)	29.30	39,9-97,65 (68,06)	21,49
Dissolved oxygen mg/L	3.81 – 8.775 (6.23 ± 1.72)	27.60	3,26-7,8 (5,33)	18,32
Relative humidity	41 – 97 (74.07 ± 20.88)	28.18	42 – 93 (85.52 ± 11.6)	13.62
pH	7.16 - 8.41 (7.94 ± 0.36)	3.27	7.2 – 8.38 (7.75 ± 0.21)	2.77
Conductivity	60 – 71 (67.77 ± 2.09)	3.08	65 – 69 (67 ± 1.46)	2.18
Maximum temperature (ºC)	21– 38 (29.77 ± 2.85)	15.42	21 – 30 (28.56 ± 2.78)	9.74
Minimum temperature (ºC)	18 – 26 (21.25 ± 2.52)	11.89	16 – 24 (19.67 ± 1.47)	7.48
O.D.	6.53	-	6.0	-
D.B.O mg/l O_2	3.1	-	5.2	-
D.Q.O mg/l O_2	183.92	-	80	-
Total hardness (mg/l $CaCO_3$)	32	-	26	-
Calcium hardness (mg/l $CaCO_3$)	12	-	16	-
Magnesium hardness mg/l $CaCO_3$	20	-	10	-
Alkalinity (mg/l $CaCO_3$)	64.28	-	28.14	-
Acidity (mg/l $CaCO_3$)	37.16	-	15.9	-
Total solids mg/l	120	-	-	-
Dissolved solids	80	-	-	-
Suspended solids mg/l	40	-	5.0	-
Chlorine mg/l	84.09	-	4.50	-
Turbidity	129 F.T.U	-	< 5 F.T.U	-
Discharge (m^3/s)	343.56			
CO_2	3.645	-	3.645	-
Fecal Coliform UFC/100ml	100	-	-	
Total Coliform UFC/100ml	120	-	-	
Substrate	Stony		Stony – Sandy	
Width (m)	16.33	-	18	
Depth (m)	1.2	-	1.4	
Color	Brown		Brown	
Velocity of current m/s.	0.018 – 0.025 (0.22)	-	2.016	-
TRANSPARENT BOTTLE				
Dissolved oxygen mg/l	3.4 – 9.71 (6.07 ± 1.74)	28.71	2,98 – 8,3 (5,21)	21,51
Oxygen saturation (%)	37.3 – 107 (66.34 ± 21.69)	32.69	36,75 - 100,8 (63,57)	18,05
Oxygen deficit mg/l	- 2.57 – 3.65 (1.057)	167.19	-3 – 2,3 (0,08)	100,78
pH	-	-	7.2 – 8.38 (7.75 ± 0.21)	2.77
Conductivity	-	-	65 – 69 (67 ± 1.46)	2.18
DARK BOTTLE				
Dissolved oxygen mg/l	3.05 – 9.5 (6.13 ± 1.73)	28.2	2,61 – 8,2 (5,24)	20,50
Oxygen saturation (%)	36.1 – 107 (67.26 ± 19.68)	29.26	30,45 – 102,9 (64,18)	17,98
Oxygen deficit	-1.83 - 4.66 (1.58)	110.71	-2,5 – 2,7 (0,10)	100,86
pH	-	-	7.2 – 8.46 (7.68 ±0.22)	2.46
Conductivity	-	-	65 – 80 (68.90 ± 2.54)	2.69

tion (1.10 %) although this was considered low it was observed that for this period data was close to an average, and that explains differences in the coefficient of variation for both seasons (Fig. 2d). Generally in both climatic seasons temperature decreased if we take into consideration maximum and minimum registered values (Table 1). ANOVA showed that water and ambient temperature had significant differences between seasons (F=9.45, p= 0.000; F= 2.31, p= 0.01).

ANOVA showed significant differences in relative humidity between seasons (F=10.76; p=0.000); for the dial cycle this variable had a high coefficient of variation (28.18 %) with mode of 74.07 % for dry season, very different from the rainy season where the coefficient of variation was low (CV 13.62), with an average of 85.52%. Nevertheless, in the dry season this variable showed higher fluctuations compared with the rainy season (Fig. 3a).

Dissolved oxygen was generally high in the dry season with an average of 6.23 mg/l and a high coefficient of variation (27.60%) in comparison with rainy season (5,32 mg/l and 18,32%).

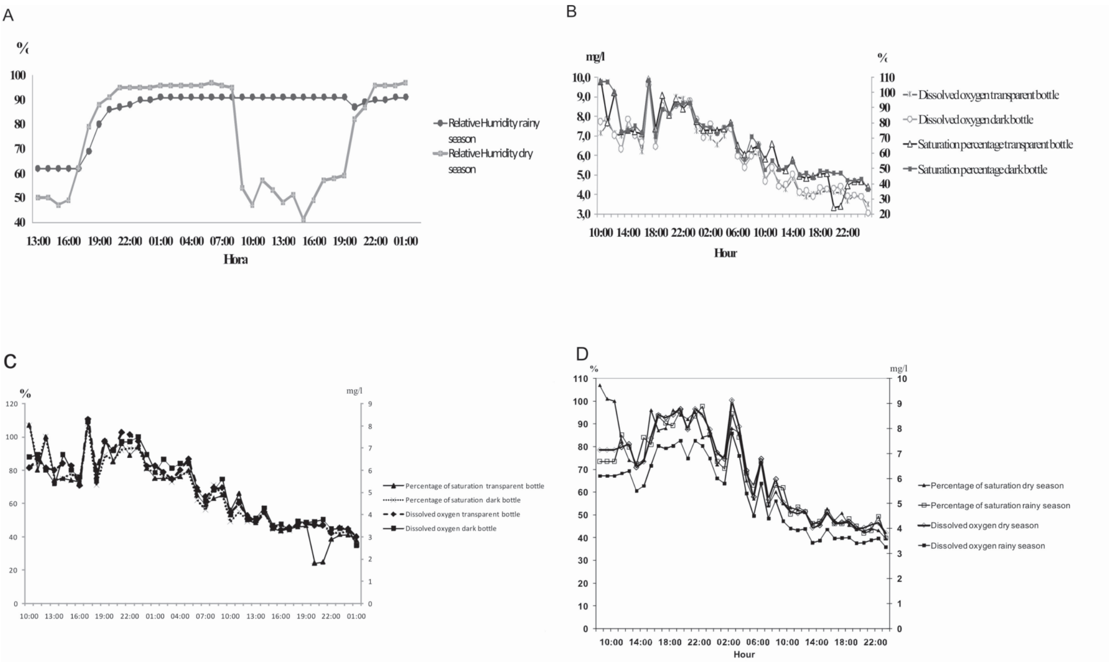

Fig. 3. Comparison of nictemeral compartment, physicochemical variables in Roble river; (A.) Relative humidity, in rainy and dry season; (B.) Dissolved oxygen and percentage of oxygen saturation in transparent and dark bottle, in dry season; (C.) Dissolved oxygen and percentage of oxygen saturation in transparent and dark bottle, in rainy season; (D.) Percentage of oxygen saturation and dissolved oxygen in dry and rainy season in the Roble river.

The same was true for percent oxygen saturation with an average of 69.28% and a high coefficient of variation in the dry season (29.30%) in comparison with rainy season (68,03% and 21,49%). Nevertheless, values of dissolved oxygen were closer to the average than the values of oxygen saturation for both seasons (Table 1). It was also observed that both of these variables decreased significantly on the second day of sampling (Fig. 3d).

For the biochemical variable DBO_5, the highest value was recorded in the rainy season; dry season values were lower (5.2 mg/l rainy and 3.1 mg/l dry). For DQO we found low values in the rainy season and higher values in the dry season (80 mg/l O_2 rainy and 183.92 mg/l O_2 dry).

Total hardness was higher in the dry season (32 mg/l $CaCO_3$ (dry) and 26 mg/l $CaCO_3$ (wet). Similar results were found for magnesium hardness: dry season (20 mg/l $CaCO_3$), rainy (10 mg/l $CaCO_3$). For calcium hardness the highest value was seen in the dry (12 mg/l $CaCO_3$) and the lowest in rainy season (16 mg/l $CaCO_3$). Generally concentrations of these variables were low. In contrast, alkalinity was high in the dry season (64.28 mg/l $CaCO_3$) and low in rainy (28.14 mg/l $CaCO_3$). The quantity of free OH in the ecosystem (Limnological acidity) varied significantly between seasons (Table 1). Suspended solids had higher concentrations in the dry season (40 mg/l), rainy (5.0 mg/l), as did total and dissolved solids (120 mg/l and 80 mg/l in rainy). Chlorine was high in the dry and low in the rainy season (84.09 mg/l and 4.50 mg/l). Turbidity had higher dry season values (129 FTU) as did suspended, dissolved and total solids in contrast to what was observed in rainy (<5 FTU). And finally the values of CO2 were the same in both climatic seasons (Table 1).

Productivity and metabolism. Percentage of oxygen saturation in the dry season was on average 66.34% for the transparent and 67.26% for the dark bottle, the coefficients of variation were high for both bottles (32.69% and 29.26%); ANOVA didn't show significant differences between bottles (F=1.00; P=0.517). In the rainy season this variable was on average 63.57% for the transparent and 64.18% for the dark bottle, the coefficient of variation were high (18.05% and 17.98%); ANOVA didn´t show significant differences between bottles (F=1,21; P=0,483).

Regarding dissolved oxygen the analysis of variability didn't show significant differences between transparent and dark bottles (F=1.11; P=0.3688), nevertheless this variable showed noticeable decrease between 6:00 h and 00:00 h in the dry season (Fig. 3b). During the rainy season this variable was on average low in compari-

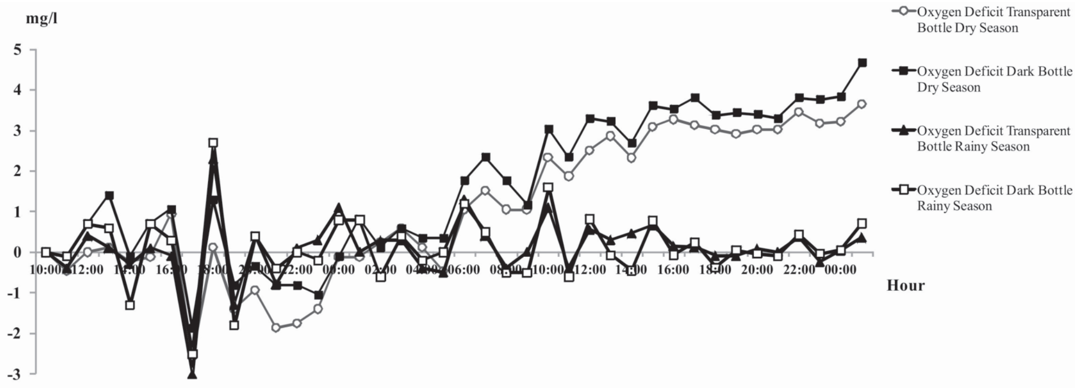

Fig. 4. Nictemeral compartment of oxygen deficit, for dry and rainy season in transparent and dark bottle, in Roble river, Upper Cauca, Colombia.

son with dry season and the dark bottle had low values in comparison with the transparent. This variable presented the same behavior between bottles and showed a decrease forthe second day (Fig. 3c), ANOVA did not detect significant differences between bottles (F=1.28; P=0.2652). Statistic analyses of pH for both seasons indicated that there were no significant differences between bottles (F= 0.89; P= 0.65 dry and F= 1.16; P= 0.31 rainy). The transparent bottle showed an average of 7.75 with coefficient of variation 2.77%, while the dark bottle showed an average of 7.68 and coefficient of variation 2.46%, in both bottles values of coefficient variation were low.

Oxygen deficit in the dry season for both the transparent and dark bottles was high (1.057 and 1.58), as was the coefficient of variation (167.19% and 110.71%). Noticeable variations of oxygen deficit in transparent vs. dark bottles (Fig. 4) were recorded between 10:00 h and 15:00 h when a production of oxygen can be observed. Nevertheless near 17:00 h this was consumed in great quantity and that is evidently deficient in oxygen during the first day of sampling. It's important to note that on the second day of sampling there was no deficit of oxygen. In the same way values of this variable were higher in dark bottle than in the transparent in dial analysis. Similar results were obtained for the rainy season where the dark bottle had a higher oxygen deficit than the transparent (0,10 and 0,08) and both bottles had high coefficients of variation (100.78% and 100.86%). For the rainy season oxygen consumption was high and production was low when compared to the dry season. ANOVA did not detect significant differences between bottles for either seasons (F= 0.78; P= 0.57 dry and F= 1.08; P= 0.46 rainy).

Using the previous data we calculated the lotic ecosystem metabolism following methods of Wetzel & Likens (2000), where in dry season the re-aeration flux of oxygen was 3586.32 mg/l, net metabolism was equal to -3585.81 and gross metabolism was equal to -3584.74. Gross primary production (GPP) of the community was -3518.41 for transparent bottle and -3514.91 for dark bottle; in rainy season the re-aeration flux of oxygen was 1282.48 mg/l, net metabolism was equal to -1281.64 and gross metabolism was equal to - 1282.38. Gross community primary production (GPP) of was -1217.59 for the transparent bottle and -1209.19 for the dark.

Biological variables. The macroinvertebrate community included 8 orders and 32 families (Table 2). The highest abundance in both seasons was found for Ephemeroptera, family Tricorythidae (55.6% in dry and 18.2 % rainy). In the case of Coleoptera the most abundant family was Psephenidae (2.6% in dry and 19.4% rainy). For the Trichoptera it was Hydropsychidae (8.3% in dry and 3.5% rainy). The order with the lowest relative abundance was Plecoptera, family Perlidae (1.9% and 5.1% for dry and rainy) (Table 2).

Generally, the alpha diversity index was low during both seasons but equity had a value of 0.68 for the rainy season but only 0.61 for the dry. This probably reflects the better ability to maintain the biotic community during higher water The Shannon Weiner (H') index and the Margalef index of diversity and dominance were both low (Table 6). Using the BMWP/Col classification system, the rainy season score was 198 and the dry 160, which gives this river a class II, or «good» rating.

Phytoplankton. This community was represented with 3 divisions, 5 families and 40 gen-

TABLE 2. Community of aquatic macroinvertebrates in the Roble river, Upper Cauca, Colombia. R.A. = Relative Abundance

ORDER	FAMILY	GENERA	RAINY	RA%	DRY	RA%
Ephemeroptera	Baetidae	*Baetodes*	131	9.90	62	6.22
		Baetis	81	6.12	13	1.31
		Moribaetis	23	1.74	8	0.80
		Dactylobaetis	45	3.40	36	3.61
	Tricorythidae	—	61	4.61	0	0.00
		Tricorythodes	146	11.04	92	9.24
		Leptohyphes	20	1.51	448	44.98
	Leptophlebiidae	*Thraulodes*	20	1.51	79	7.93
		Traverella	2	0.15	0	0.00
	Oligoneuriidae	*Lachlania*	0	0.00	11	1.10
	Ethyploaidae	*Compilacia*	0	0.00	1	0.10
		Ephemerella	0	0.00	1	0.10
Coleoptera	Elmidae	*Cylloepus*	2	0.16	4	0.40
		Macrelmis	2	0.15	0	0.00
		Disersus	3	0.23	0	0.00
	Psephenidae	*Psephenops*	242	18.29	25	2.51
		Termanectus	0	0.00	1	0.10
		Promoresia	0	0.00	1	0.10
		Hydrochus	0	0.00	1	0.10
	Ptilodactylidae	*Anchitarsus*	5	0.38	2	0.20
Trichoptera	Hydropsychidae	*Leptonema*	20	1.51	13	1.31
		Smicridea	24	1.81	68	6.83
		Hyproptila	0	0.00	1	0.10
		Ochrotrichia	0	0.00	1	0.10
		Atopsyche	0	0.00	1	0.10
	Helicopsyche	*Helicopsyche*	5	0.38	0	0.00
		Limneohilus	0	0.00	2	0.20
		Mystacides	0	0.00	3	0.30
		Borealis	0	0.00	1	0.10
	Calamoceratidae	*Phylloicus*	16	1.21	0	0.00
	Hydropsichidae	*Leptonema*	2	0.15	0	0.00
	Leptoceridae	*Nectopsyche*	3	0.23	0	0.00
		Atanatolica	4	0.30	0	0.00
Odonata	Libellulidae	*Erythrodiplax*	4	0.30	0	0.00
		Libelulido	1	0.08	0	0.00
		Macrothemis	1	0.08	4	0.40
		Dythemis	83	6.27	14	1.41
		Pantala	0	0.00	4	0.40
		Sympetrum	0	0.00	3	0.30
		Erythemis	0	0.00	1	0.10
		Berchmorhoga	0	0.00	3	0.30
		Espetugomphus	0	0.00	5	0.50
	Caenagrionidae	*Acanthogrion*	7	0.53	0	0.00
	Gomphidae	*Progomphus*	2	0.15	0	0.00
	Calopterygidae	*Hetaerina*	9	0.68	0	0.00
Diptera	Simuliidae	*Simulium*	243	18.37	12	1.20
	Chironomidae	—	3	0.23	1	0.10
	Psychodidae	*Maruina*	1	0.08	0	0.00
		Clognia	1	0.08	0	0.00
	Empididae	*Chelifera*	0	0.00	1	0.10
		Hydrocanthus	0	0.00	1	0.10
		Anophelex	0	0.00	1	0.10
	Blepharoceridae	*Limonicola*	1	0.08	0	0.00
	Musadae	*Limnophora*	1	0.08	0	0.00
Hemiptera	Veliidae	*Microvelia*	0	0.00	14	1.41
		Rhogovelia	7	0.53	4	0.40
		Striduvelia	0	0.00	1	0.10
	Gerridae	*Brachymetra*	19	1.44	1	0.10
	Naucoridae	*Limnocoris*	2	0.15	0	0.00
Neuroptera	Corydalidae	*Corydalus*	17	1.28	30	3.01
Plecoptera	Perlidae	*Anacroneuria*	64	4.84	18	1.81
		Patoperla	0	0.00	3	0.10
		Pteronoscela	0	0.00	2	0.20
	1323	100.00	996	100.00		

TABLE 3. Phytoplankton community of the Roble river, Upper Cauca, Colombia. R.A= Relative Abundance.

DIVISION	FAMILY	GENERA	RAINY	RA%	DRY	RA%
Chlorophyta	Desmidiaceae	*Closterium*	8	0.06	38	0.15
		Gonatozygon	15	0.11	185	0.72
		Microspora	11	0.08	11	0.04
		Mougeotia	6	0.05	29	0.11
		Netrium	4	0.03	5	0.02
		Nitzschia	26	0.19	10	0.04
		Mesotaenium	16	0.12	0	0
		Penium	1	0.01	0	0
		Docidium	3	0.02	0	0
		Staurastrum	116	0.86	0	0
		Spirotaenia	1	0.01	0	0
		Genicularia	2	0.01	2	0.01
		Pleurotaenium	1	0.01	1	0.00
		Ankistrodesmus	3	0.02	2398	9.38
	Chroococcaceae	*Chaetophora*	5	0.04	0	0
		Characium	2	0.01	0	0
		Protococus	1571	11.66	3162	12.37
		Chrococcales	9120	67.68	7581	29.65
		Chroococcus	0	0	112	0.44
		Cladophora	105	0.78	522	2.04
	Chlorophyceae	*Cosmarium*	1	0.01	0	0
		Kirchneriella	4	0.03	0	0
		Spirogyra	4	0.03	9	0.04
		Caetophora	0	0	84	0.33
		Crucigenia	0	0	5383	21.05
		Zygnema	0	0	2	0.01
		Ophiocytium	0	0	454	1.78
		Anabaena	1	0.01	15	0.06
Chrysophyta	Bacillariophyceae	*Ephithemia*	3	0.02	0	0
		Navicula	52	0.39	78	0.31
		Stauroneis	2	0.01	1	0.00
		Stephanodiscus	1	0.01	1	0.00
		Synedra	1	0.01	0	0
		Tetrapedia	2350	17.44	5377	21.03
		Turbellaria	12	0.09	10	0.04
		Cyclotella	0	0	4	0.02
		Cymbella	0	0	4	0.02
		Diatoma	0	0	19	0.07
		Frustulia	0	0	3	0.01
		Gyrosigma	0	0	2	0.01
		Pinnularia	0	0	4	0.02
		Oscillatoria	0	0	10	0.04
Cyanophyta	Xanthophyceae	*Coelosphaerium*	33	0.24	6	0.02
		Melosira	0	0	3	0.01
		Phormidium	0	0	43	0.17
	TOTAL	13475	100	25568	100	

era (Table 3). We found 110 ind./ml in the dry season but only 58 ind./ml during high water. Divisions with more relative abundance were Chlorophyta (dry 78.18%, rainy 81.82%), next Chrysophyta (dry 21.58%, rainy 17.97%); and in last place the division Cyanophyta (dry 0.20%, rainy 0.24%). The most common families were Chroococcaceae (dry 51.83%, rainy 79.41%), Bacillariophyceae (dry 21.58%, rainy 17.97%), Chlorophyceae (dry 25.24%, rainy 0.85%), Desmidiaceae (dry 1.10%, rainy 1.56%) and Xanthophyceae (dry 0.20%, rainy 0.24%). The most abundant genera in both seasons were *Chorococcales* (dry 29.65%, rainy 67.68%), *Tetrapedia* (dry 21.03%, rainy 17.44%), *Crucigenia* (dry 21.05%, rainy 0%), and *Ankistrodesmus* (dry 9.38%, rainy 0.02%) (Table 3).

Zooplankton. Zooplankton was represented with 2 divisions and 6 genera (Table 4). There was 1 ind./ml in dry season and 2 ind./ml in rainy. The most abundant divisions were Protozoa (dry 100%, rainy 80%) and Rotifera (rainy 20%). The most common organisms present in both seasons were *Paramecium* (dry 50%. rainy 10%), next

TABLE 4. Zooplankton community of the Roble river, Upper Cauca, Colombia. R.A= Relative Abundance.

DIVISION	GENERA	RAINY	RA%	DRY	RA%
Protozoos	*Vorticella*	3	30	2	33.33
	Euglena	0	0	1	16.67
	Stentor	4	40	0	0
	Paramecium	1	10	3	50
Rotifera	*Colurella*	1	10	0	0
	Testudinella	1	10	0	0
TOTAL		10	100	6	100

TABLE 5. Absolute and relative abundance (RA) of fish community in the Roble river, Upper Cauca, Colombia.

TAXON	RAINY	RA%	DRY	RA%
Astyanax fasciatus	91	19.36	201	39.18
Astyanax microlepis	0	0	12	2.34
Argopleura magdalenensis	164	34.89	143	27.88
Aequidens sp.	0	0	1	0.19
Bryconamericus caucanus	30	6.38	55	10.72
Brycon henni	58	12.34	7	1.36
Creagrutus brevipinnis	67	14.26	56	10.92
Creagrutus sp	1	0.21	0	0
Characidium caucanum	3	0.64	10	1.95
Chaetostoma fisheri	21	4.47	1	0.19
Hypostomus sp.	27	5.74	13	2.53
Hyphessobrycon ocasoensis	0	0	4	0.78
Imparfinis nemacheir	1	0.21	0	0
Lasciancistrus caucanus	2	0.43	7	1.36
Poecilia caucana	2	0.43	1	0.19
Rhamdia quelen	0	0	1	0.19
Roeboides dayi	1	0.21	1	0.19
Sturisomaticthys longianalis	1	0.21	0	0
Trichomycterus caliensis	1	0.21	0	0
TOTAL	470	100	513	100

Vorticella (dry 33.33%. rainy 30%); and lastly *Stentor* (dry 0%, rainy 40%) (Table 4).

Alpha diversity for phytoplankton was low except for the index of dominance (rainy 0.70, dry 0.65), indicating that there are communities with exceptional numbers of individuals in ecosystem that occupy different niches. For this reason, equity (E) was low (dry 0.49 and 0.3 rainy). In the case of the Shannon Winner diversity index (H´) values were also low (dry 0.53, rainy 0.48). Specific richness (M) was about 0.20 for both seasons (Table 6).

For zooplankton only general indexes of diversity were evaluated for the rainy season. In the dry season no Rotifera were present. This index indicates that for this biotic community equity (E) was high with a value of 0.72, while dominance (D) (0.64), diversity (H´) (0.5) and specific richness (0.43) were low.

Fishes. We recorded 19 species, with total of 470 individuals in the rainy season and 513 in the dry (Table 5). Species with higher relative abundance were: *Argopleura magdalenensis* (27.88% in dry and 34.89% in rainy), *Astyanax fasciatus* (39.18% in dry and 19.36% in rainy) and *Creagrutus brevipinnis* (10.92% in dry and 14.22% in rainy). In general equity (E) was high (0.61 in dry and 0.68 in rainy), while dominance, diversity and specific riches were low for both climatic seasons.

Index of contamination for organic matter (ICOMO) with a value of 0.6 indicates that there is an average concentration of organic matter in this water body. Nevertheless, index of contami-

TABLE 6. Alpha diversity of phytoplankton, zooplankton, macroinvertebrates and fish community, for two climatic seasons. H'= Shannon-Wiener Diversity. D = Simpson dominante. E = Pielou equity. M = Margalef riches

TAXON	RAINY				DRY			
	H'	D	M	E	H'	D	M	E
PHYTOPLANKTON								
Chlorophyta	0.59	0.70	2.14	0.19	1.58	0.25	1.71	0.54
Chrysophyta	0.16	0.94	0.89	0.07	0.15	0.94	1.27	0.06
Cyanophyta	-	-	-	-	0.92	0.51	0.72	0.66
General	0.48	0.70	0.21	-	0.53	0.65	0.19	0.49
ZOOPLANKTON								
Protozoos	0.97	0.32	0.96	0.88	1.01	0.26	1.11	0.92
Rotiferos	-	-	-	-	-	-	-	-
General	0.50	0.64	0.43	0.72	-	-	-	-
MACROINVERTEBRATES								
Ephemeroptera	1.85	0.18	1.27	0.84	1.35	0.39	1.35	0.58
Coleoptera	0.22	0.92	0.90	0.12	0.88	0.57	1.43	0.49
Trichoptera	1.81	0.19	1.84	0.82	0.97	0.56	1.76	0.44
Odonata	0.86	0.61	1.28	0.44	1.68	0.21	1.70	0.86
Diptera	0.16	0.94	0.90	0.09	1.42	0.25	1.80	0.79
Hemiptera	0.79	0.51	0.60	0.72	0.87	0.51	1.00	0.62
Neuroptera	-	-	-	-	0.23	0.87	0.28	0.33
Plecoptera	-	-	-	-	0.5	0.73	0.65	0.45
General	1.64	0.24	0.97	0.79	0.99	0.57	1.01	0.47
FISHES								
General	1.84	0.20	2.27	0.68	1.67	0.25	2.24	0.61

nation for suspended solids (ICOSUS) with value of 0.68 indicates good water quality.

DISCUSSION

Limnological studies of water quality are based on the principle that every type of aquatic ecosystem is associated with one specific community of organisms (Posada *et al.*, 2000). The living communities that develop in aquatic ecosystems depend on specific physicochemical characteristics of the water and are noticeably modified when those conditions change (López *et al.*, 1995). Dry season physicochemical variables recorded in the lower Roble river showed high coefficients of variation for relative humidity, percentage of oxygen saturation, dissolved oxygen and oxygen deficit in transparent and dark bottles. This can be attributed to environmental fluctuations that were high for the dry season and also, the discharge of municipal residual waters about three km above the sampling site, which permitting some auto-purification of the system (Dodds, 2006; 2007). The high coefficient of variation for oxygen deficit can be explained if we take into account that it's closely related with the trophic state of the water body and is easily influenced by the day-night interface where a change from an autotrophic state to a heterotrophic (and vice versa) can be observed according to Dodds & Cole (2007).

Bimodal variation of water and ambient temperature is attributed to a high specific energy of water and fluctuations from the day-night interface (Roldan, 1992). Relative humidity in this analysis had more fluctuation in the dry season because it was conditioned by environmental factors such as temperature that vary considerably during this season. Conductivity values obtained for both climatic seasons did not show noticeable differences; nevertheless it's important to take into account existing relationship between this variable and pH. According to Roldan (1992) pH influences conductivity with the quantity of present free ions, atypical values of this variable are explained with the presence of sporadic precipitation in dry season which alternate ecosystem because of allochthonous material influx. Moreover, increase of discharge input decreased the concentration of dissolved solids dilution per cubic meter enabling in this way process of mineralization of ecosystem (Allan 1995; Wetzel 2001; Toro *et al.,* 2002). Other factors such as river vegetation, land use and various sewage contaminants influence on the values of obtained conductivity in this aquatic ecosystem (Toro *et al.,* 2002).

Usually, higher levels of dissolved oxygen indicate better water quality (Roldan, 1992). For the Roble river, the average of dissolved oxygen values were found to be at optimal levels. Nevertheless, lower oxygen concentrations possibly may indicate that higher turbidity in the rainy season in the upper part of the river inhibits light penetration and autotrophic activity. Higher concentrations dissolved and particulate organic material flushed out during the rainy season probably caused increased oxygen demand for mineralization that resulted in lower overall values for dissolved oxygen at that time. Percent oxygen saturation indicates that for the first day of sampling light heterotrophic conditions were present (Urrego & Ramírez, 2000). DBO was low and DBQ high for dry season, indicating possible eutrophication due to the constant addition of nutrients to this water body in the form of allochthonous material that enables biological communities that process organic material to become established, which may in turn have affected acidity which was observed to have lower values than alkalinity.

Metabolism of aquatic ecosystem refers to the processes of production, consumption and decomposition (Roldan, 1992). They normally occur simultaneously in balanced and synchronized form, but when the balance is disturbed due to contamination by organic matter, processes of decomposition and photosynthesis are accelerated in the day-night cycle causing unbalance in the ecosystem that affects the ecosystem's stability and communities that live there (Roldan, 1992). Because of this, trophic state in water bodies can be determined from metabolism activity (Dodds, 2006). Following the methodology of transparent and dark bottle, it can be observed that the ecosystem is heterotrophic.

The macroinvertebrate community found coincides with that reported by García-Alzate ., (2007). The index of alpha diversity calculated for this river showed that Diptera had high dominance values associated with the trophic conditions of the water body. Diptera larvae prefer productive ecosystems with good nutrient availability. Ephemeroptera showed a higher index of diversity because some families have some tolerance to contamination (Roldan, 2003).

In the case of phytoplankton various families of the Chlorophyta division were present that are characteristic of productive environments (Roldan, 1992). But we also found Chrorococcales, division Chrysophyta, which are usually common in low productivity environments. The occurrence of Cyanophyta indicated increase nutrient input that favors proliferation of these algal types (González *et al*., 2004). The presence of algae that usually indicate very different trophic conditions let us to classify the lower Roble river as oligo-trophic, with a tendency to eutrophication.

Regarding fishes, 19 species were recorded, dominating the Characidae. According to García-Alzate *et al.* (2007), the species found are indicators of oligotrophic or little intervened systems, although some have a wide range of distribution, and are somewhat tolerant of contamination and are often found in this type of transitional environment.

Taking in to account information from physicochemical and biological parameters together with the index of contamination for organic matter (ICOMO), this river is moderately contaminated with organic matter, from domestic and industrial waste, and discharge of livestock, in coincidence with what was reported by Rivera & Mejia (2005). The index of contamination for suspended solids (ICOSUS) indicated that water quality was «good» possibly because auto purification occurred above our sampling site. These results coincide with that of BMWP, also stating that water quality was «good». It can be concluded that the lower Roble river has a heterotrophic allochthonous trophic state, and is oligotrophic with a tendency to eutrophication.

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