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Biomass of macroinvertebrates and physicochemical characteristics of water in an Andean urban wetland of Colombia

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With 3 figures

Abstract

Aquatic macroinvertebrates (AMI) play an important role in the ecology of wetlands, either by their job as regulators of the cycles of matter, as for their energy storage function represented in their biomass, which is transferred to higher trophic levels. To answer the question of how biomass of different AMI trophic guilds is related with physicochemical variables in the wetland Jaboque (Bogotá, Colombia), four samplings were achieved between April 2009 and January 2010, according to periods of rain and drought in the region. The AMI biomass values obtained were rated as of intermediate rank. No temporal but spatial significant differences were found. Apparently these spatial differences appear to be associated with variations in anthropogenic pressure, which differs in each area of the wetland. In dry months (January and August), biomass was greater and dominated by detritivores. We observed a positive relationship between the specific conductance of water and the biomass of predators and detritivores and between water temperature and the biomass of detritivores and shredders. These relationships suggest that the physical and chemical variables influence the distribution, abundance, and biomass of functional groups. The physical and chemical conditions of water exhibited spatiotemporal fluctuations related to changes in the concentration of organic matter and nutrients, which presumably were related to the affluents discharges and the high impact of local human populations.

Keywords: biomass, aquatic macroinvertebrates, urban wetlands, Jaboque, Andes.

Biomassa de macroinvertebrados e características físicas e químicas da água em um pantanal urbano dos Andes na Colômbia

Resumo

Macroinvertebrados aquáticos (MIA) desempenham um importante papel na ecologia das zonas úmidas, quer pelo seu emprego como reguladores dos ciclos da matéria, como para a sua função de armazenamento de energia representada na sua biomassa, que é transferido para elevados níveis tróficos. Para responder à questão de como a biomassa de diferentes categorias tróficas de MIA está relacionada com as variáveis físicas e químicas da água do pantanal Jaboque (Bogotá, Colômbia), quatro amostragens foram realizadas entre abril de 2009 e janeiro de 2010, de acordo com os períodos de chuva e seca na região. Os valores de biomassa de MIA obtidos foram classificados como de grau intermediário. Nós não encontramos nenhuma diferença significativa no tempo, mas foram observadas diferenças espaciais. Aparentemente, estas diferenças parecem estar associadas com as variações espaciais na pressão antrópica, que difere em cada região do pantanal. Nos meses de menor precipitação (janeiro e agosto), a biomassa foi maior e dominado por detritívoros. Observou-se uma relação positiva entre a condutividade específica da água ena biomassa de predadores e detritívoros e entre a temperatura da água e a biomassa de detritívoros e trituradores. Estas relações sugerem que as variáveis físicas e químicas influenciam a distribuição, abundância e biomassa de grupos funcionais. As condições físicas e químicas da água tiveram flutuações espaço-temporais relacionadas com alterações na concentração de matéria orgânica e nutrientes, que foram presumivelmente relacionadas com a descarga do efluente e o elevado impacto das populações humanas locais.

Palavras-chave: biomassa, macroinvertebrados aquáticos, áreas úmidas urbanas, Jaboque, Andes.

1. Introduction

Urban wetlands suffer anthropogenic pressure and therefore are altered with respect to their composition and species diversity. In Colombia, the most affected wetlands are those in the Andean region, which are vital because of their water regulation function. They are essential for the maintenance of forests and human populations that depend on these wetlands for their water supply. These systems are fragile because this region has the highest population density in the country with accelerated urban development that seriously threatens most of its wetlands (Donato, 1998).

In aquatic systems, the hydrological regime is a decisive factor for metabolism of organic matter, dissolved solids, phosphorus, and nitrogen, wich affects the aquatic macroinvertebrate (AMI) community. The abundance and biomass of these organisms are determined by resource availability and biotic interactions. The ecosystem energy flows through food chains in which organisms are grouped by dietary guilds, which are defined as sets of species that similarly exploit the same type of environmental resource. The term "guild" classifies species according to their niche requirements, regardless of taxonomic classification. In this work AMI trophic guilds are named as functional feeding groups (FFG).

In a food web, it is not common to refer to the dimensions of each level of the pyramid based on the number of individuals, given that this number is not significant for the knowledge of the food possibilities of the next higher level if the dimensions of such organisms are not taken into account. Thus, we have used the concept of biomass, which is defined as the weight of an individual or group of individuals. Knowledge of AMI biomass is of great ecological importance from the perspective of both populations and communities. In terms of population dynamics, biomass combines measures of individual growth and population survival, and within community aspects, is of great value to quantify the energy flow and its direction in the food chains. Biomass can also be a suitable variable for understanding the mechanisms of regulation of populations and communities because it is directly related to the basal food resource (Benke and Wallace, 1997). Thus, biomass can be used to determine the amount of secondary production available to higher trophic levels (e.g. other macroinvertebrates, fish and birds). This paper evaluates the variation of biomass of AMI by guilds according to their diet, both spatially and temporally, and explores the relationship with the physical and chemical variables of water of the Jaboque urban wetland in the city of Bogotá. The hypothesis to be tested is that the biomass of AMI changes temporarily due to climatic variations of each sampling period.

2. Material and Methods

2.1. Study area

The Jaboque wetland covers an area of 75 ha at Bogotá City (Eastern mountain range of the Colombian Andes, Figure 1), and is located at 2546 m.a.s.l. in a quadrant with the following geographic coordinates: 4.728570° to 4.696868° N, 74.115514° to 74.149692° W, Daton WGS84 (Google Earth™, Digital Globe™). Based on the work of Rangel et al. (2005), three zones were differentiated: a highly disturbed zone that is inside the city, a transition zone with semi-urban areas, and a least impacted zone of semi-rural characteristics. Average depth is 0.6 m, mean temperature is 13.4 °C, relative humidity reaches 80%, and the average annual rainfall achieves 792 mm. Rainfall regime has a bimodal distribution with two dry periods (December-February and June-August) and two high rain fall periods (September-November and March-May). There are permanently flooded areas with aquatic vegetation (floating or rooted), and riparian plants. This vegetation includes species like *Schoenoplectus californicus* C.A. Mey. Soják, *Juncus effusus* L., *Typha latifolia* L., *Polypogon elongatum* Kunth, *Rumex conglomerates* Murray, *Carex luridiformis* Mack. ex Reznicek and S. González, *Bidens laevis* (L.) Britton, Sterns and Poggenb, *Ludwigia peploides* (Kunth), P.H. Raven, *Hydrocotyle ranunculoides* L. f., *Polygonum punctatum* Elliott, *Eichhornia crassipes* Solms, *Limnobium laevigatum* Humb. and Bonpl., *Lemna gibba* L., and *Pennisetum clandestinum* Hochst. ex Chiov (Hernández and Rangel, 2009).

2.2. Sampling and analysis of physical and chemical variables

Seven sites were selected (Figure 1), two in the area of least disturbance in the lower third of the wetland (A: 4.726481° N - 74.145864° W, and B: 4.722653° N -74.142661° W), two in the area with an intermediate level of disturbance in the middle third (C: 4.716375° N -74.131614° W, and E: 4.7118° N -74.129953° W), and three in the top third or more disturbed area influenced by urban activity and waste water collectors (D: 4.710714° N -74.134047° W, F: 4.709978° N -74.127336°W, and G: 4.703069° N -74.125133° W). Samplings were conducted in April and October 2009 (seasons of high rainfall) and in August 2009 and January 2010 (dry seasons). Temperature, pH, specific conductance (conductivity), and dissolved oxygen (DO) were measured with a multiparameter probe (HANDYLAB MULTI 12/PH02 SCHOTT). Water samples were taken to the Universidad Nacional de Colombia Ecology Laboratory, where nitrite (mg L^{-1} NO_2^-), nitrate (mg L^{-1} NO_3^-), ammonium (mg L^{-1} NH_4^+), and soluble reactive phosphorus (SRP, mg L^{-1} $PO_4^{=}$) were determined with a spectrophotometer HACH DR/2000. Total suspended solids (TSS, mg L^{-1}) were estimated gravimetrically. The biological oxygen demand (BOD_5, mg L^{-1} O_2) was determined in a BOD_5 incubator. In all cases, the Standard Methods procedures (APHA et al., 2012) were followed.

2.3. Sampling, identification, and quantification of macroinvertebrates

AMI were collected from the roots of floating aquatic plants. Samples were taken with a hand net of 0.5 mm of mesh size, over a combined area of 0.126 m^2. The net was placed beneath the plant roots; aquatic plants were

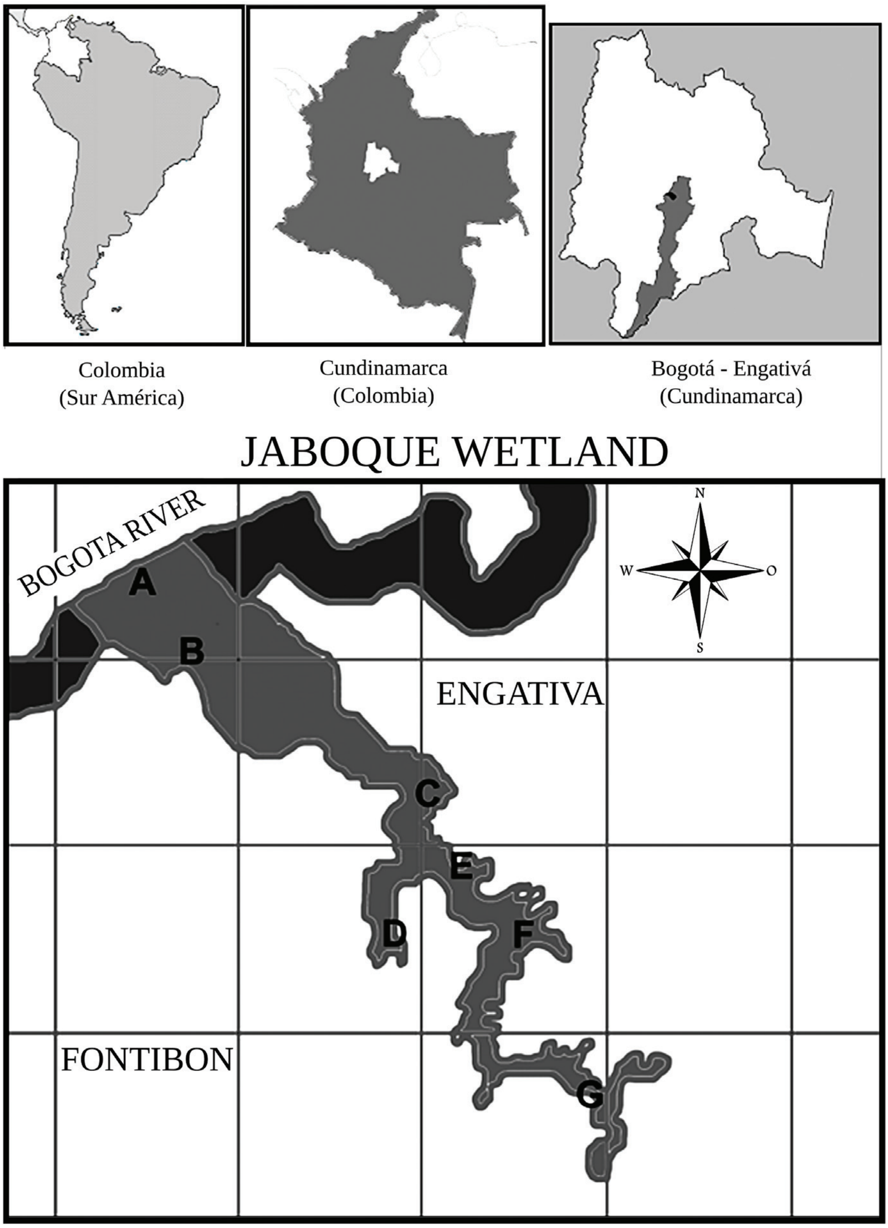

Figure 1. Jaboque wetland location in the city of Bogotá (scale 1:25000). A and B stations have less disturbance, C and E are of intermediate alteration, and D, F and G are in the most urbanized. Source: this study.

removed, transferred to plastic bags and carefully washed to remove the organisms present, wich were preserved in 70% ethanol. Taxonomic determinations were conducted in the Palynology Laboratory at the Universidad Nacional de Colombia Natural Sciences Institute, using specialized keys (Pennak, 1978; Roldán, 1988; Epler, 1996; Merritt and Cummins, 1996; Fernández and Domínguez, 2001). Taxa were classified into functional feeding groups (FFG) according to their trophic specialization, as defined by Cummins and Klug (1979), Merritt and Cummins (1996), Cummins et al. (2005), Tomanova et al. (2006) and Lievano and Ospina (2007). FFG that we used were shredders (*SH*), that feed on coarse particulate organic matter (CPOM); detritivores (*DT*), that consume CPOM and sediment microflora (and occasionally macrophytes); scrapers/grazers (*SG*), that are herbivores and feed on periphyton; collectors-gatherers (*CG*), that consume fine particulate organic matter (FPOM); collector-filterers (*CF*), which filter FPOM in the water column; and predators (*PR*) that feed on other living organisms. The biomass as dry weight (DW) was obtained by drying the organisms in an oven (24 h at 60°C) and weighing them on a balance accurate to 0.0001 g at the Universidad Nacional de Colombia Genetics Institute.

2.4. Statistical analysis

Analysis of variance was used to test for differences in AMI biomass associated with aquatic macrophytes between periods of high rainfall and dry season and between sites. The variables were transformed to natural logarithms (Ln) for meet the assumptions of normality and homoscedasticity. Relationships between physicochemical and biological variables (FFG biomass) were explored with a canonical correspondence analysis (CCA). Canonical correlation analysis was used to clarify those relationships. These analyses were performed with PAST (Hammer et al., 2001), and R software (R Development Core Team, 2010).

3. Results

3.1. Physical and chemical variables

The physicochemical data for the Jaboque wetland water are shown in Table 1. The average temperature was above 15°C. In general, these variables decreased by 2-3 °C during high rainfall periods (April and October 2009). The average pH (6.44± 0.34) corresponds to neutral to slightly acidic water with a minor increase at sites A (less disturbed area) and C (transitional area). Specific conductance ranged from 169 to 678 µScm^{-1} (mean 316.6±124.15), which indicates a relatively mineralized system. Dissolution processes in April 2009 (rainy season) reduced the average to 281.14 µScm^{-1}.

Ammonium varied greatly and was notably high (1.38 to 13.51 mg L^{-1} NH_4^+, mean 5.95± 7.84). Same behavior was recorded for nitrates, the highest averages of which were observed in the transition zone, sites C and E (13.41 and 10.92 mgL^{-1} NO_3^-, respectively), most likely due to the organic pollution. Nitrites were low (average 0.0059±0.003 mg L^{-1} NO_2^-) with maximum values at sites C and D (area of high human impact). DO was also low (0.36 to 2.19 mg L^{-1}, mean 0.89±0.63), consistent with the high BOD_5 (average 92.93±109.6mg L^{-1} O_2). SRP concentrations were similarly elevated, particularly at sites C and E, indicating that the Jaboque wetland system is greatly eutrophicated. SRP levels far exceed the 0.01 mg L^{-1}, value at which eutrophic conditions occur. The maximum average value took place in August (2.55±2.25 mg L^{-1} $PO_4^=$) and the lowest in April (0.88±0.49 mg L^{-1} $PO_4^=$). TSS were quite high (mean 37.25±28.24 mg L^{-1}) and reflect the benthic material resuspension. The highest values happened at sites C and D (transition and high human impacted zones).

3.2. AMI community composition of Jaboque

The AMI community in the floating aquatic vegetation of the Jaboque wetland consists of 10 orders, 27 families, and 26 genera. The average density in the macrophytes was 908 ind m^{-2}. The maximum average abundance was observed during the dry season (January, 1099 ind m^{-2}), and lower values occurred in a rainy month (October, 805 ind m^{-2}). The most abundant genus was *Helobdella* Blanchard, (leeches of the Glossiphoniidae family), which represented 43% of the abundance. The second most abundant family was Hyalellidae (23%), which includes the genus *Hyalella* Smith.

3.3. Biomass of AMI functional feeding groups associated with macrophytes

Biomass of AMI associated with floating aquatic plants averaged 5.3 gm^{-2} per site. The highest values arose in January and August (dry periods) with averages of 5.83 gm^{-2} and 5.68 gm^{-2}, respectively. There were no temporal statistically significant differences (p= 0.74), but the lowest average month was April (4.69 gm^{-2}). Sites A and B (less disturbed area) had highest average biomass in January (10.3 and 11.7 gm^{-2}, respectively, Figure 2).

Table 1. Mean and standard deviation of physical and chemical parameters in the Jaboque wetland, Bogotá.T = Temperature C°; SC = Specific Conductance or Conductivity µS/cm; BOD_5 = Biological Oxygen Demand mg L^{-1} O_2;SRP = Soluble Reactive Phosphorus or $PO_4^=$ mg L^{-1}; NA =Nitrate or NO_3^- mg L^{-1}; NI = Nitrite or NO_2^-mg L^{-1}; AM = Ammonium or NH_4^+mg L^{-1}; TSS = Total Suspended Solids mg L^{-1}; DO = Dissolved Oxygen mg L^{-1}. A and B stations have less disturbance, C and E are of intermediate alteration, and D, F and G are in the most urbanized.

	A	B	C	D	E	F	G
T Air	14.3 ± 0.65	15. 8 ± 2.41	16.6 ± 2.17	17.4 ± 2.19	18.4 ± 2.37	18.1 ± 3.87	16.8 ± 3.49
T Water	13.1 ± 0.53	14.1 ± 0.28	16.0 ± 1.49	15.0 ± 1.40	15.6 ± 1.33	14.35 ± 0.96	15.1 ± 3.35
SC	259.25 ± 10.07	298.75 ± 8.35	436.75 ± 91.47	366.0 ± 138.26	321.75 ± 238.74	255.75 ± 380.12	278.0 ± 361.11
BOD_5	11.25 ± 4.57	18.25 ± 11.87	187.0 ± 139.8	106.0 ± 96.03	257.75 ± 64.81	37.5 ± 18.04	32.75 ± 9.5
SRP	1.11 ± 0.58	2.1 ± 1.46	3.84 ± 2.63	1.03 ± 0.44	3.19 ± 1.91	0.76 ± 0.32	0.45 ± 0.20
NA	4.22 ± 2.03	4.33 ± 1.88	13.41 ± 5.34	6.87 ± 5.39	10.9 ± 8.26	5.0 ± 1.43	4.38 ± 1.66
NI	0.0060 ± 0.0018	0.0058 ± 0.0015	0.0088 ± 0.0046	0.0075 ± 0.0034	0.0068 ± 0.0036	0.0033 ± 0.0013	0.0035 ± 0.0019
AM	3.18 ± 2.54	4.77 ± 3.47	13.51 ± 6.05	4.34 ± 2.94	5.12 ± 4.45	1.38 ± 1.10	5.74 ± 0.65
pH	6.73 ± 0.41	6.32 ± 0.31	6.75 ± 0.39	6.46 ± 0.47	6.26 ± 0.21	6.28 ± 0.03	6.29 ± 0.15
TSS	13.5 ± 3.87	9.7 ± 3.09	55.5 ± 14.61	30.7 ± 9.77	41.0 ± 12.24	23.7 ± 5.05	9.7 ± 3.86
DO	0.93 ± 0.23	0.99 ± 0.30	0.36 ± 0.16	0.59 ± 0.17	0.56 ± 0.33	0.58 ± 0.14	2.19 ± 0.58

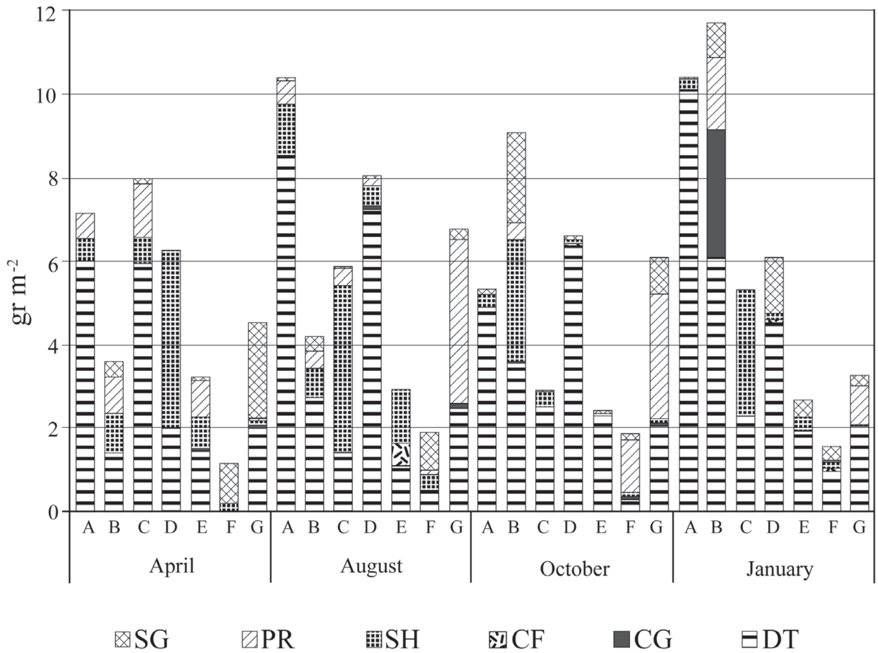

Figure 2. Biomass of AMI associated with floating aquatic plants in Jaboque wetland, by functional feeding groups (gm^{-2}) at the sampling sites (A and B stations have less disturbance, C and E are of intermediate alteration, and D, F and G are in the most urbanized) and months. Collector-Scrapers (*SG*), Collector-Shredders (*SH*), Collector-Gatherers (*CG*), Collector-Filterers (*CF*), Predators (*PR*), Detritivores (*DT*).

Detritivores was the dominant FFG (Figure 2), which represented 62% of the total biomass. Overall, the *DT* guild provided much of the biomass in almost all sites, particularly at sites A, B, and D, which are covered by abundant aquatic vegetation. The second most important guild was the *SH* that comprises seven taxa (Table 2) and represented 16% of the total biomass. Sites D and C exhibited the greatest biomass of *SH* (Figure 2). The organisms in this group like the isopods of the family Asellidae (7.1 mm) and the dipterous of genus *Tipula* L. (18.4 mm) recorded great abundance and size.

Other FFGs represented smaller fractions of the total biomass but were important at certain sites and times. The *PR* guild, for example, reached peaks of biomass in August and October, especially in site G (Figure 2). There were no significant differences in the *PR* guild either temporally (by month $p= 0.74$) or spatially (by site $p= 0.54$). The *CG* guild (composed of eight taxa, Table 2) has its maximum biomass in January (Figure 2). There were no significant differences between months ($p= 0.16$) or between sites ($p= 0.25$). Oligochaetes (Tubificidae and Lumbriculidae) represented the largest fraction in this group, particularly at site B (less disturbed area). The *CF* guild had low representation and showed no temporal ($p= 0.80$) or spatial ($p= 0.54$) significant differences.

3.4. Influence of physical and chemical variables on AMI biomass

Figure 3 shows the CCA ordination. The firs and second axes explained 52% and 30.5% of variance, respectively. Monte Carlo procedure (9999 ramdom replicates) indicated a significant relation of environmental and biotic data in the axe 1 ($p= 0.02$). Canonical correlation analysis performed between FFG biomass and physicochemical variables revealed that *DT* was correlated with water temperature ($p= 0.04$, $r= 0.37$). There were also significant correlations of *DT* biomass with conductivity ($p= 0.0094$ $r= 0.48$) and nitrates ($p= 0.029$ and $r= 0.41$). These results show a clear positive effect of mineralization and nitrogen on the biomass of this FFG. The *PR* biomass was correlated with conductivity ($p= 0.003$, $r= 0.40$), SRP ($p= 0.0004$ and $r= 0.62$), and TSS ($p= 0.011$, $r= 0.47$). DO correlated with biomass of *CG* ($p= 0.0012$, $r= 0.57$) and *SG* ($p= 0.006$, $r= 0.5$). *SH* exhibited a positive relationship with water temperature ($p= 0.02$, $r= 0.42$), as did *CF* with conductivity ($p= 0.04$, $r= 0.38$).

4. Discussion

4.1. Water physicochemical characteristics

Jaboque wetland waters are remarkably rich in nutrients and dissolved ions. The contributions of affluent wastewaters are responsible for the increase in these substances. Ammonium increased in January 2010 (dry season), most likely because there was greater ammonification in the wetland benthos but also because of less dilution and superior evaporation. In dry periods (high radiation), hypoxia becomes stronger, and reduction processes (denitrification) tend to increase the production of ammonium in the wetland sediments. Medium to high concentrations (0.05 to 1.3 mg $L^{-1}NH_4^+$) are considered lethal to many aquatic organisms, depending

Table 2. Macroinvertebrates biomass (gm^{-2}) associated with macrophytes in the Jaboque wetland, Bogotá. A and B stations have less disturbance, C and E are of intermediate alteration, and D, F and G are in the most urbanized. SG= Collector-Scraper, SH = Collector-Shredders, CG = Collector-Gatherers, CF = Collector-Filterers, PR = Predators, DT = Detritivores.

ORDER	FAMILY	SUBFAMILY OR GENERA	FUNCTIONAL GROUP	STATIONS						
				A	B	C	D	E	F	G
DIPTERA	CHIRONOMIDAE	Chironominae (gen1)	SG	0.0005	0.0000	0.0000	0.0000	0	0	0.0177
		Chironominae (gen2)	SG	0.1758	2.5427	0.0186	0.0005	0.0195	0.0923	1.1902
		Orthocladiinae (gen1)	SG	0.0000	0.1827	0.0086	0.0000	0	0.1173	0.5733
		Orthocladiinae (gen2)	SG	0.0000	0.1166	0.0005	0.0000	0	0.4265	0.2658
		Tanypodinae	PR	0.0000	0.0000	0.0000	0.0000	0	0	0.1039
	TIPULIDAE	Tipula	SH	0.3958	3.7253	0.8281	0.5210	0.1057	0.4279	0.0199
	SCIOMYZIDAE	Sciomyzidae	PR	0.0281	0.0159	0.0000	0.0000	0	0.0011	0.0024
	STRATIOMYIDAE	Stratiomys	CG	0.0000	0.0000	0.0000	0.0000	0	0	0.0006
	EPHYDRIDAE	Ephydra	CG	0.0000	0.0000	0.0090	0.0000	0	0	0
		Ephydridae (gen1)	CG	0.0073	0.0150	0.0000	0.0000	0	0	0.0072
	CULICIDAE	Culex	CF	0.0011	0.0000	0.0000	0.0649	0	0	0
	DIXIDAE	Dixella	CG	0.0000	0.0000	0.0000	0.0000	0	0	0.0235
	SYRPHIDAE	Eristalis	CG	0.0080	0.0000	0.0006	0.0000	0.0073	0.0281	0.0329
	PSYCHODIDAE	Psychoda	CG	0.0000	0.0000	0.0000	0.0000	0	0	0.0081
	CERATOPOGONIDAE	Ceratopogonidae (gen1)	SH	0.1638	0.0096	0.0096	0.0000	0	0	0
COLEOPTERA	SCIRTIDAE	Scirtes	SH	0.0984	0.8418	0.0386	0.0000	0	0.022	0.0132
	HYDROPHILIDAE	Tropisternus	SH	0.0000	0.0148	0.0000	0.0000	0	0	0.0218
		Hydrophilus	PR	0.0000	0.0000	0.0000	0.0077	0	0	0.0077
		Enochrus	SH	0.0130	0.0000	0.0000	0.0000	0	0.013	0.0911
	DYTISCIDAE	Rhantus	PR	0.2338	0.0000	0.0000	0.0000	0	0.1169	0.0978
	ELMIDAE	Heterelmis	SH	0.0000	0.0000	0.0000	0.0000	0.0073	0	0
HETEROPTERA	NOTONECTIDAE	Buenoa	PR	0.0000	0.0000	0.0000	0.0721	0.012	0	0
	CORIXIDAE	Centrocorisa	PR	0.0000	0.0000	0.0000	0.0259	0	0	0
ODONATA	AESHNIDAE	Aeshnidae (gen1)	PR	0.8592	34.366	17.183	0.0000	0	1.2887	7.7324
	COENAGRIONIDAE	Acanthagrion	PR	0.0150	0.0000	0.0000	0.0160	0.007	0	0
LEPIDOPTERA	PIRALIDAE	Piralidae (gen1)	SH	0.0000	0.0000	0.0000	0.0066	0	0	0
AMPHIPODA	HYALELLIDAE	Hyalella	SG	0.0063	0.4051	0.0000	0.0082	0.1727	0.5074	1.035
ISOPODA	ASELLIDAE	Asellus	SH	16.602	0.0000	71.197	45.017	2.2029	0.3512	0.0958
BASOMMATOPHORA	PHYSIDAE	Physa	SG	0.0000	0.4432	0.1007	14.100	0.3424	1.1482	0.4834
VENEROIDA	SPHAERIIDAE	Pisidium	CF	0.0000	0.0000	0.0000	0.0725	0.6521	0.1304	0.0435
HAPLOTAXIDAE	TUBIFICIDAE	Tubificidae (gen1)	CG	0.0239	0.0070	0.0617	0.0199	0.0139	0.0378	0.0756
	LUMBRICULIDAE	Lumbriculidae (gen1)	CG	0.0000	30.255	0.0000	0.0000	0	0	0
RHYNCHOBDELLIDA	GLOSSIPHONIIDAE	Helobdella	DT	29.508	13.761	12.041	20.047	6.7155	1.6871	8.568
	PISCICOLIDAE	Piscicola	PR	0.0000	0.0000	0.0000	0.1791	0.8957	0	0
TOTAL				33.198	28.543	21.955	26.953	11.154	6.4239	20.5111

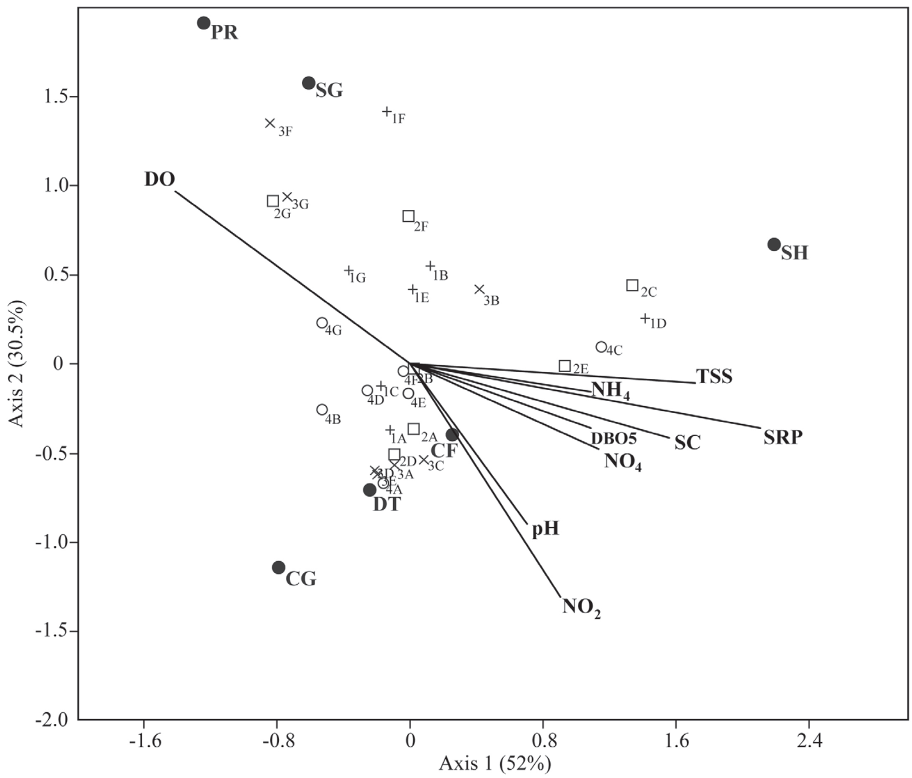

Figure 3. CCA of AMI biomass and physicochemical variables in wetland Jaboque. SG= Collector-Scraper, SH = Collector-Shredders, CG = Collector-Gatherers, CF = Collector-Filterers, PR = Predators, DT = Detritivores. A and B stations have less disturbance, C and E are of intermediate alteration, and D, F and G are in the most urbanized. 1 = sampling April 2009, 2 = sampling August 2009, 3 = sampling October 2009, 4 = sampling January 2010. SC = Specific Conductance; BOD_5 = Biological Oxygen Demand; SRP = Soluble Reactive Phosphorus; NO_3 = Nitrate; NO_2 = Nitrite; NH_4 = Ammonium; TSS = Total Suspended Solids; DO = Dissolved Oxygen.

on their sensitivity (Ogbonnam and Chinomso, 2010). In Jaboque, ammonia can be considered a stressor for AMI.

Increased water temperature in dry periods (greater radiation) promotes the development of plants and, consequently, accelerates the process of organic matter production (Álvarez, 2005). This effect augments the BOD_5 and decreases DO, particularly in January. The highest DO occurred at site G, which high human impact, but with a water surface free of macrophytes, which favored reaeration and oxygen production by photosynthesis. In general, oxygen exhibited undersaturation conditions, most likely because of the high organic load.

SRP was high. This element arrives in the wetland through wastewater discharges and illegal residential connections. The presence of cattle in some areas of the wetland could also contribute to this enrichment. Phosphorus promotes biomass increase of phytoplankton and plants, which decompose when they die, thereby reducing the DO and increasing the nutrients. Decomposition of aquatic vegetation leads to an increase in the trophic status and reduces the wetland useful life (environmental quality, environmental services). TSS are directly related to the hydrological dynamics of the affluent flow and tend to settle.

BOD_5 and nutrients are high in Jaboque and cause the system to be classified as a eutrophic in conformity with the values set by Salas and Martino (2001). The central area of the wetland (sites C, D, and E) had greatly polluted conditions throughout the study because this zone has a strong urban incidence. It may be noted that physicochemical environment of Jaboque is restrictive for many AMI that require water with less organic matter and nutrients; thus, those groups that thrive have adapted to the high saprobic level.

4.2. AMI biomass compartments in Jaboque

Biomasses recorded in this study are similar to those of large rivers (Benke et al., 1984), where the DW of AMI are between 0.1 and 5.8 gm^{-2} (Rabeni and Hoel, 2000). Average biomass of AMI associated with macrophytes in Jaboque (5.3 gm^{-2}) is within the limits of variation of 81% of systems with biomass less than 10 gm^{-2} (Huryn and Wallace, 2000). Values of stations A and B are within 19% of sites that recorded values greater than 10 gm^{-2} of AMI biomass. These maximum records are most likely as a result of the high content of nutrients at these locations. Sites E (transition area) and F (area of high human impact) are, on average, part of the 68% that fall below 5 gm^{-2}.

Spatial differences in the AMI biomass of the wetland aquatic vegetation may be due to the availability and quality of food resources at each site and to the water quality conditions. Few of these sites belong to the least disturbed area (A and B), but the others are more affected by urbanization and are influenced by the perimetric wastewater channel that runs alongside to the wetland. This impact is reflected in the water physicochemical characteristics, which in turn, alter the development of the AMI community. Concentration of oxygen and other variables control the succession and distribution of organisms in permanent and stagnant waters (Maul et al., 2004). For this reason, fluctuations in the physicochemical environment between sites cause spatial changes in this community's biomass (Klemm et al., 1990). For example, site G had a water mirror that improved the physical and chemical characteristics and that favored the AMI community at this site. The opposite was true at point C, where human impact is markedly higher and is reflected in the elevated levels of nutrients and low oxygen concentration, features that support only a few AMI taxa, such as Hirudinea (Glossiphoniidae). Representatives of the Glossiphoniidae family usually live in standing or slow-moving water and tolerate low oxygen concentrations; thus, these organisms are common in places where there is abundant decaying organic matter (Pennak, 1978; Zúñiga, 1985; Rivera and Mejía, 2004).

Although *Helobdella* species are typically considered predators (Sket and Trontelj, 2008), in this study we found in their stomachs a 42.3% of organic matter and plant debris, for wich they were classified as *DT*. Juárez and Ibáñez (2003) also found that *Helobdella elongata* had detritivorous habits in Lake Metztitlán (Mexico). Bud et al. (2006) similarly have stated that leeches are highly able to exploit available detritus. Pennak (1978) and Sket and Trontelj (2008) have noted as well, that in some cases these organisms are detritivores and even scavengers. In the wetland Jaboque is possible that the large amount of debris found in the stomach contents of *Helobdella* sp. obeys to their possible scavenger habits. Laboratory bioassays will be required to test this hypothesis in the future.

The dominance of the *DT* group at Jaboque is a clear reflection of the large quantity of organic matter in the system, mainly from the wastewater affluents and floating aquatic plants. The amount of decaying floating macrophytes and other organic debris are of vital importance for the development of the AMI populations (Marco et al., 2001; Silva and Henry, 2013). Detritus is a food source that contributes to the increment of biomass of these organisms and to the energy flow to other trophic levels (Allan, 1982). Poi de Neiff et al. (1994) noted that *DT* were favored by the vast amount of food resources contained in the roots of plants like *E. crassipes*. According to these authors, 100 g of dry weight of roots holds 170 g of FPOM, an important supply for this group of detritivorous, which feed on that resource. Moreover, Hirudinea present parental care of their offspring (Tello et al., 2007), a feature that could help to increase the biomass of this group.

The second largest group in biomass (*SH*) was represented mainly by crane flies. *SH* are large body organisms, making them notably important because they contribute in high proportion to the decomposition of plant material. They preferred leaves and floating macrophytes. By contrast, Wantzen and Wagner (2006) state that Tipulidae species are usually scarce in tropical regions and therefore have low biomass because the function of decomposition of plant material performed by *SH* can be better achieved to by microorganisms because of higher temperatures. However, in high altitude tropical lentic systems, such as the Andean wetlands, which are located more than 2500 m.a.s.l., these processes may vary as a result of the lower temperatures that affect nutrient cycling and degradation of organic matter. In this aspect, the high Andean wetlands would be more similar to the systems of the temperate zone.

Like *SH*, predators (*PR*) of Jaboque had large body sizes, as Odonata (primarily Aeshnidae and Coenagrionidae families) and other taxa such as beetles of the family Dytiscidae and leeches of the family Piscicolidae. It must be noted that renewal rates, life cycles, and feeding strategies of *PR* are larger compared to those of other guilds, causing alternations in their prey. Piscicolidae and Aeshnidae have longer life cycles and reach a longer length (Jackson and Fisher, 1986), thus, their biomass tends to be higher.

Tubificidae family was abundant because it endures hypoxic and anoxic sediments (Pennak, 1978; Giere et al., 1999). For these organisms, Wolfram et al. (2010) reported values between 0.14 and 0.29 gm^{-2}, similar to those found in Jaboque. These individuals (belonging to the *CG* guild) generally consume organic waste, transforming this detritus of low quality and energy into better quality biomass represented in their own bodies. This biomass is available to the other trophic levels or stages of the food chain, such as birds and amphibians, or other invertebrate predators, like species of Aeshnidae and Piscicolidae, which exhibited remains of oligochaetes in their gut contents. According to Wallace et al. (1991), the high values of abundance and biomass of *CG* are related to their work as processors of CPOM, which is transformed into FPOM, particularly after the rainy season, explaining the higher values of this guild biomass in Jaboque in January. Velásquez and Miserendino (2003) observed a significant correlation between *CG* biomass and FPOM. Moreover, FPOM collectors are mostly characterized as generalists and omnivores (Cummins and Klug, 1979), and therefore have great success in colonizing environments in which there is food availability, particularly fine particles found in floating aquatic plants. Furthermore, oligochaetes, which are *CG* members, support hypoxic and even anoxic waters, thanks to the high concentrations of hemoglobin in their blood (Giere et al., 1999).

Abundance of some groups (*DT, SH*, *CG*) that stay in floating macrophytes could be explained because these plants provide an unlimited supply of food resources, such as debris and its associated bacterial biomass (Duggan, 2001). Such resources are linked to the decomposition processes of organic matter, which favor the establishment of the AMI community and promote their increase in biomass (Stout, 1980; Benstead, 1996). Thus, dominant taxa of Glossiphoniidae, Asellidae, and Tipulidae found in Jaboque presented large quantities of debris in their stomach contents.

During the less rainy months, the AMI biomass (particularly that of *DT*) increased, perhaps caused by enhance in nitrogen, which accelerates the decomposition rate of detritus by augmenting the protein content of the macrophyte leaves. The greatest amount of organic debris is related to the increase in the abundance of microorganisms that are consumed by the invertebrates (Kaushik and Hynes, 1971). Might be expected therefore that the biomass of organisms presents a positive relationship with the availability of organic detritus; these hypotheses mostt o be tested in future studies.

4.3. Functional feeding groups biomass and its relationship to physiochemical variables

Organizational patterns detected by CCA (Figure 3) are not totally well-defined. The conditions of high nutrients, suspended solids, organic matter and conductivity are very widespread in the wetland, preventing detect a robust structure for each zone. Nevertheless some general configurations emerge. *PR* and *SG* are mainly found in the stations F and G (the more urbanized). Despite this human influence, the presence of a water surface in this area without macrophytes causes a greater DO (average 2.19 mg L^{-1} O_2). The penetration of light promotes growth of periphyton and the presence of the scrapers herbivores.

SH appear to predominate in sites C, D and E (medium to high disturbance), where SRP and TSS tend to be high. Shredders grow well at these sites rich in phosphorus, a nutrient that promotes the growth of aquatic plants (Rangel et al., 2005). Other guilds (*CG*, *DT*, *CF*) are preferably located at stations A-B (less disturbance) and D (high disturbance), in which there were higher concentrations of nitrite, and pH was a little closer to neutrality. All these FFG are specialized in detritus consumption, and apparently in these areas they find abudant food.

The numerous statistical relationships identified with canonical correlation between FFG biomass and physical and chemical variables corroborate the statements of Ryan and Curtis (2007), who suggest that physical factors control the distribution and abundance of functional groups, which determines the structure of the community. Silva and Henry (2013) also have demonstrated that the dissolved oxygen and pH have a great number of significant positive correlations with the different AMI taxa associated to *Eichhornia azurea*. Fluctuations in temperature cause a decrease in biomass, a situation that was evident in Jaboque, where the temperature had a positive relationship with the biomass of *DT*.

FPOM collectors tolerate low levels of oxygen and can quickly become proficient in aquatic systems that have high concentrations of FPOM (Spieles and Mitsch, 2003). Positive relationships between increased *DT* biomass and augmented nitrate concentration (Graça, 2001) have also been observed. More nitrates generate a favorable environment for microorganisms, which, in turn, influence the production of AMI by supplying better quality food. Butler and Anderson (1990) observed that low concentrations of oxygen have a negative effect on growth and development (and thus on biomass) of Chironomidae, which belong to the *SG* guild. Chironominae (*SG*), *Physa* (*SG*), and Oligochaeta (*CG*) are expected to increase their biomass with the decreasing in DO because these invertebrates are tolerant to low oxygen concentrations (Toro et al., 2003). In Jaboque, however, there was a positive relationship between oxygen and *CG* and *SG*, which may indicate that some taxa of these FFG prefer more oxygenated environments (Irving et al., 2004; Heron, 2007). It has been shown through simulations that variations in DO concentrations affect the trophic structure of the AMI community in artificial wetlands and that this influence is greater for the herbivores (Spieles and Mitsch, 2003). With respect to phosphorus, Ryan and Curtis (2007) demonstrated that the Everglades are limited by this nutrient; therefore, an increase in its concentration favors groups such as Hirudinea, gastropods, dipteran, and oligochaetes, while coleopteran, heteropteran, and isopods are less influenced by phosphorus. In Jaboque, phosphorus is abundant, and it therefore does not seem to limit the development of the AMI community.

In conclusion, studies of the composition and structure of the AMI community should be complemented with an evaluation of the biomass of the FFGs to observe changes from a functional perspective and to obtain general knowledge of the ecosystem. As demonstrated in Jaboque, biomass studies on FFGs permit an assessment of changes or not within communities, in response to climatic fluctuations and anthropogenic pressures, and are a suitable tool for assessing the health of wetlands. Finally, it was found that seasonal changes had less drastic affects on variations of the trophic guilds biomass, that those due to pollution from urban sources. So, the proposed hypothesis was overcome by the human impact.

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