Journal of Environmental Biology
©Triveni Enterprises, Lucknow (India)
Free paper downloaded from: www.jeb.co.in

September 2008, 29(5) 693-700 (2008)
For personal use only
Commercial distribution of this copy is illegal

Water quality and zooplankton composition in a receiving pond of the stormwater runoff from an urban catchment

Jose de Paggi Susana*[1,2], Paggi Juan[1], Collins Pablo[1,2], Collins Jorge[3] and Graciela Bernal[3]

[1]Instituto Nacional de Limnologia (CONICET-UNL), Macia 1933, 3016 Santo Tome, Santa Fe, Argentina
[2]Facultad de Bioquimica y Cs. Biologicas, Universidad Nacional del Litoral, 3000 Santa Fe, Argentina
[3]Facultad de Ingenieria en Ciencias Hidricas, Universidad Nacional del Litoral, 3000 Santa Fe, Argentina

(Received: December 21, 2006; Revised received: August 02, 2007; Re-revised received: August 22, 2007; Accepted: September 10, 2007)

Abstract: *Six storm periods were monitored from November 2002 to September 2005 at two stations of a receiving pond of the stormwater runoff from a small urban catchment of the city of Santa Fe, Argentina. Weekly samples were taken before and after rain events under different conditions of temperature, pluvial precipitation, and duration of the previous dry period. A sampling station was established at the outlet of the catchment (S1) and another one near the outlet of the receiving pond (S2). Both stations differed significantly in their dissolved oxygen (DO) concentration, temperature, transparency, and zooplankton composition. The concentrations of nutrients and* BOD_5 *values indicated permanently eutrophic condition at both stations. After rainstorms, the concentrations of lead, zinc and suspended solids showed a marked increase. The zooplankton composition at S1 was characterized by the abundance of protozoans (Dexiostoma campylum (Stokes) Didinium nasutum Muller, Plagyopila cf nasuta, and Bdelloidea rotifers (Philodina sp and Rotaria sp), while Monogononta rotifers and small cladocerans were dominant at S2. The most abundant species were the rotifers Platyias quadricornis (Ehrenberg), Mytilina ventralis (Ehrenberg) and Lepadella ovalis (Muller), and the cladoceran Chydorus pubescens Sars.*

Key words: *Protozoans, Bdelloidea, Monogononta, Storm events, Water quality*
PDF of full length paper is available with author ***(*sjdepaggi@gmail.com)***

Introduction

Urban stormwater runoff not only transport substances washed from streets and buildings but also, domestic and industrial sewage, thus constituting one of the most important sources of diffuse contamination (Carpenter *et al*., 1998). The effect of urban drainage on receiving water bodies is reflected in their water quality, hydrology and habitat conditions (Sonneman *et al*., 2001). The contribution of suspended sediments, nutrients and toxic substances is related to urban development, catchment imperviousness and state of drainage systems (Leopold, 1968; Ryding and Rast, 1992; Brown *et al*., 2005).

Although some relationships among these factors and macro invertebrates and fish composition have been reported (May *et al*., 1997; Fitzpatrick *et al*., 2004; Gray, 2004; Park and Shin, 2007), the aquatic communities of receiving waters have been scarcely studied. The fact that these water bodies are merely perceived as drains (Walsh, 2000) may explain why their study has been almost neglected by limnologists. However, the proximity of the receiving water bodies to their sources of disturbance, turns them into sensitive and valuable systems for the evaluation of the impacts produced by the urbanization of a catchment.The purpose of this paper is to assess the water chemistry and the composition and abundance of zooplankton in the receiving pond of the stormwater runoff of small urban catchment of the Santa Fe City, Argentina. Two hypotheses were tested: 1) urban stormwater determines high concentration of nutrients, low dissolved oxygen (DO) concentration and high values of zinc and lead in the reservoir water. 2) The zooplankton composition of the reservoir differs from that of waterbodies of the region without direct human impact.

Materials and Methods

Study area: The city of Santa Fe has 370.000 inhabitants and its population density attains 115.2 inhabitants per km^2. It is located in a temperate region, with most frequent rainfalls during the spring-summer season. The studies were carried out in an artificial pond that receives the totality of the stormwater runoff of the urban catchment of West Guadalupe, located in the northwestern zone of the city (31°38'22" S - 60°41'43" W) (Fig. 1). This catchment extends over 1.98 km^2, 50% of which have an impervious cover composed by buildings (mostly family housing), supermarkets (4), service stations (2), mechanical workshops (5), and dry-cleaning shops (1) ; the mean slope of the basin is 0.0034 m m^{-1}.The receiving pond has a surface area of 58606 m^2, a perimeter of 1467 m, a maximum depth scarcely exceeding 1 m and a mean water residence time of approximately 100 hr (depending on rainfall intensity and duration). The pond drains through a channel into the shallow lake (Laguna Setúbal). During the study period the pond had a vegetation cover of *Paspalum repens* (Berg).

Two sampling stations were established, one at the outlet of the catchment (S1) and another one near to the outlet of the receiving pond (S2). Six storm periods were monitored from November 2002 to September 2005, corresponding to different thermal and precipitation conditions and duration of the previous period without rainfalls (Table 1). During the first five periods, the samples were

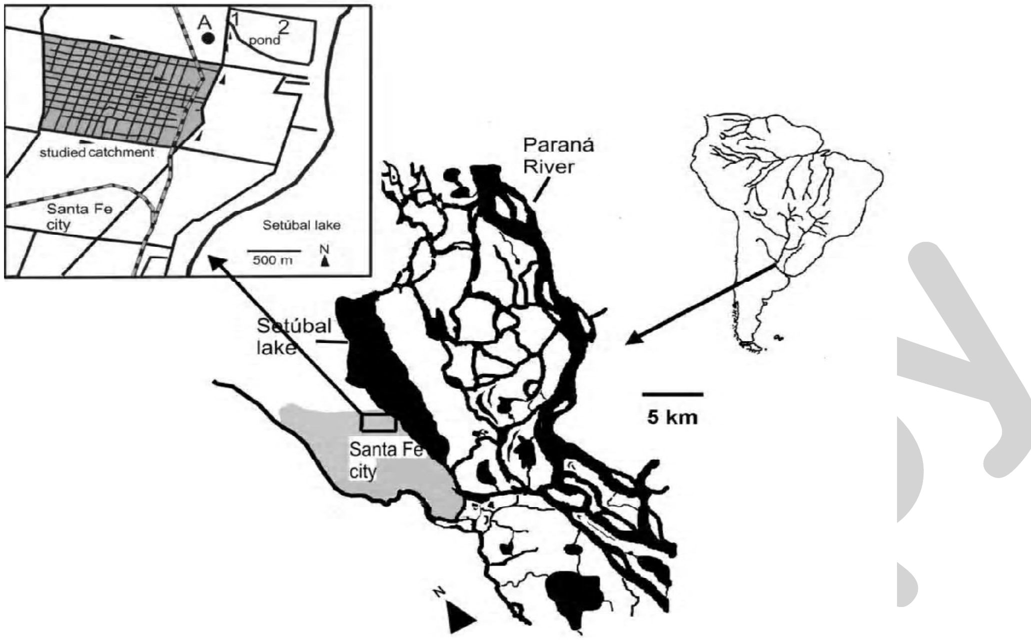

Fig. 1: Urban catchment of West Guadalupe showing the location of the sampling stations S1 (1) and S2 (2) in the receiving pond. A = monitoring site for precipitations

Table - 1: Mean values and coefficients of variation (CV) of water temperature, rainfall amount, and number of previous days without rain (D)

Periods	Temperature (°C) Mean CV (%)	Rainfall (mm)	D (days)
Nov.-Dec. 2002	22.6 (11)	13.77	4
Feb.-March 2003	25.67 (6)	46.6	17
Jul. 2003	14.78 (15)	17.8	46
Aug.- Sep. 2003	15.58 (17)	6.5-27*	26
Aug.- Oct. 2004	17.78 (13)	15-25*	31
Aug.- Sep. 2005	16.35 (6)	23-14*	30

* two rain event were recorded

taken one or two days before each rain event, then two days after the rain and subsequently on a weekly basis. Water level, pH, specific conductivity, temperature, dissolved oxygen (DO) concentration (Hanna portable equipment) and transparency (Secchi disk) were measured *in situ.*

The concentrations of phosphorus, nitrates (at S1) and lead (at S1 and S2) were determined in three of study periods (November – December 2002, July 2003 and August – October 2004). Zooplankton samples were taken by filtering 100 liters of water through a net of 50 µm mesh size.

During the sixth period, two weekly samplings were carried out throughout a 45-day continuous period at S1. Two rainstorms of similar intensity (23 and 21 mm) occurred during this period. The post-rain samples were taken 40 hr after the first rain and one hour after the second rain. The sampling consisted in the measurement of the aforementioned environmental parameters *in situ*, the extraction of zooplankton and water samples for the analysis of BOD_5, total phosphorus, nitrates, nitrites, ammonium, calcium, magnesium, potassium, and total suspended solids. Samples for lead and zinc analyses, and for acute toxicity tests using *Daphnia magna* (Straus) and *Macrobrachium borelli* (Nobili) were taken before and after the rain. Since dissolved oxygen (DO) dropped below 2.5 mgl^{-1} after

Table - 2: Mean values and coefficients of variation (CV%) of the physical and chemical variables, during the first five study periods, before and after rainstorms in sampling stations S1 and S2

	Before rain		After rain	
	Station 1	Station 2	Station 1	Station 2
Transparency (cm)	28.0 (29)	49.8 (17)	27.2(50)	40.0 (36)
pH	7.31 (5)	7.14 (5)	6.88 (6)	6.81 (7)
Specific conductivity (µS cm^{-1})	465.00 (15)	438.75 (22)	403.75 (23)	337.00 (34)
Dissolved oxygen (mg l^{-1})	1.19 (31)	2.34 (22)	1.16 (50)	2.21 (56)
Phosphorus (mg l^{-1})	2.72 (29)		2.07 (54)	
Nitrate (mg l^{-1})	1.97 (97)		1.22 (74)	

Table - 3: Mean values and coefficients of variation (CV) of the chemical variables of the water throughout a 45-day period (n= 9) in S1

	Mean	CV (%)
pH	7.11	5.82
Calcium (mg l^{-1})	27.88	9.67
Magnesium (mg l^{-1})	5.38	13.84
Sulphate (mg l^{-1})	50.05	14.70
Potassium (mg l^{-1})	7.00	15.27
Specific conductivity (µS cm^{-1})	368.56	28.96
Ammonia (mg l^{-1})	6.14	28.77
Total phosphorus (mg l^{-1})	3.00	41.75
Nitrate (mg l^{-1})	3.06	49.21
BOD_5 (mg l^{-1})	33.33	50.41
Dissolved oxygen (mg l^{-1})	2.64	100.77

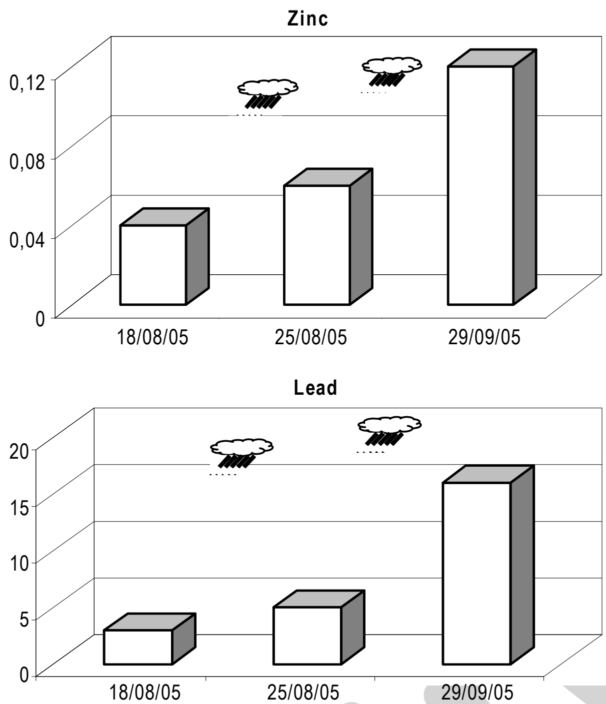

Fig. 2: Lead and zinc concentrations before and after rainstorms at the outlet of the urban catchment (S1). Small cloud: Sampling carried out 40 hr after the rain event; large cloud: Sampling carried out one hour after the rain event

rain events, bioassays were carried out both with and without oxygenation.

Nitrates, nitrites, ammonium, suspended solids, and total solids were determined following APHA (2005). Ca, Mg, K, and Zn determinations were carried out using atomic absorption spectrometry with flame atomization and those of Pb by electrothermic atomization under STPF (stabilized temperature platform furnace) conditions. The toxicity bioassays performed followed the standardized protocol of the EPA (1975).

Qualitative and quantitative analyses of zooplankton samples were carried out under optical binocular microscope and stereoscopic microscope. Rotifers, cladocerans and copepods were identified to

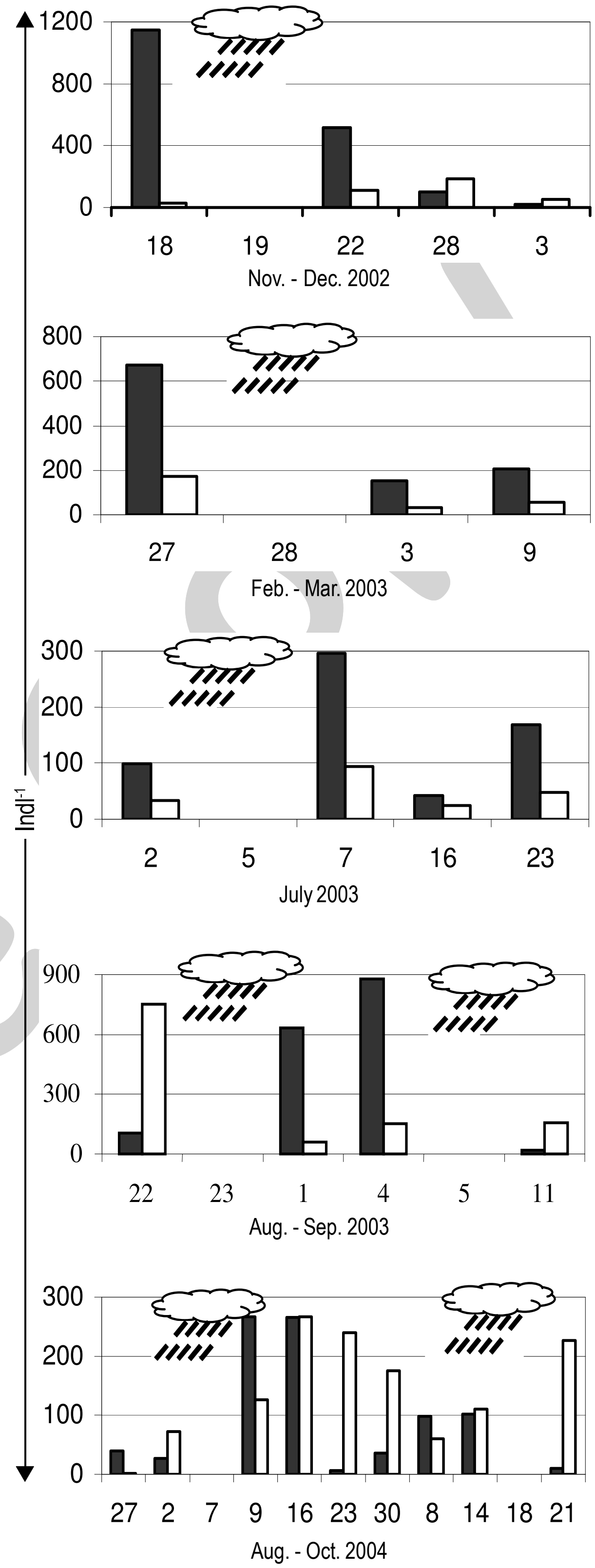

Fig. 3: Total zooplankton density (protozoans, rotifers, cladocerans, and copepods) (ind.l^{-1}) before and after the rain event. S1: Outlet of the urban catchment (black); S2: Outlet of the receiving pond (white)

Table - 4: Mean values and coefficients of variation (CV) before rainstorms and values after 40 hr and 1 hr of the first and second rain events, during the August-September 2005 period in S1

	Mean	CV (%)	Storm 1	Mean	CV (%)	Storm 2
Specific conductivity ($\mu S\ cm^{-1}$)	386.6	6	262	411.25	33	250
pH	7.17	4	6.5	7.05	5	7.8
Oxygen ($mg\ l^{-1}$)	4.57	33	0.83	1.28	39	1
Calcium ($mg\ l^{-1}$)	29.33	2	26	27.25	13	23
Magnessium ($mg\ l^{-1}$)	6.00	0	4	5.25	10	6
Potassium ($mg\ l^{-1}$)	7.67	8	7	6.5	20	12
BOD_5 ($mg\ l^{-1}$)	41.47	66	22.8	29.85	22	30
Sulfate (mgl^{-1})	48.90	9	37.5	54.05	12	34
Nitrate ($mg\ l^{-1}$)	3.37	27	2	3.1	67	7.7
Ammonnia ($mg\ l^{-1}$)	6.90	29	3	6.35	12	6.9
Total phosphorus ($mg\ l^{-1}$)	4.03	40	1.8	2.52	10	1.4

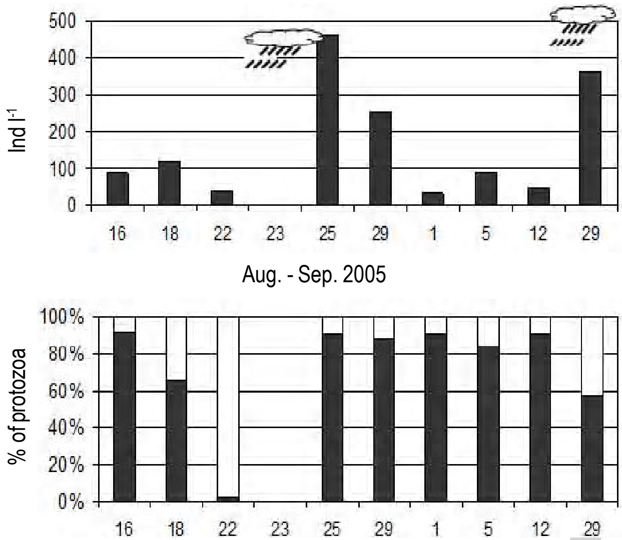

Fig. 4: S1, August-September 2005 period. Upper panel : Total zooplankton density (ind.l^{-1}). Lower panel: Percentage of protozoans (black)

various taxonomic levels (genera or species) and counted. Several identification keys were used (Korovchinsky, 1992; Smirnov, 1992; Segers, 1995; De Smet and Pourriot, 1997; Ricci and Melone, 2000; Foissner *et al.*, 1999). Abundance was expressed as individuals per liter (ind l^{-1}).

The relationships between variables were analyzed using the Sperman Correlation Coefficient. Mean values were compared using the Student t-test. Depending on the nature of the data, in some cases the Welch's correction of the t-test was applied (Zar, 1996). The faunistic affinity between the zooplankton compositions in both stations was calculated by means of the Jaccard's Similarity Coefficient (Margalef, 1981).

Results and Discussion

Water quality: The receiving pond was characterized by its high specific conductivity, low dissolved oxygen (DO) concentration and circumneutral pH (Table 2). Both stations differed in their transparency (p=0.0001), temperature (p=0.041) and dissolved oxygen (DO) concentration (p=0.001). The lower dissolved oxygen (DO) concentration and transparency, and higher temperature were recorded in S1. The water level was highly fluctuating, with maxima of 0.70 m at S2 and 1.50 m at S1. The dissolved oxygen (DO) concentration was significantly different before and after the rainstorms in both stations (p=0.0002 and p=0.003, respectively). Specific conductivity values were significantly different only after rain events (p=0.080). The values of pH before and after the rains were significantly different only in S1 (p=0.012).

Lead concentration ranged between <4 and 21.7 μgl^{-1} in both stations, with a peak value in S1 after the rain event of July 2003. A great variability in dissolved oxygen (DO) concentration, BOD_5, nitrates, and total phosphorus was observed in S1, throughout the 45 days, that comprised the sixth study period (Table 3). A reduction in the levels of dissolved oxygen (DO), BOD_5, sulphate, nitrate, ammonium, phosphorus, calcium, magnesium, and an acidification of the pH was observed 40 hr after the first rainstorm respect to the mean values registered during the previous weeks (Table 4). In general, one hr after the second rainstorm we also observed a dilution effect, and at the same time an increase in the concentrations of potassium and nitrate and the pH values (Table 4).

Zinc and lead were higher after rainstorms, particularly one hour after the rain (Fig. 1). Nitrite values were <0.1 mgl^{-1}. The values of suspended solids were always <20 mgl^{-1}, but after the first and second rainstorms they attained 20 and 73 mgl^{-1} respectively.

Toxicity tests: The EC50 (48 hr) for the *Daphnia magna* bioassay was 78.20% before the rain. After the rain it attained 58.36% without added dissolved oxygen (DO) and 62.06% with oxygenation. In the first sampling date the EC50 for *Macrobrachium borelli* was 73.4% (48 hr) and 41.3% (72-96 hr) before the rain. After the rain it attained 58.7% (72 hr) and 48.3% (96 hr).

Zooplankton composition and abundance: A total 37 Monogononta rotifers, 16 cladocerans, 10 copepods, 3 ciliates, 1 Suctorian were recorded. The Bdelloidea rotifers belonged to the genera *Philodina* (Ehremberg) and *Rotaria* (Scopoli). In addition,

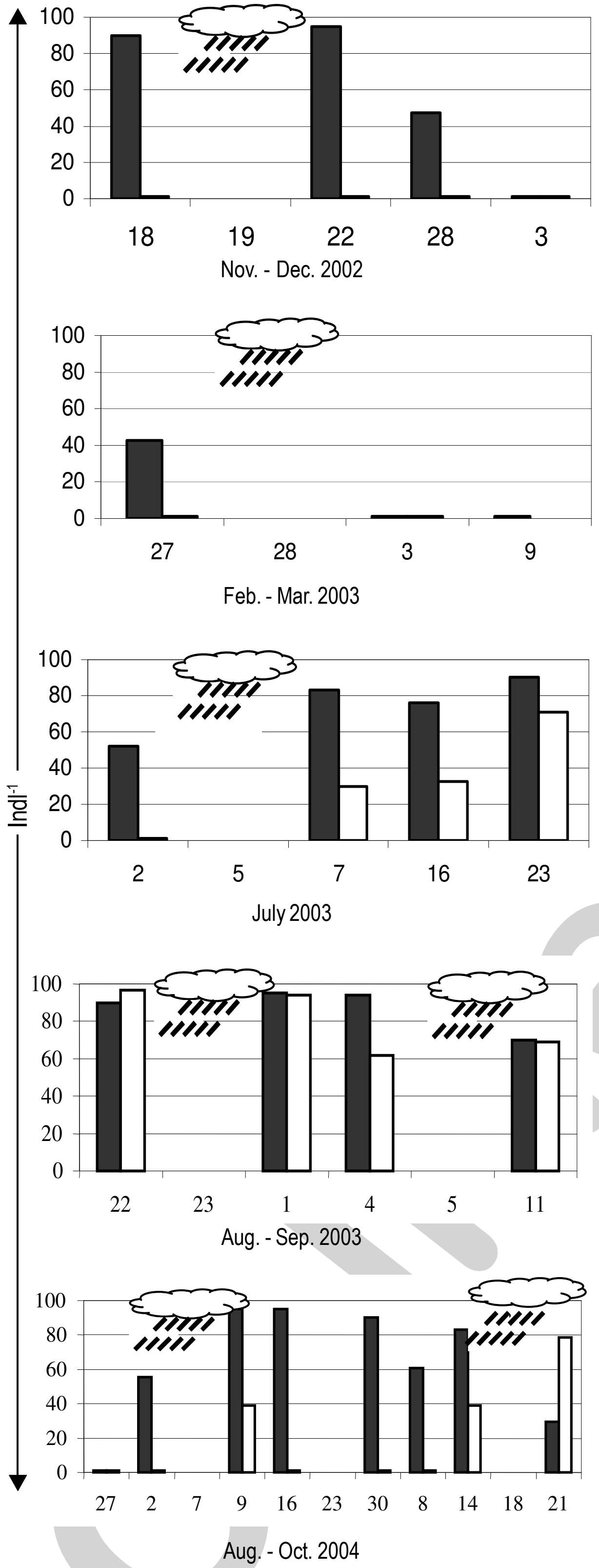

Fig. 5: Percentage of protozoans (black) on total zooplankton density in sampling stations S1 (black) and S2 (white)

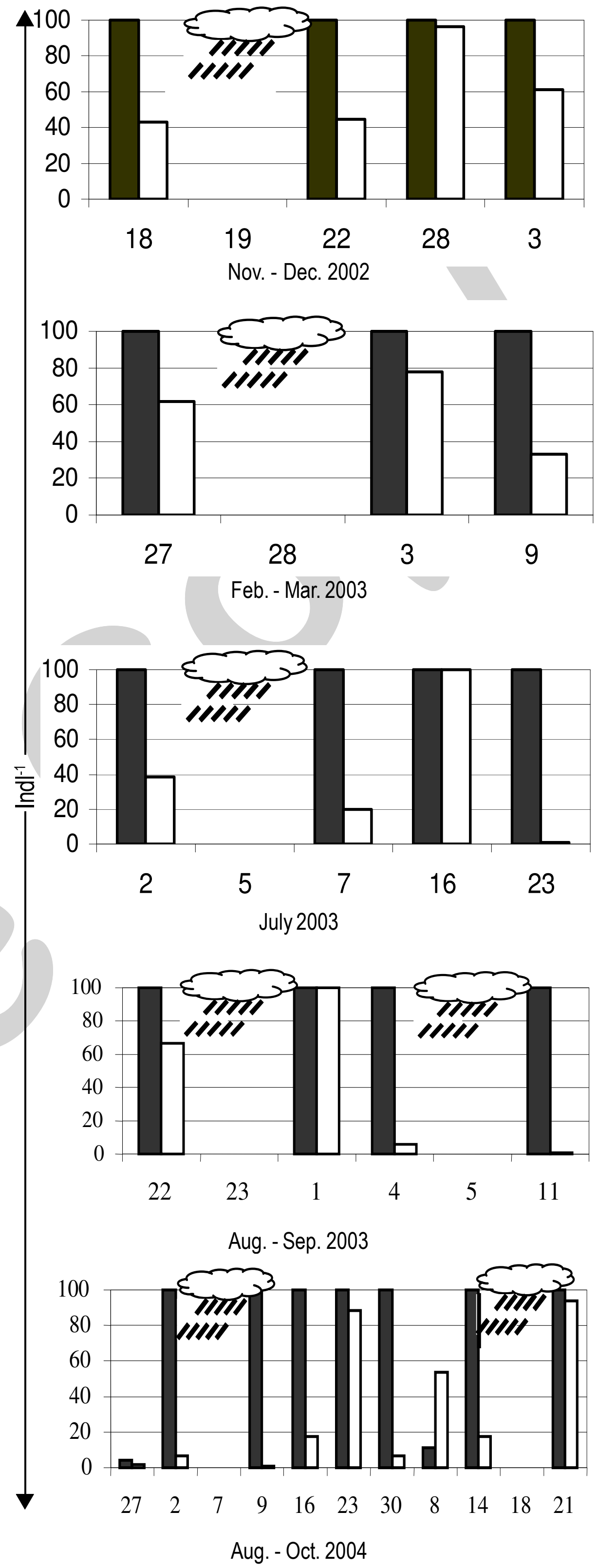

Fig. 6: Percentage of bdelloids on total rotifer density in sampling stations, S1 (black) and S2 (white)

Table - 5: List of invertebrates recorded in sampling stations S1 and S2 during the study periods

	S1	S2
Rotifers Monogononta		X
Asplanchna sp	X	X
Brachionus quadridentatus (Hermann)		X
Cephalodella catellina (Muller)		X
C. gibba (Ehrenberg)		X
Colurella colurus (Ehrenberg)		X
C. sp		X
Dicranophoroides caudatus Ehremberg	X	X
Dipleuchlanis propatula (Gosse)		X
Encentrum sp		X
Euchlanis dilatata (Ehrenberg)		X
Lecane aspasia Myers	X	X
L. bulla (Gosse)		X
L. closterocerca (Schmarda)	X	X
L. cornuta (Muller)		X
L. curvicornis (Murray)		X
L. eutarsa (Harring and Myers)		X
L. hamata (Stokes)	X	X
L. lunaris (Ehrenberg)		X
L. ludwigii (Eckstein) *F. ohioensis* (Herrick)		X
L. pyriformis (Daday)		X
L. quadridentata (Ehrenberg)		X
Lepadella acuminata (Ehrenberg)	X	X
L. heterodactyla Fadeew	X	
L. ovalis (Muller)	X	X
L. rhomboides (Gosse)		X
L. patella (Muller)	X	X
Mytilina ventralis (Ehrenberg)	X	X
M. sp		X
Platyias quadricornis (Ehrenberg)	X	X
Plationus patulus (Muller)	X	X
Testudinella patina (Hermann)		X
Trichocerca iernis (Gosse)		
T. porcellus (Gosse)		X
T. pusilla (Lauterborn)		X
T. rattus (Muller)		X
T. similis (Wierzejski)		X
T. sp	X	X
Rotifers Bdelloidea		
Philodina sp	X	X
Rotaria sp	X	X
Cladocerans		
Alona glabra Sars	X	X
Camptocercus dadayi Stingelin	X	X
Ceriodaphnia richardi Sars		X
Chydorus pubescens Sars	X	X
Dadaya macrops Sars		X
Diaphanosoma brevirreme Sars		X
Echinisca elegans (Sars)		X
Ilyocryptus spinifer Herrick	X	X
Kurzia latissima (Kurz)		X
Moina macrocopa (Sars)	X	
Moina reticulata (Daday)		X
Moinodaphnia macleayi (King)		X
Leydigia quadrangularis (Leydig)		X
Pleuroxus similis Vavra	X	X
Simocephalus daphnioides Herrick	X	X
Scapholeberis spinifera (Nicolet)	X	X
Copepods		
Acanthocyclops robustus (Sars)		X
Eucyclops neumani (Pesta)	X	X
Eucyclops silvestrii (Daday)	X	X
Eucyclops subciliatus Dussart		X
Ectocyclops phaleratus (Koch)	X	X
Macrocyclops albidus (Jurine)	X	X
Notodiaptomus carteri Lowndes		X
N. sp	X	X
Paracyclops cfr. poppei (Rehberg)	X	
Tropocyclops prasinus Kiefer	X	X
Ciliates		
Dexiostoma campylum (Stokes)		X
Didinium nasutum (Muller)	X	X
Plagiopyla cfr.nasuta Stein	X	X
Suctorians		
Tokophyra sp	X	
Platyhelminths	X	
Ostracods	X	
Cercariae larvae	X	

catenulid platyhelminths, ostracods and cercariae larvae were detected. The faunistic list of taxa found in the pond is presented in Table 4. The most frequent organisms in the samples throughout the study period were: bdelloid rotifers(93%), copepod larvae (copepodites 93%, nauplii 86%) and protozoans (68%).

The zooplankton composition at the outlet of catchment (S1) was represented by 36 taxa. Rotifers, ciliates, suctorians, cladocerans and copepods. Monogononta rotifers were recorded only on two occasions during the fifth study period. In S2 the zooplankton was represented by 63 species (Table 4), the most frequent Monogononta rotifers were the littoral genera *Lecane*, *Lepadella* and *Trichocerca*. The faunistic affinity was 39 %. The species richness was significantly different between stations (p= 0.0001).

The highest abundance of organisms was observed during the spring- summer samplings (November 2002, February 2003 and August-September 2003), with maximum value of 1149 ind l^{-1} (S1) (Fig. 3 and 4).

Zooplankton abundance did not differ significantly between stations, but the proportion of protozoans were significantly different (p=0.001), since they were the most abundant organisms in the station corresponding to the outlet of the catchment (Fig. 5). The percentages of bdelloids were also significantly different between both stations (p=0.001). These rotifers were dominant in S1 (Fig. 6). The most abundant rotifer species in S2 were *Platyias quadricornis* (Ehrenberg), *Mytilina ventralis* (Ehrenberg), *Lepadella ovalis* (Müller), and *Dicranophoroides caudatus* Ehrenberg, and the dominant crustacean was *Chydorus pubescens* Sars (156 ind l^{-1}).

In general, after the most intense rainstorms (23, 33.5 and 38 mm) the zooplankton abundance declined in S1, probably because of a dilution effect, as a result of the increased runoff (Fig. 3, 4). After most rains, protozoans became dominant followed by bdelloids.

The mean concentrations of phosphorus and nitrogen in both stations of the receiving pond indicated its permanently eutrophic and even hypereutrophic status (Kalff, 2002), either before or after rains. The BOD_5 also indicate a high load of biodegradable organic matter. On the other hand, the concentration of nitrates, ammonium, calcium, sulphate, and potassium were three or more times higher than the mean values recorded in natural unimpacted waterbodies of this region (Maine *et al.*, 1999). Excessive nutrients concentrations have been proved to have a great effect on eutrophication processes in water bodies but also a direct toxic effect upon some organisms (Puzo and Law, 2006).

The BOD_5 and the concentration of dissolved oxygen (DO), nitrates and total phosphorus, as well as their variability, indicate the intensity of the decomposition processes of organic matter as well as the existence of a probably permanent contribution of small inputs. The concentrations of zinc and lead were higher one hour after the rain than 40 hr after it, showing the point source effect of the substances washed from streets, which include lead from the motor combustion and zinc from the friction of vehicles pneumatics on the pavement. Toxicity and accumulation of both heavy metals in freshwater organism is widely known (Gupta and Srivastava, 2006; Yongpisanphop *et al.*, 2005). The concentration of suspended sediments were also higher, in agreement to literature reports on urban catchments that contribute up to 1000 times more than comparable agricultural areas (Ryding and Rast, 1992).

Although there are many factors impacting on receiving waters, such as population development, climate, soil, and vegetation (Hardinger *et al.*, 1998; Brown *et al.*, 2005), the water quality of the pond can be primarily associated to the proportion of impervious cover (50%). In a watershed such proportion is a good indicator of its level of urbanization and its effects, such as an increase in water temperature, water transparency reduction, higher load of nitrogen, phosphorus and contaminants like those registered in this study. Different studies indicate that when total impervious area in a watershed reaches 10%, receiving waters begin to show evidence of ecological effects (Schueler, 1994; Arnold and Gibbons, 1996; Brattebo and Booth, 2003).

Studies carried out by Valsagna in the receiving pond have demonstrated the toxicity of the stormwater runoff and its variation during rain events, with its maximum 30 minutes after the onset of the rain. Our results also highlight the toxicity of the pond and the relatively little incidence of the low dissolved oxygen (DO) concentration on the mortality of *Daphnia magna*, which seems to be more sensitive to contamination than *Macrobrachium borelli*.

The zooplankton composition in the station receiving the runoff of the catchment was characterized by the abundance of protozoans and bdelloid rotifers. The species of ciliates and suctorians recorded in this study have also been reported from waters having a strong organic contamination (Modenutti, 1987; Fogetta and Boltovskoy, 1995; Martin-Cereceda *et al.*, 2002; Tirjakova, 2003). Bdelloid rotifers are known to be tolerant to a wide range of ecological conditions, including low dissolved oxygen concentrations and desiccation (Sladecek, 1983; Ricci, 1987). On a single occasion in S1, *Moina macrocopa* (Sars), a cladoceran probably introduced to South America, which so far has been reported from small urban waterbodies of this region (Paggi, 1997) was recorded in this study.

In spite of the low dissolved oxygen (DO) concentrations prevailing in S2, the slightly more favorable general conditions, favored the dominance of littoral genera of Monogononta rotifers, evidently associated to macrophyte development, which probably promotes a higher water transparency. The sapropelic species *Dicranophoroides caudatus* (Ehremberg), typical of decomposing organic mud (De Smet and Pourriot, 1997), was also recorded in S2.

The presence of protozoans and bdelloid rotifers would depend on the pluvial runoff of the catchment. Both organisms can thrive in small accumulations of water (Pennak, 1989; Ricci, 1987), in roofs, streets and mosses, from where they can be washed by the rain. Usually, there is an inverse correlation between the abundance of bdelloids and water depth (Klimowicz, 1972). Therefore, the shallowness of the receiving pond is probably suitable for their development and permanence during several weeks.

Comparing the zooplankton composition of aquatic environments of this region that are not exposed to anthropic impact with the studied receiving pond, the most important difference resides in the abundance of protozoans, bdelloids and in the absence of planktonic rotifers (Paggi, 1980;José de Paggi, 1993). Taking into account the short generation time of these organisms (Kalff, 2002), their dominance may be explained not only by water chemistry, but also by the short water residence time of the pond. Conversely, the abundance of copepods, which have longer generation times, was very low.

It is concluded that both water chemistry and zooplankton composition reflect the impact of the urbanization of the catchment. In spite of their small surface, the urban basins can produce deep changes on a local scale of the receiving water bodies.

Acknowledgments

We wish to thank Mr. Cristian Debonis for his assistance. The work was supported by a grant of the Universidad Nacional del Litoral, Project CAI+D 2000.

References

APHA: Standard Methods for the examination of water and wastewater. 21st Edn., Washington DC, USA (2005).

Arnold, C.L. and C.J. Gibbons: Impervious surface coverage: The emergence of a key environmental indicator. *J. Am. Plan. Assoc.,* **62**, 243-258 (1996).

Brattebo, B.O. and D.B. Booth: Long-term stormwater quantity and quality performance of permeable pavement systems. *Water Res.,* **37**, 4369-4376 (2003).

Brown, L.R., R.H. Gray, R.M. Hugies and M.R. Meador: Introduction to effects of urbanization on stream ecosystems. *Am. Fish. Soc. Symp.*, **47**, 1-8 (2005).

Carpenter, S.R., N.F. Caraco, D.L. Conell, R.W. Howart, A.N. Sharpley, and V.H. Smith: Nonpoint pollution of surface waters with phosphous and nitrogen. *Ecol. Appl.*, **8**, 559-568 (1998).

De Smet, W.H. and R. Pourriot: The Dicranophoridae (Monogononta) and the Ituridae (Monogononta). *In*: Rotifera Vol. 5, Guides to the identification of the microinvertebrates of the continental waters of the world (*Eds*.: H. Dumont). SPB Academic Publishing, The Hague, The Netherlands pp. 1-344 (1997)

EPA: Methods for Acute Toxicity Tests with Fish, Macroinvertebrates and Amphibians. Ecol. Res. Ser. U.S. Environ. Prot. Agency, 660/3-75-009 (1975).

Fitzpatrick, F.A., M.A. Harris, T.L. Arnold and K.D. Richards: Urbanization influences on aquatic communities in northeastern Illinois streams. *J. Am. Water Res. Assoc.*, **40**, 461-475 (2004).

Fogetta, M. and A. Boltovskoy: Ciliated Protozoa from dissolved oxygen (DO) depleted waters from Cassaffousth reservoir (Cordoba: Argentina). *Rev. Asoc. Cienc. Nat. Litoral*, **26**, 25-31 (1995).

Foissner, W., H. Berger and J. Schaumburg: Identification and Ecology of Limnetic Plankton Ciliates. Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, Heft 3/99, Munich (1999).

Gupta, P. and N. Srivastava: Effects of sub-letal concentrations of zinc on histological changes and bioaccumulation of zinc by kidney of fish *Channa punctatus* (Bloch). *J. Environ. Biol.*, **27**, 211-216 (2006).

Gray, L.: Changes in water quality and macroinvertebrate communities resulting from urban stormflows in the Provo River, Utah, USA. *Hydrobiologia*, **518**, 33-46 (2004).

Hardinger, J.S., E.F. Benfield, P.V. Bolstad, G.S. Helfman and E.B. Jones: Stream biodiversity: The ghost of land use past. *Proc. Nat. Acad. Sci.*, **95**, 14843-14847 (1998).

Jose de Paggi, S.: Composition and seasonality of planktonic rotifers in limnetic and littoral region of a floodplain lake (Parana river system). *Rev. Hydrobiol. Trop.*, **26**, 53-64 (1993).

Kalff, J.: Limnology. Inland Water Ecosystem. Prentice Hall (2002).

Klimowicz, H.: Rotifers of the near bottom zone of lakes Mikolajskie and Taltowisko. *Pol. Arch. Hydrobiol.*, **19**, 167-178 (1972).

Korovchinsky, N.M.: Sididae y Holopedidae (Crustacea: Daphniiformes). *In*: Cladocera Vol. 3. Guides to identification of the microinvertebrates of the continental waters of the world (*Ed.*: H. Dumont). SPB Academic Publishing, The Hage, The Netherlands. pp. 1-82 (1992).

Leopold, L.B.: Hydrology for Urban Land Planning: A Guidebook on the Hydrological effects of Urban Land Use. U.S. Geological Survey, Circular 554. Whashington, D.C. (1968).

Maine, M.A., N.L. Sune, M.C. Panigatti, M.J. Pizarro and F. Emiliani: Relationships between water chemistry and macrophyte chemistry in lotic and lentic environments. *Arch. Hydrobiol.,* **145**, 129-145 (1999).

Margalef, R.: Ecología. Planeta, Barcelona (1981).

Martin-Cereceda, M., J. Zamora, B. Perez-Uz and A. Guinea: Ciliate communities of rotating biological contactor biofilms: A multivariate approach. *System. Appl. Microbiol.*, **25**, 301-313 (2002).

May, C.W., R.R. Horner, J.R. Karr, B.W. Mar and E.B. Welch: Effects of urbanization on small streams in the Puget sound lowland ecoregion. *Watersh. Protect. Technol.*, **2**, 483-494 (1997).

Modenutti, B.E.: Limnological survey Keratella I of middle Paraná River (Argentina). Zooplankton of lentic environments (Spanish). *An. Inst. Cienc. Mar Limnol. Univ. Nac. Auton. Mex.*, **14**, 21-28 (1987).

Paggi, J.C.: Assessment of the spatial variation of Rodriguez River (Buenos Aires Province) (Spanish). *Ecologia*, **4**, 77-88 (1980).

Paggi, J.C.: *Moina macrocopa* (Straus, 1820) (Branchiopoda, Anomopoda) in South America: Another case of species introduction? *Crustaceana*, **70**, 886-892 (1997).

Park, K.S. and H.W. Shin: Studies on phyto-and-zooplankton composition and its relation to fish productivity in a west coast fish pond ecosystem. *J. Environ. Biol.,* **28**, 415-422 (2007).

Pennak, R.W.: Fresh-water invertebrates of the United States. John Wilely and Sons, New York (1989).

Puzo, F. and S. Law: Effect of nitrate-related compounds on growth, survival and hematological responses in tadpoles of the Cuban tree frog, *Osteopilus septentrionalis* (Boulenger). *J. Environ. Biol.*, **27**, 187-190 (2006).

Ricci, C.: Ecology of bdelloids: How to be successful. *Hydrobiologia*, **147**, 117-127 (1987).

Ricci, C. and G. Melone: Key to the identification of the genera of bdelloid rotifers. *Hydrobiologia*, **418**, 73-80 (2000).

Ryding, S.O and W.Rast: El control de la eutrofización en lagos y pantanos. UNESCO, The Partenon Publishing Group, París, Francia (1992).

Segers, H.: The Lecanidae (Monogononta). *In*: Rotifera 2 vol 6 Guides to the identification of the microinvertebrates of the continental waters of the world (*Ed.*: H. Dumont). SPB Academic Publishing bv, The Hague, The Netherlands. pp. 1-226 (1995).

Schueler, T.R.: The importance of imperviousness. *Watersh. Protect. Techn.*, **1**, 100-111 (1994).

Sladecek, V.: Rotifers as indicators of water quality. *Hydrobiologia*, **100**, 169-201 (1983).

Smirnov, N.N.: The Macrothricidae of the World. *In*: Cladocera Vol.1 Guides to identification of the microinertebrates of the continental waters of the world (*Ed.*: H. Dumont). SPB Academic Publishing, The Hage, The Netherlands. pp. 1-143 (1992).

Sonneman, J.A., C.J. Walsh, P.F. Breen and A.K. Sharpe: Effects of urbanization on streams of the Melbourne region, Victoria, Australia. II Bentic diatom communities. *Freshw. Biol.*, **46**, 553-565 (2001).

Tirjakova, E.: Micro and meiozoobenthos with focus on ciliates (Ciliophora) of the Gidra River basin. *Acta Zool. Univ. Comen.*, **45**, 29-40 (2003).

Walsh, C.J.: Urban impact on the ecology of receiving waters: A framework for assessment, conservation and restoration. *Hydrobiologia*, **431**, 107-114 (2000).

Yongpisanphop, J., M. Kruatrachue and P. Pokethitiyook: Toxicity and accumulation of lead and chromium in *Hydrocotyle umbellata. J. Environ. Biol.*, **26**, 79-89 (2005).

Zar, J.H.: Biostatistical Analysis. Prentice Hall International Ed. Upper Saddle River, NJ, USA (1996).