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PRIMARY RESEARCH PAPER

Environmental significance of freshwater mollusks in the Southern Pampas, Argentina: to what detail can local environments be inferred from mollusk composition?

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Abstract The aim of the present contribution is to assess whether the abundance of mollusk species in the Southern Pampas (Argentina), an environmentally homogeneous region, reflect the local conditions of water bodies. In order to test this hypothesis, a comprehensive study was conducted in 30 sites regularly distributed across the region. At each site, the abundance of mollusk species was determined, and a series of physico-chemical measurements taken. Principal Component Analysis (PCA) and Cluster Analysis (CA) were used for the ordination of sampling sites based on the measured environmental variables. In addition, Canonical Correspondence Analysis (CCA) was conducted to explore the relationships between environmental variables and mollusk abundances. Mollusk species were represented by the gastropods *Biomphalaria peregrina, Chilina parchappii, Heleobia parchappii*, *Physa acuta*, *Pomacea canaliculata, Stenophysa marmorata, Uncancylus concentricus* and the bivalve *Musculium argentinum*. Although aquatic vegetation cover, conductivity, and substrate were among the main parameters influencing mollusk distribution, their effect was insufficient to explain the spatial distribution pattern of the species in a regional scale. It is because the Southern Pampas is a very homogeneous area, and the ranges of these environmental conditions are within the range of ecological tolerance of most of the species represented. Yet, some species resulted good indicators of environmental conditions at local (microhabitat) scale, i.e., particular microhabitats that occur in different water bodies as well. In fact, even distributed in many different water bodies along the Southern Pampas *C. parchappii* is always linked to lotic environments, and *U. concentricus* is exclusively restricted to hard substrata. On the other hand, *H. parchappii* is the only species represented in mesohaline waters and *P. acuta* appeared to be a good indicator of pollution in the area.

Keywords Freshwater mollusks · Buenos Aires · Argentina

Introduction

There are several species of freshwater mollusks that are widely known for being good bioindicators of environmental conditions. At least a dozen studies over the last 30 years have returned strong positive correlations between the abundance and/or diversity of freshwaters mollusks and water-quality variables (Dillon, 2000). In Argentina, the study of freshwater mollusks has been developed for more than

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120 years. However, the knowledge on ecological aspects of the main species has not advanced much. In fact, studies were limited in most cases to species mentions in discrete localities without an integrated vision that allow understanding the origin and patterns of species diversification (del Río et al., 2007). Only recently, studies on distributional ecology of freshwater mollusks have been initiated in the semiarid region of Mendoza, central-western Argentina (Ciocco & Scheibler, 2008; De Francesco & Hassan, 2009). These studies indicated that mollusks are good bioindicators to infer the presence of environments that differ in their water dynamics (lentic vs. lotic systems) and conductivity.

At present, there is scarce ecological information on how mollusk assemblages vary among freshwater systems from homogeneous, humid areas such as those of the Southern Pampean region. Although for some species of economic and medical importance such as *Biomphalaria peregrina* (Rumi, 1986, 1991) and *Pomacea canaliculata* (see Martín et al., 2001; Estebenet et al., 2006, and references therein) there is abundant ecological information, a comprehensive distributional study encompassing the total malacofauna inhabiting this region has not been performed yet. The scarce distributional studies conducted on the whole malacofauna present in freshwater Pampean systems were exclusively restricted to fluvial environments (Martín, 1998) not having information at present on how mollusks distribute in shallow lakes.

The aim of the present contribution is to assess whether the abundance of mollusk species in the Southern Pampas (Argentina), an environmentally homogeneous region, reflect the local conditions of water bodies.

Study area

The Southern Pampas are located in the Buenos Aires province (Argentina) and are characterized by plains that are interrupted by two small mountain systems, the Tandilian (500 m) and Ventanian (1,100 m) ranges. Overall, the climate is temperate humid with a mean annual temperature of 16.4°C. The Southern Pampas are delimited by the isohyets of 800–900 mm in the east and 500–600 mm in the west. Due to the gentle slope of the region, running waters have a similar slow current velocity (between 6 and 25 cm s^{-1}; Feijoó & Lombardo, 2007). The most depressed areas of the Pampas plains usually develop permanent or temporary shallow lakes. These particular types of lakes called "lagunas pampeanas" are very shallow and lack thermal stratification except for short periods of time. In addition, they are eutrophic water bodies with highly variable salinity content (Quirós & Drago, 1999).

Materials and methods

Field sampling

Between April and May 2008, a total of 30 sites were surveyed in the southeastern Buenos Aires Province (Fig. 1). The sites were chosen to represent the maximum heterogeneity in water bodies from the area. As this area is characterized by numerous streams and a less number of shallow lakes, a higher number of streams were sampled. Rivers, shallow lakes, and streams were sampled once. All samples were obtained simultaneously to avoid variation due to seasonal effects.

Water temperature, depth, pH, and conductivity were recorded at each sampling site with field instruments. Aquatic vegetation cover was estimated visually and a nominal variable erected for statistical purposes (0 = no vegetation, 1 = low vegetation cover, and 2 = very high vegetation cover). Water samples were collected in polyethylene bottles and stored in ice chest until they were transported to the laboratory. In addition, one sediment bulk sample per site (0.5 kg) was taken for grain size analysis, humidity, and organic content.

Living mollusks were searched among the submerged vegetation, under stones, and on the substratum. Mollusks were collected both manually (picking up by hand) and with the aid of sieves (0.5 mm). Sampling was carried out for time of effort (number of snails caught per hour) following Martín et al. (2001), and conducted by the same person to avoid sampling bias.

Laboratory analyses

Water samples were analyzed for chemical parameters within 2 days from collection. Chemical data

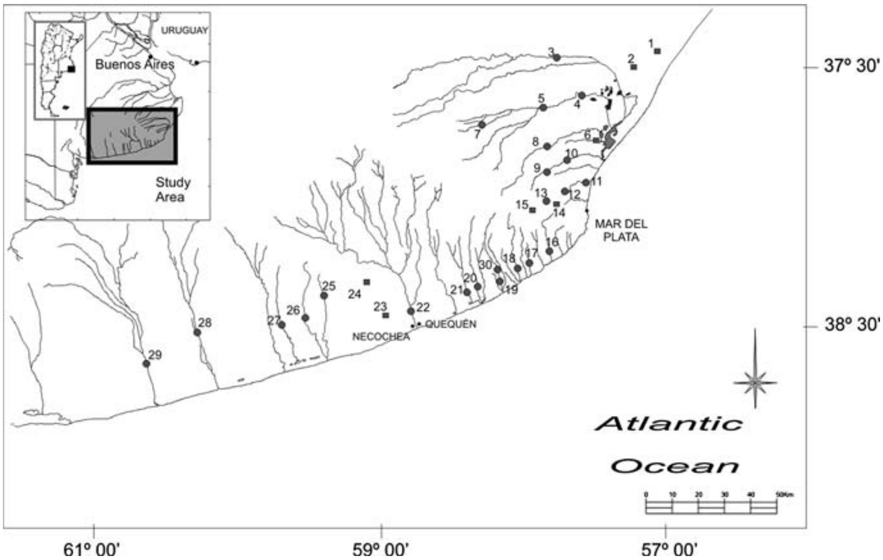

Fig. 1 Location map of study sites in the Southeastern Buenos Aires Province. Circles represent lotic water bodies and squares indicate lentic ones

included nitrate (NO_3^-), sulfate (SO_4^{2-}), chloride (Cl^-), fluoride (F^-), phosphate (PO_4^{-3}), carbonate (CO_3^{-2}), bicarbonate (HCO_3^-), magnesium (Mg^{+2}), calcium (Ca^{+2}), and silica (SiO_2). Chemical analyses were performed applying standard methods: chloride following the Mhor method, sulfate by turbidimetry, calcium, and magnesium by complexometric titrations with EDTA, sodium, and potassium by flame spectrometry, silica by means of the silicomolibdate method, fluorine by the zirconyl chloride method, and nitrate by the brucine method (APHA, 1992).

Sediment characteristics included the presence of stones ("tosca", artificial boulders, gravel) and grain size, which was analyzed by using the dry-sieving technique of Folk (1968). Categories of grain size included coarse sand (>500 μm), medium sand (250–499 μm), fine sand (125–249 μm), very fine sand (62–124 μm), and mud (silt and clay, <62 μm). Additionally, the organic content of each sample was estimated using the loss-on-ignition method (LOI; for 4 h at 550°C) and water content was calculated by drying the sediment for 24 h at ca. 105°C (Heiri et al., 2001).

Mollusk species were identified using external (shell) and internal (soft parts) morphology, and counted. Mollusk identification was based on de Castellanos & Fernández (1976), Gaillard & de Castellanos (1976), Fernández (1981a, b), de Castellanos & Gaillard (1981), Rumi (1991), and de Castellanos & Landoni (1995).

Data analysis

Standard product-moment correlation analyses were conducted to identify strongly intercorrelated environmental variables, permitting some of them to be omitted from subsequent statistical analyses at $P < 0.01$. Environmental data were log transformed, as $\log(x + 1)$, to meet the assumption of normality and homoscedasticity, except for aquatic vegetation cover.

Ordination of samples was performed using Principal Components Analysis (PCA). Cluster Analysis (CA) based on Euclidean similarity measure was used to group sites recording similarity in environmental parameters. These analyses were run with the program PAST ver. 1.81 (Hammer et al., 2008). The clusters defined by CA were marked on the PCA ordination plot.

Canonical Correspondence Analysis (CCA) was used to elucidate the relationships between mollusk abundances and environmental variables. The CCA was performed using CANOCO 4.0 (ter Braak & Šmilauer, 1998). A series of partial CCAs, run with one explanatory variable at a time, was used to separate the total variation in mollusk abundance into components that represent the unique contributions of individual environmental variables (Bocard et al., 1992). The statistical significance was assessed by unrestricted Monte Carlo tests (full model) involving 999 permutations at $P \leq 0.001$.

Results

The sampled streams and lakes were very shallow (<1 m), and characterized by alkaline (pH 8.19–9.80) and very hard (96.5–743 mg l^{-1} $CaCO_3$) waters. In general, conductivity increased from NE to SW, ranging from 0.5 to 4.3 mS cm^{-1}. However, two of the lakes located northwards (sites 1 and 2) showed high conductivities (~6 mS cm^{-1}) as well as the highest hardness values (~700 mg l^{-1} $CaCO_3$). All the water bodies sampled showed very high nutrient concentrations, ranging, in general, from eutrophic to hypereutrophic. Most shallow lakes showed only nitrate traces (below 0.5 mg l^{-1}), whereas streams exhibited higher concentrations (up to 39.8 mg l^{-1}). Phosphates, on the other hand, were very variable, ranging between 0 and 1.5 mg l^{-1}, although most of the sites showed values between 0.15 and 0.3 mg l^{-1} (Table 1).

Mollusks were present in 29 out of the 30 sampling sites sampled. The unique site lacking mollusks was Laguna Salada (S24). A total of 1,708 specimens belonging to 8 species (7 gastropods and 1 bivalve) were recorded. The gastropod species were represented by *B. peregrina* (d'Orbigny, 1835), *Chilina parchappii* d'Orbigny, 1835, *H. parchappii* (d'Orbigny, 1835), *Physa acuta* (Draparnaud, 1805), *P. canaliculata* (Lamarck, 1822), *Stenophysa marmorata* (Guilding, 1828) and *Uncancylus concentricus* (d′Orbigny, 1835). The bivalve was represented by *Musculium argentinum* (d′Orbigny, 1835) (Fig. 2).

Aquatic vegetation was dominated by macrophytes such as *Ludwigia* sp., *Hydrocotyle* sp., *Potamogeton* sp., *Ceratophyllum* sp., *Myriophyllum* sp., *Lemna* sp., *Ricciocarpus* sp., *Azolla* sp., and *Wolffia* sp. Also, algae belonging to the orders Ulvales (*Enteromopha*) and Charales were present.

The specific richness varied between 1 and 3, except for site 10 in which it was 5. The most widely distributed and abundant species in the studied area was *H. parchappii*, being found even in sites with high conductivity (Table 1). This species was recorded in sediments and on the submerged vegetation. The bivalve *M. argentinum* was recorded for the first time in the area, at low abundance. This is an infaunal bivalve that was recorded buried within the first centimeters below the sediment–water interface.

The standard product-moment correlation analysis of environmental data was useful to reduce the 24 variables measured (Table 1) to 15. Humidity showed a significant positive correlation ($r > 0.55$) with LOI, fine sand, very fine sand, and mud. Medium sand and coarse sand were correlated with fine sand ($r = 0.62$, $r = 0.81$, respectively). Very fine sand was correlated with mud ($r = 0.76$) and F^- ($r = 0.47$). CO_3^{2-} was correlated with pH ($r = 0.50$). Cl^- was positively correlated with hardness ($r = 0.58$), SO_4^{2-} ($r = 0.60$), and Mg^{2+} ($r = 0.56$), and negatively with NO_3^- (r = −0.51). Hardness and Mg^{2+} were correlated with Ca^{2+} ($r = 0.69$, $r = 0.55$, respectively) and F^- with HCO_3^-($r = -0.48$). Therefore, the reduced matrix included LOI, stones, fine sands, mud, pH, conductivity, temperature, depth, Ca^{2+}, PO_4^{3-}, SO_4^{2-}, NO_3^-, HCO_3^-, SiO_2, and aquatic vegetation cover. Choice was made taking into account the variables that were more relevant to mollusk physiology and ecology.

Four groups were defined according to CA (Fig. 3A). The first group was represented only by site S30 (Arroyo de la Tigra II) and was early separated from the other groups, which was possibly due to the presence of artificial substrata (that was absent in the other sites). The second group was represented by saline shallow lakes (Laguna La Salada Grande S1 and La Salada S24). The remaining sites were clustered in two main groups that are differentiated by substrata (soft vs. hard substrata) and aquatic vegetation cover (no vegetation, low, or very high aquatic vegetation cover). The first two components of the PCA explained 63% of variation in the data (Fig. 3B). The first component explained 37.7% of the total variance and was highly positively correlated with aquatic vegetation cover ($r = 0.76$) and negatively with hard substrata ($r = -0.52$). The second component explained 24.5% of the total variance and exhibited high positive correlation with hard substrata ($r = 0.64$) and vegetation cover ($r = 0.48$) and a negative correlation with SO_4^{2-} ($r = -0.40$). Therefore, the first component represented a gradient of vegetation cover. In fact, the sites located on the right side of the plot were more vegetated than those located on the left side. The second component differentiated sites with hard substrata (top) from those having soft substrata (bottom). The presence of artificial boulders in site 30 may be the main reason why this site appeared to be clustered alone. This site was located just below a bridge, and the boulders represented the remaining of

Table 1 Values obtained for environmental variables in the 30 sampling sites

Sitio	Hum	LOI	Stone	CS	MS	FS	VFS	Mud	T	Cond	pH	Depth	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Hard	Ca^{2+}	Mg^{2+}	SiO_2	NO^{3-}	F^-	PO_4^{3-}	Veg
1-Lag Salada Grande	40.78	1.35	0.40	0.63	2.13	8.35	43.96	44.49	19.7	5.98	8.96	40	0	673.0	1680.5	158.2	743.0	38.1	155.40	3.53	0.50	2.06	0.14	0
2-Lag Los Horcones	55.77	88.69	0.40	0.63	2.13	8.35	43.96	44.49	19.2	5.90	8.98	50	0	820.0	1661.0	95.0	687.2	31.8	145.80	6.46	0.50	3.60	0.59	2
3-Arroyo Chico- R2	64,64	5.12	0.03	0.05	0.47	14.12	25.47	59.82	19.4	0.87	9.05	25	0	857.5	78.4	16.3	245.3	35.4	37.60	29.50	1.45	1.84	0.04	2
4-Arroyo Grande-SI	32.41	3.50	48.10	0.08	1.41	6.17	11.23	32.99	18.1	1.13	8.99	90	0	698.2	104.6	33.0	167.0	22.7	26.40	34.00	13.43	2.15	0.20	2
5-Arroyo Grande SII	49.07	6.85	48.17	0.82	1.99	8.32	19.46	21.21	14.3	0.91	8.77	55	0	808.5	75.4	24.2	261.6	24.6	50.40	50.50	11.00	0.78	0.17	0
6-Lag Nahuel Rucá	83.63	31.97	2.65	3.73	13.14	23,76	40.03	16.65	15.4	1.16	8.60	60	0	502.0	157.0	81.8	255.0	30.0	43.20	7.22	0.50	3.32	0.50	1
7-Arroyo Grande SIII	32.41	3.50	48.10	0.08	1.41	6.17	11.23	32.99	17.2	0.46	8.67	80	0	539.0	101.3	0.5	200.0	24.5	33.30	31.20	17.16	2.00	0.08	2
8-Arroyo El Pantanoso	52.29	6.56	50.29	0.59	0.36	1.59	27.14	20.01	15.0	1.05	8.56	45	0	820.7	88.0	53.4	223.0	21.1	40.80	48.40	39.80	1.70	0.76	0
9-Arroyo del Junco	61.91	12.80	0	3.51	9.50	14.54	31.06	41.36	14.6	0.82	8.49	45	0	722.7	88.0	20.7	214.6	23.5	37.40	44.30	13.27	1.55	0.29	1
10-Arroyo Dulce	41.76	6.41	0.17	0.95	1.02	7.06	48.08	42.70	14.1	0.95	8.65	50	0	771.7	110.0	40.0	295.4	35.8	49.40	44.50	1.74	0.99	0.24	0
11-Arroyo los Ortiz	32.28	4.69	0.70	0.60	0.47	1.36	42.80	54.04	14.3	1.01	8.65	40	0	1384.2	81.6	24.6	201.0	19.9	36.30	68.50	4.73	1.39	0.06	1
12-Arroyo Vivoratá	49.81	9.98	52.65	0.79	0.83	4.55	20.22	20.93	13.2	1.17	8.75	20	0	906.5	75.4	20.4	229.3	23.5	41.00	70.30	24.85	0.96	0.20	0
13-Arroyo el Peligro	48.43	5.00	50.15	0.29	1.20	2.66	19.64	26.05	16.9	0.70	8.45	35	0	379.0	58.8	4.6	245.0	15.4	49.56	13.70	14.68	2.35	0	2
14-Lag La Brava	29.72	0.44	0.07	0.25	0.54	1.32	64.34	33.45	17.4	0.65	9.12	45	0	514.0	68.6	6.3	096.5	12.7	15.54	3.58	0.50	2.36	0	1
15-Lag Los Pinos	57.10	14.91	0.34	1.63	4.06	20.51	43.45	29.98	20.3	1.06	8.25	15	0	673.0	137.3	2.5	173.8	17.2	31.30	22.10	0.50	0.76	0.14	2
16-Arroyo La Totora	39.95	9.20	4.69	4.66	6.55	25.64	35.43	22.99	13.8	1.34	8.39	20	0	165.7	292.2	11.1	297.0	49.0	41.80	6.83	5.41	2.53	3.50	2
17-Arroyo La Ballenera	28.51	5.12	49.46	0.09	0.15	2.01	24.67	23.60	16.1	1.22	8.38	25	0	1041.2	94.2	52.6	177.2	17.3	32.08	53.24	17.67	2.10	0.03	0
18-Arroyo La Carolina	49.29	6.28	0	0.15	0.59	7.06	32.25	59.93	16.9	1.23	8.77	15	0	1200.0	185.3	62.1	171.5	20.0	29.10	433.4	11.00	2.66	0.02	2
19-Arroyo de la Tigra SI	59.23	15.48	46.73	2.25	4.09	6.01	18.56	18.28	16.8	1.63	8.19	30	0	1445.5	286.0	38.3	165.8	24.5	26.00	30.60	0.50	0	0.17	2
20-Arroyo El Pescado	38.47	8.08	1.48	5.15	4.56	13.12	42.62	33.05	18.7	0.81	8.77	40	0	833.0	125.6	31.0	220.0	19.0	41.40	26.00	20.00	2.44	0	2
21-Arroyo Malacara	40.02	6.84	1.06	0.83	1.02	11.68	44.01	41.37	20.5	1.03	8.56	40	0	1139.2	147.6	54.1	217.0	24.5	37.40	23.20	6.60	1.44	0.05	2
22-Rio Quequen Grande	42.13	6.53	51.08	3.83	3.08	10.41	20.64	10.92	15.7	1.06	7.83	35	0	820.0	180.0	121.0	183.0	19.0	32.50	29.30	20.50	0	0.10	1
23-Lag Tupungato	s/d	s/d	s/d	s/d	s/d	s/d	s/d	s/d	14.4	1.04	8.95	20	0	710.5	190.0	28.3	221.5	24.5	38.40	21.00	14.11	1.03	0.08	2
24-Lag La Salada	31..25	4.72	5.91	1.78	0.83	9.52	34.13	47.76	22.8	5.93	9.80	15	2082.5	2597.0	1118.4	320.0	124.0	15.4	20.50	9.77	0.50	0	1.67	0
25-Arroyo Zabala	21.74	0.75	2.69	1.26	0.92	24.06	54.70	16.33	14.5	1.49	9.13	30	0	906.5	209.2	148.0	266.0	21.8	50.70	43.00	11.30	2.60	0.14	2
26-Arroyo Cortaderas	47.98	6.75	0.39	4.22	6.56	14.69	28.79	45.32	11.4	2.20	9.02	35	0	1041.2	353.0	339.0	350.0	56.3	50.20	42.00	11.50	1.85	0.13	1
27-Arroyo Seco	41.01	5.94	2.34	1.46	1.55	18.48	45.85	30.28	11.3	1.28	9.22	55	0	1004.5	186.3	77.8	220.0	34.5	32.10	25.70	13.77	2.53	0.17	2
28-Arroyo Claromecó	42.75	2.71	51.09	0.62	2.23	7.77	26.04	12.21	12.9	1.48	8.88	35	0	857.5	255.0	148.0	230.0	31.0	36.60	43.10	13.50	2.71	0.25	1
29-Rio Quequen Salado	34.94	5.89	2.05	3.17	2.43	9.14	49.54	33.64	14.4	4.30	8.96	35	0	931.0	1076.0	107.0	671.3	40.0	137.10	45.80	0.50	2.68	0.15	1
30-Arroyo De la Tigra SII	0	0	100.00	0	0	0	0	0	16.8	1.63	8.19	10	0	1445.5	286.0	38.3	165.8	24.5	26.00	30.60	0.50	0	0.17	0

Hum Humidity (%); LOI (organic content) (%); Stone, *CS* Coarse Sand; *MS* Medium Sand; *FS* Fine Sand; *VFS* Very Fine Sand, Mud. Categories of grain size are expressed in %. *T* Water temperature (°C); *Cond* conductivity (mS cm^{-1}); Depth is expressed in cm; *Hard* Hardness (mg l^{-1} of $CaCO_3$); Concentrations of ions are expressed in mg l^{-1}; *Veg* Vegetation cover

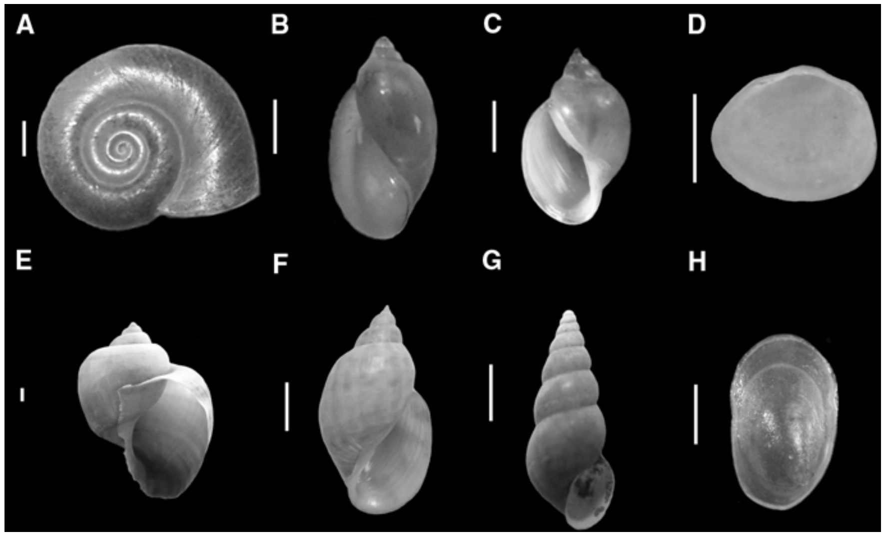

Fig. 2 Shells of the mollusk *taxa* identified in the Southeastern Buenos Aires Province. **A.** *B. peregrina.* **B.** *S. marmorata.* **C.** *P. acuta.* **D.** *M. argentinum.* **E.** *P. canaliculata.* **F.** *C. parchappii.* **G.** *H. parchappii.* **H.** *U. concentricus*. Scale bars: 2 mm

the construction. The saline shallow lakes were located on the left bottom side of the PCA plot. These shallow lakes were characterized by high conductivity, which may have prevented the development of vegetation.

The ordination of species based on CCA (Fig. 4) showed that 77% of the variance was explained by the selected variables. The unrestricted Monte Carlo test for all canonical axes was significant at $P = 0.017$. Partial CCAs showed that the total explained variance was mainly composed of fine sands (14.4%), SO_4^{2-} (11.1%), mud (10.6%), depth (7.6%), HCO_3^- (7.4%), hard substrata (6.9%), PO_4^{3-} (6.4%), NO_3^{2-} (6.3%), and vegetation cover (6.0%). The remaining variables explained 17.9% of the variance. The first two axes of the CCA accounted for 43.2% of variation in species composition and 56.1% of the species–environment relationship. The species–environment correlations of CCA axis 1 ($r = 0.98$), and axis 2 ($r = 0.87$) were high and indicated a strong relationship of species to environmental variables (Tables 2, 3).

The biplot of species and environmental variables related *P. canaliculata* and *B. peregrina* to vegetation cover. The abundance of *H. parchappii* was related to fine sands, mud, pH, Ca^{2+}, and conductivity. *Chilina parchappii* was restricted to hard substrata. Although *M. argentinum* was found at the same sites where *C. parchappii* occurred it was always restricted to zones where soft sediments accumulated. It was always found at very low abundance (one or two individuals per sampling unit). *Uncancylus concentricus* was recorded at very low abundance in most sites but only in Arroyo de la Tigra II (S30) exhibited high abundance. *Stenophysa marmorata* was only present in Arroyo El Peligro (S13), on hard substrata, and abundant aquatic vegetation. Except for one individual found in Arroyo Grande II (S5), *P. acuta* was abundant in sites with high values of NO_3^- and PO_4^{3-} (Arroyo El Pantanoso S8).

Discussion

The main parameters affecting mollusk distribution were aquatic vegetation cover, conductivity, and substrate. Depth, substrate, flow, and vegetation have been mentioned as important variables in explaining snail distribution. Evidence suggested that the snails are attracted to the macrophytes as sources of food, substrate, and even as effective buffers of current velocity (see Dillon, 2000 and references therein). Pulmonate snails are primarily adapted to calmer waters, with few species inhabiting lotic environments, their occurrence in rivers restricted to calm backwaters and eddies (Dillon, 2000). Most species were present both in lentic and lotic environments. It may be consequence of the environmental similarity exhibited by the water bodies of the Pampean region, which is related to the low scope of the basin. In fact, both lotic and lentic habitats have low current velocity and high vegetation cover. Only one site, La Salada (S24), did

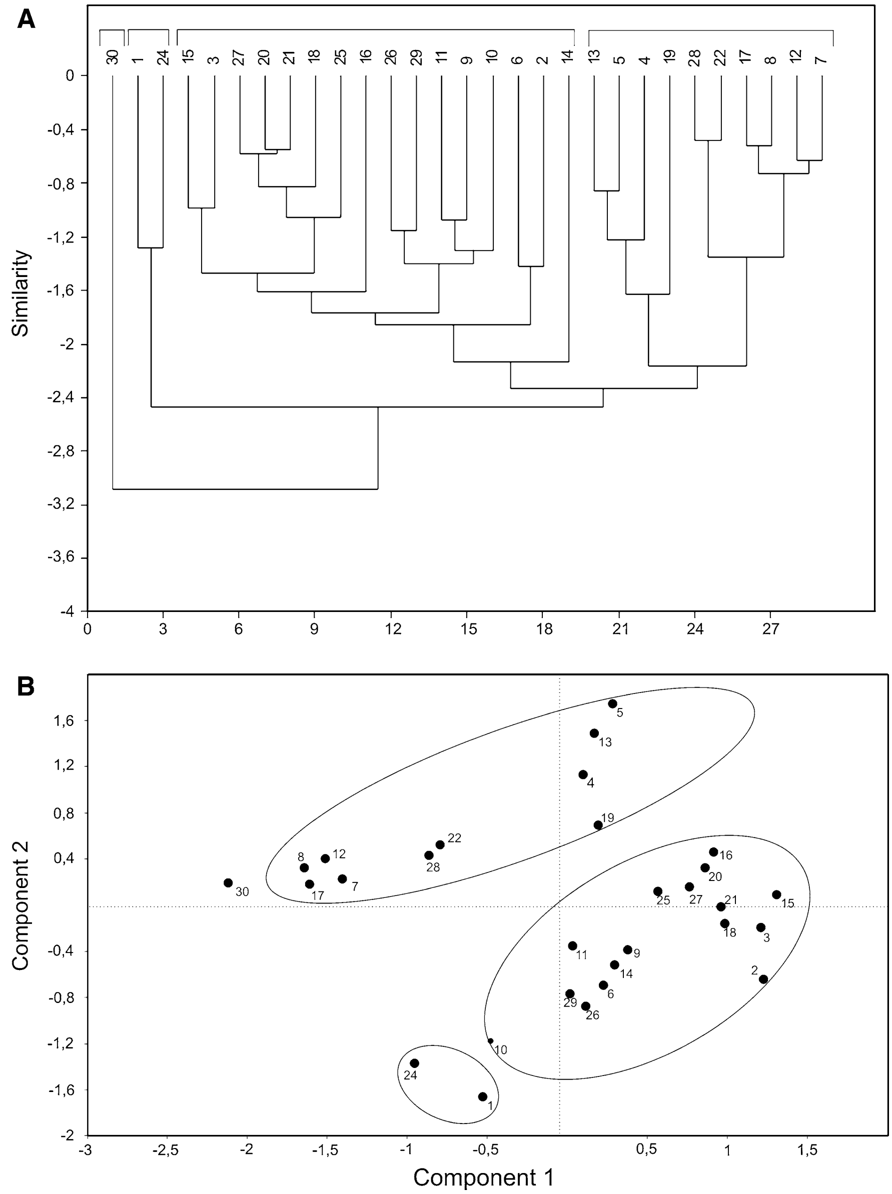

Fig. 3 **A**. Cluster Analysis (CA) for sites. **B**. Principal component analysis (PCA): plot for sites

not have any mollusk species at all, which might be due to the high levels of carbonates (2082.5 mg l^{-1}) and bicarbonates (2,597 mg l^{-1}) not recorded in any other site. Although in the present study *P. acuta* and *S. marmorata* were exclusively linked to lotic environments, it is known that they also occur in lentic habitats from the area (González Sagrario, pers. comm.).

Heleobia parchappii is a species of wide distribution in Argentina, abundant in the Pampean Region (Gaillard & de Castellanos, 1976; de Castellanos & Landoni, 1995). Despite being very widespread in freshwater environments, the species can develop and maintain stable populations in brackish waters with mean salinity values between 17 and 23‰ (De Francesco & Isla, 2004). The relationship between *H. parchappii* and conductivity has also been demonstrated by Martín (1998), Peretti (2005), De Francesco (2007), Ciocco & Scheibler (2008), and De Francesco & Hassan (2009). Accordingly, in the present study, the CCA showed that conductivity influences the distribution of *H. parchappii* in the Southern Pampas. In fact, it was the unique species represented in sites with conductivity levels higher than 1.7 mS cm^{-1}. Similarly, Peretti (2005), Ciocco

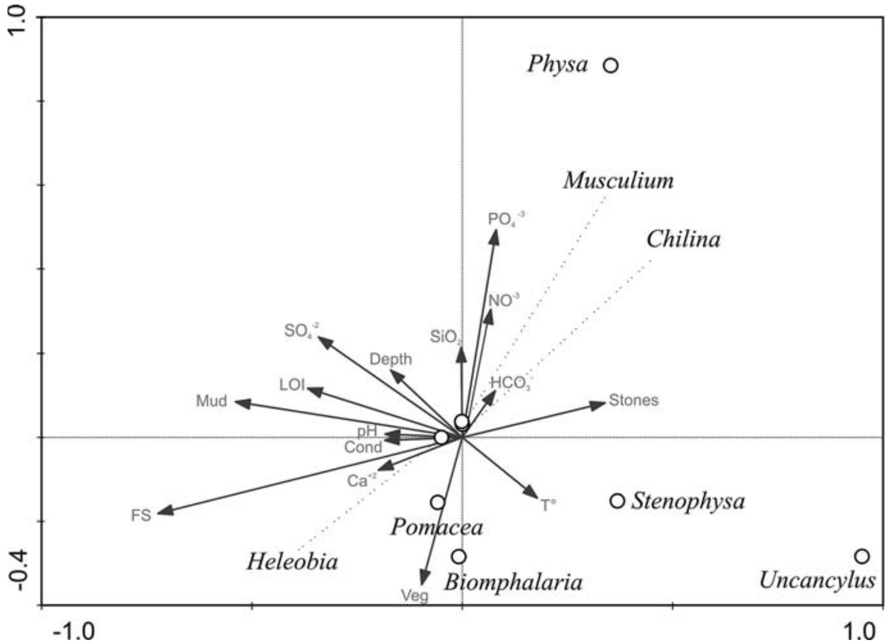

Fig. 4 Canonical correspondence analysis (CCA) ordination plot showing the relationship between species (*white circles*) and environmental variables (*arrows*)

& Scheibler (2008), and De Francesco & Hassan (2009) also found this species inhabiting alone in saline lakes from La Pampa, and Mendoza Provinces. Therefore, the presence of *H. parchappii* without any other coexisting species may be indicative of mesohaline waters.

Despite their different life habits, *M. argentinum* was found at the same sampling sites than *C. parchappii*. The coexistence of these two species could be explained by the spatial heterogeneity of the sites, where accumulation of soft sediments, presence of hard substrates, and patchy vegetation were common. In Argentina, different species of the genus *Chilina* are found in low turbidity waters of temperate and temperate-cold areas. Particularly, *C. parchappii* lives attached to stones, rocks, aquatic plants, and also on mud substrata (de Castellanos & Gaillard, 1981). Many authors pointed out the preference of *Chilina* for rocks or stones as substrata. However, they also observed snails crawling over muddy–sandy substrata as well as on submerged macrophytes. In fact, stones and stems are the preferred sites for oviposition of *C. parchappii* (Martín, 1998). Moreover, the distribution of *C. parchappii* appears to be limited by its physiological regulatory capability in poor mineralized waters as well as by its need of an adequate substrate for oviposition (Martín, 1989). The results obtained here support previous interpretations. The species is recorded in streams with hard substrata and is absent in lentic water bodies having soft substrata as well as in mesohaline waters.

Biomphalaria peregrina develops abundant populations, preferably in lentic waters with submerged vegetation (Rumi, 1991). The relationship of this species to vegetation may be explained by the fact that these plants reduce the current velocity, supply oxygen, and absorb toxic substances. In addition, they are suitable substrata for oviposition and feeding due to the periphyton growing on the macrophytes (Van Schayck, 1985). This snail shows reotaxis to plant chemical stimuli and is capable of following concentration gradients (Martín, 1998). Accordingly, the results obtained in the present study (the CCA related these species to aquatic vegetation cover) coincide with these previous findings. The low abundance of *B. peregrina* (as well as *P. canaliculata*) may be explained by the sampling date (fall). As submerged vegetation exhibits lower density in this season, snails may be present in lower abundance as well. It is known that *P. canaliculata* remains buried into the sediment until warmer conditions arise in the water body (Martín et al., 2001).

The preference of Ancylidae for hard substrata has been widely documented. Crawling appears to be

Table 2 Number of captured specimens per species per sampling site

	Heleobia parchappii	*Biomphalaria peregrina*	*Uuncancylus concentricus*	*Musculium argentinum*	*Chilina parchappii*	*Pomacea canaliculata*	*Stenophysa marmorata*	*Physa acuta*
1	28	0	0	0	0	0	0	0
2	92	0	0	0	0	0	0	0
3	68	5	0	0	0	3	0	0
4	4	0	2	1	0	0	0	0
5	96	0	0	0	36	0	0	1
6	3	1	0	0	0	0	0	0
7	0	2	3	0	17	0	43	0
8	0	1	0	0	0	0	0	38
9	65	0	0	0	0	0	0	0
10	145	1	1	2	9	0	0	0
11	2	1	0	0	0	0	0	0
12	33	1	0	1	35	0	0	0
13	13	27	2	0	0	0	0	0
14	5	0	0	0	0	0	0	0
15	0	3	0	0	0	0	0	0
16	0	4	0	0	0	0	0	0
17	5	0	0	0	32	0	0	0
18	50	0	0	0	0	0	0	0
19	0	10	0	1	0	0	0	0
20	14	0	0	0	0	0	0	0
21	4	0	0	0	0	0	0	0
22	147	0	0	1	66	0	0	0
23	20	4	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0
25	11	0	0	0	0	0	0	0
26	7	0	0	0	0	0	0	0
27	0	7	0	0	0	0	0	0
28	179	0	0	0	56	0	0	0
29	267	0	0	0	4	0	0	0
30	0	0	29	0	0	0	0	0

Table 3 Summary statistics for the first two axes of CCA, with the 15 selected environmental factors

CCA axes	Axis 1	Axis 2
Eigenvalues (λ)	0.793	0.670
Species–environment correlation	0.978	0.871
Cumulative % variance		
Of species data	23.4	43.2
Of species–environment relationship	30.4	56.1
Sum of all eigenvalues		3.38
Sum of all canonical eigenvalues		2.61

difficult on fine sediments and requires a significant amount of pedal mucus. *Uncancylus concentricus* has been cited in association with aquatic macrophytes, allochthonous vegetal material, and stones (Martín, 1998). In the present study, the species was recorded on macrophytes *Schoenoplectus californicus* and on artificial boulders. Martín (1989) associated this species to boulders due to the particular morphology of its foot and shell. Therefore, the presence of this species may be indicative of the presence of hard substrata (macrophytes and boulders) in the water body, which is needed to provide them the proper support.

Physa acuta was recorded for the first time in the region (data already published as Tietze & De Francesco, 2008). Only one population of this species was found in the present survey. It was recorded in site 8 (Arroyo El Pantanoso), which was characterized by high values of phosphates and nitrates (Table 1). The remaining snails appear not to be tolerant to such pollution values. In Arroyo Grande SII (S5) only one individual was found. Mouthon (1996) pointed out that *P. acuta* appears to be one of the most tolerant species and Martín (1989) found this snail in two stations near Bahia Blanca city which has significant anthropic impact. The other physiid recorded in the area (*S. marmorata*) was only present in Arroyo Grande SIII (S7), a site that did not differ significantly from other sites. No populations were found, just a few floating individuals that may represent allochthonous components. It is likely that the presence of *S. marmorata* here may be consequence of its great mobility because of its big foot as well as to its flotation ability (Núñez, pers. comm.).

Conclusion

The mollusks species represented in the southeastern Buenos Aires province display a wide range of ecological tolerance, i. e., most species are found in different kinds of water bodies (e. g., *H. parchappii* and *B. peregrina*). It may be explained by the fact that environments have similar environmental characteristics because of the homogeneity of the area. On the contrary, subtle differences in specific microhabitats (which occur in different water bodies as well) can be reliably recognized from the presence of some species. The results obtained in the present study constitute a first step toward a better understanding of the distribution pattern of mollusks in the Southern Pampean region according to the main environmental data.

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