Mollusks (Gastropoda and Bivalvia) of the Multiple-Use Reserve Martín García Island, Río de la Plata River: biodiversity and ecology

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Abstract

The Island of Martin Garcia is located in the Upper Río de la Plata, to the south of mouth the Uruguay River. The aim of the present study was to analyse the biodiversity of the island freshwater mollusks and their relationships to environmental variables. Twelve sampling sites were selected, five were along the littoral section of the island and seven were Inland ponds. Seven major environmental variables were measured: water and air temperature, percentage of oxygen saturation, dissolved oxygen, electrical conductivity, total dissolved solids and pH. Twenty-seven mollusk species were found, *Antillorbis nordestensis*, *Biomphalaria tenagophila tenagophila*, *B. t. guaibensis*, *B. straminea*, *B. peregrina*, *Drepanotrema kermatoides*, *D. cimex*, *D. depressissimum*, *Chilina fluminea*, *C. rushii*, *C. megastoma*, *Uncancylus concentricus*, *Hebetancylus moricandi*, *Stenophysa marmorata*, *Heleobia piscium*, *H. parchappii*, *Potamolithus agapetus*, *P. buschii*, *P. lapidum*, *Pomacea canaliculata*, *P. megastoma*, *Asolene platae*, *Corbicula fluminea*, *Eupera platensis*, *Pisidium sterkianum*, *P. taraguyense* and *Limnoperna fortunei*. UPGMA clustering of species based on their occurrence in different ecological conditions revealed two main species groups. The Canonical Correspondence Analysis suggests that the species distribution is related to the physico-chemical condition of water. Axis two of the ordination diagram displayed the approximately 95.6% of the correlation between species and environmental variables. Dissolved oxygen, conductivity, water temperature and pH showed the highest fluctuations during the sampling period. The species richness (S) showed relationships mainly with water temperature and conductivity. The biodiversity of the gastropods and bivalves from Martín García Island amounts to up to 26 species. Among the Gastropoda, the Planorbidae family made the most sizeable contribution. The Lithogliphidae *P. agapetus* (26.28%) and *P. buschii* (9.50%) showed the highest relative frequencies of occurrence within the littoral environments, while the Planorbidae *D. cimex* (23.83%) and *D. kermatoides* (11.59%) likewise did so in the inland ponds.

Keywords: biodiversity, CCA, ecology, mollusks, Martín García Island.

Moluscos (Gastropoda e Bivalvia) da Reserva Natural de Usos Múltiplos Ilha Martín García, Rio de La Plata: biodiversidade e ecologia

Resumo

A Ilha de Martín García está localizada na parte alta do Rio de la Plata, ao sul da desembocadura do Rio Uruguay. Este estudo tem como objetivo analisar a biodiversidade dos moluscos de água doce da ilha e sua relação com variáveis ambientais. Doze pontos de amostragem foram selecionados: cinco foram ao longo da seção litoral da ilha e sete em lagunas interiores. Sete variáveis ambientais foram medidas: temperatura da água e do ar, porcentagem de saturação de oxigênio, oxigênio dissolvido, condutividade elétrica, sólidos totais dissolvidos e pH. Vinte e seis espécies de moluscos foram encontrados: *Antillorbis nordestensis*, *Drepanotrema kermatoides*, *D. cimex*, *D. depressissimum*, *Biomphalaria tenagophila tenagophila*, *B. t. guaibensis*, *B. straminea*, *B. peregrina*, *Chilina fluminea*, *C. rushii*, *C. megastoma*, *Uncancylus concentricus*, *Hebetancylus moricandi*, *Stenophysa marmorata*, *Heleobia piscium*, *H. parchappii*, *Potamolithus agapetus*, *P. buschii*, *P. lapidum*, *Pomacea canaliculata*, *P. megastoma*, *Asolene platae*, *Corbicula fluminea*, *Eupera platensis*, *Pisidium sterkianum*, *P. taraguyense* e *Limnoperna fortunei*. A análise de agrupamento das espécies com base em sua ocorrência em diferentes condições ecológicas revelou dois grupos principais de espécies. A Análise de Correspondência Canônica sugere que a distribuição das espécies é relacionada com a condição físico-química da água. No eixo dois do diagrama de ordenação apresentado, há cerca de 96% de correlação entre as espécies e as variáveis ambientais. O oxigênio dissolvido, a condutividade, a temperatura da água e pH apresentaram as maiores oscilações durante o período de amostragem. A riqueza de espécies (S) apresentou relações principalmente com a temperatura da água e a condutividade. A biodiversidade de gastrópodes e bivalves da Ilha Martín García é de 26 espécies. Entre os Gastropoda, a família Planorbidae exibe a contribuição mais importante. O Lithogliphidae *P. agapetus*. (26,28%) e *P. buschii* (9,50%) apresentaram as maiores frequências relativas de ocorrência dentro dos ambientes costeiros, enquanto o Planorbidae *D. cimex* (23,83%) e *D. kermatoides* (11,59%) também apresentaram frequências expressivas nas lagunas interiores.

Palavras-chave: biodiversidade, CCA, ecologia, moluscos, Ilha Martín García.

1. Introduction

The Island of Martín García is located in the Upper Río de La Plata River, to the South of the mouth of the Uruguay River (34° 11' 09" S and 58° 15' 09" W). This island is an outcropping of crystalline Brazilian basement and inland, contains both permanent and temporary ponds, some hollows of which having originated in the old basalt excavations and are located in several sectors around the plateau (centre and southern regions of the island). In addition, small temporary ponds are formed in natural depressions, within the marginal forests in regions close to the coasts or at the bottom of sand dunes.

Several recent studies have been published on the biota of the Multiple-Use Reserve Martín García Island – e.g., hydrophyte plants (Lahitte and Hurrell, 1996), vertebrates (Juárez, 1995; Lahitte et al., 1995; Lahitte and Hurrell, 1998), the platyhelminth Temnocephala (Damborenea et al., 1997), aquatic oligochaetes (Armendáriz et al., 2000; Armendáriz and César, 2001), Hirudinea (César et al., 2009), aquatic and semiaquatic insects (Fernández and López Ruf, 1999), ostracod crustaceans (César et al., 2001; César and Liberto, 2008), aquatic mollusks (Rumi et al., 1996; Rumi et al., 2004; Martín and Negrete, 2006; Rumi et al., 2007; Martín, 2008), and terrestrial mollusks (Martín et al., 2009).

The aim of the present study, conducted in the Multiple-Use Reserve Martín García Island, was to analyse the biodiversity of the island freshwater mollusks and their relationships to environmental variables.

2. Material and Methods

The sampling was conducted on eight occasions from 1995 through 1997. Twelve sampling sites were selected: five lay along the littoral section of the island and seven were inland ponds (Figure 1). Specimens were collected with 15 cm diameter and 0.14 mm–mesh-size sieves (captures per unit effort = specimens/30 minutes/person). The mollusks were taken in vivo for identification with a binocular stereoscopic microscope. In the laboratory, the animals were fixed in 70° alcohol and deposited in the Molluscan Collection of the La Plata Museum.

The following physicochemical variables were measured with portable digital sensors: water and air temperature (T °C), dissolved oxygen, percentage of oxygen saturation, conductivity ($\mu s.cm^{-1}$), total concentration of dissolved solids (TDS $mg.L^{-1}$), and the pH.

The relationships between the species and the environmental variables were examined by the Canonical Correspondence Analysis (CCA), upon consideration of the 19 most abundant and frequently occurring species along with 7 environmental variables. Because the temperature of the air and the concentration of dissolved solids contained redundant information (inflation factors >20), these parameters were not considered in the analysis (Ter Braak, 1986; Ter Braak and Verdonschot, 1995; Külköylüoğlu, 2003; 2005; Külköylüoğlu and Dügel, 2004; Maltchik et al.,2010). The mean value of each environmental variable together with data on the species abundance from eight sampling stations were used in the CCA (Kovach, 1998). Associations among the species were analysed by species-clustering analysis (UPGMA) with a Jaccard Index (Crisci and López Armengol, 1983). The species analysed were the same as those used for CCA. Pearson correlation analysis was conducted and the statistical significance of the correlations tested by means of the Student *t*-test.

3. Results

During the sampling period 20 species and 2 subspecies of the Gastropoda were found, belonging to the families Planorbidae, Chilinidae, Physidae, Ancylidae, Cochliopidae, Lithogliphidae, and Ampullariidae along with 5 species of the Bivalvia of the families Corbiculidae, Sphaeridae, and Mytilidae. Table 1 shows the species found at the sites surveyed and their relative frequency.

With respect to the relative abundances of the mollusk species throughout the four seasons (Figure 2), the Planorbiidae family as represented by *Drepanotrema cimex* (Moricand, 1839) was the most frequent and abundant species, with a peak in autumn followed by another in summer and similar, but lower, values during winter and spring. *D. kermatoides* (D'Orbigny, 1835) was not found in the winter, but rather exhibited a peak of abundance in the autumn that declined towards the summer reaching a minimum value in the springs. *D. depressissimum* (Moricand, 1839) showed a peak of abundance in summer but exhibited poor values during the rest of the seasons of the year. *Biomphalaria straminea* (Dunker, 1848) evidenced the highest frequency of occurrence in autumn, lower values in summer and spring, and the lowest representation in winter. *B. tenagophila tenagophila* (D'Orbigny, 1835) displayed a peak of abundance in summer that gradually declined towards autumn and winter and finally became reduced to

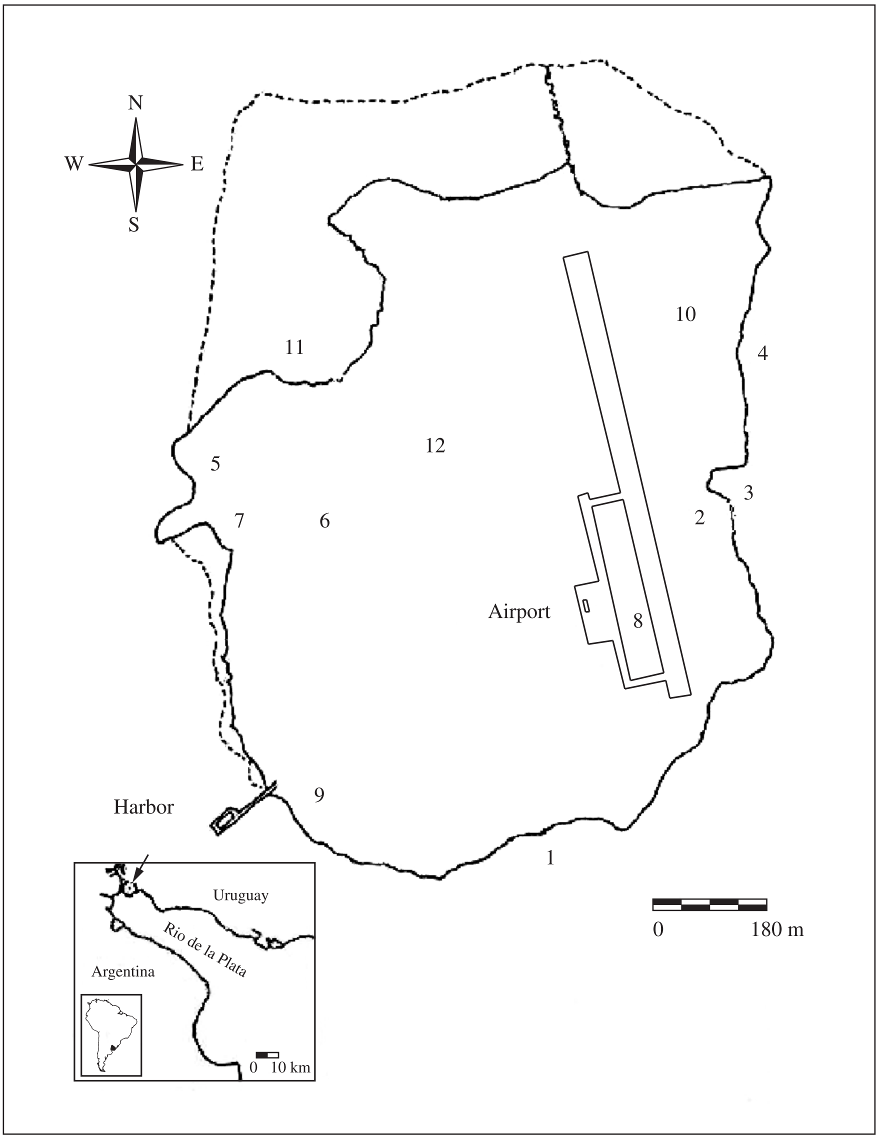

Figure 1. The sampling stations at Martín García Island.

a very low percentage in spring. *B. tenagophila guaibensis* Paraense, 1984 was scarcely found at all, with the highest peak occurring in spring but with minimum values during the rest of the year. *B. peregrina* (D'Orbigny, 1835) passed through a peak of abundance in spring but likewise declined to minimum values in the other seasons. Finally, although *Antillorbis nordestensis* (Lucena, 1954) exhibited a peak of abundance in autumn; the species became scarcely present in winter, but then recovered to give lower values in spring and summer.

The Chilinidae family was represented by three species: *Chilina fluminea* (Maton, 1809) was found throughout the four seasons, with a peak of abundance in summer, followed by high values in autumn and lower but similar values in winter and spring. *C. rushi* Pilsbry, 1911 and *C. megastoma* Hylton Scott, 1958 occurred sporadically, but always with low values of abundance. Both species were found mainly in autumn.

The Physidae family was represented by only one species, *Stenophysa marmorata* (Guilding, 1828) throughout the four seasons of the year, with peak values in autumn that gradually decreased from winter through spring to summer.

The Ancylidae family was represented by two species: *Hebetancylus moricandi* (D'Orbigny, 1837) was found the most frequently with peak values in spring, slightly lower levels in winter and summer, and a minimum representation in autumn. *Uncancylus concentricus* (D'Orbigny, 1835) evidenced a peak of abundance in summer, but gave minimum values in winter.

The Cochliopidae family was represented by *Heleobia piscium* (D'Orbigny, 1835) and *H. parchappii* (D'Orbigny, 1835). The former species showed a peak of

Table 1. Mollusk species with their code and collection sites on Martín García Island during eight samplings.

Species	Code	Site	Freq. %
Antillorbis nordestensis	Anord*	2, 10, 11,12	1.07
Biomphalaria tenagophila	Btena*	2, 5, 9	1.6
Biomphalaria (T) guaibensis	Btguai	5	0.04
Biomphalaria straminea	Bstra*	1, 2, 11	4.00
Biomphalaria peregrina	Bper	5	0.72
Drepanotrema kermatoides	Dker*	2, 5, 7, 9	11.59
Drepanotrema cimex	Dci*	5, 6, 7, 8, 9	23.83
Drepanotrema depressisimum	Ddep*	2	0.15
Chilina fluminea	Chflum*	1, 3, 4	1.41
Chilina rushi	Chru	1	0.39
Chilina megastoma	Chmega	1	0.01
Uncancylus concentricus	Uncon*	1, 2, 3, 4	2.52
Hebetancylus moricandi	Hebemo*	1, 2, 3, 4	2.89
Stenophysa marmorata	Smar*	1, 5, 7, 9	1.81
Heleobia piscium	Hpis*	1, 2, 3, 4	4.98
Heleobia parchapii	Hpar*	1, 2, 6	2.44
Potamolithus agapetus	Poaga*	1, 2, 3, 4	26.28
Potamolithus buschii	Pobu*	1, 2, 3, 4	9.50
Potamolithus lapidum	Pola	1	0.75
Pomacea canaliculata	Pcana*	2, 3, 5, 8	1.08
Pomacea megastoma	Pmega*	1, 2, 3	0.28
Asolene platae	Apla	1	0.01
Corbicula fluminea	Coflu*	1, 4	0.43
Eupera platensis	Eupla	2	0.08
Pisidium sterkianum	Pister	11	0.04
Pisidium taraguyense	Pitar*	2, 5	1.43
Limnoperna fortunei	Lfor*	1, 2, 3, 4	1.21

Frequency (Freq. %) indicates percentage of occurrence of the species as a percentage of the total number of species registered for the entire sample. The asterisk (*) indicates the 19 most frequently occurring species, which group accounts for more than 98% of the total species recorded.

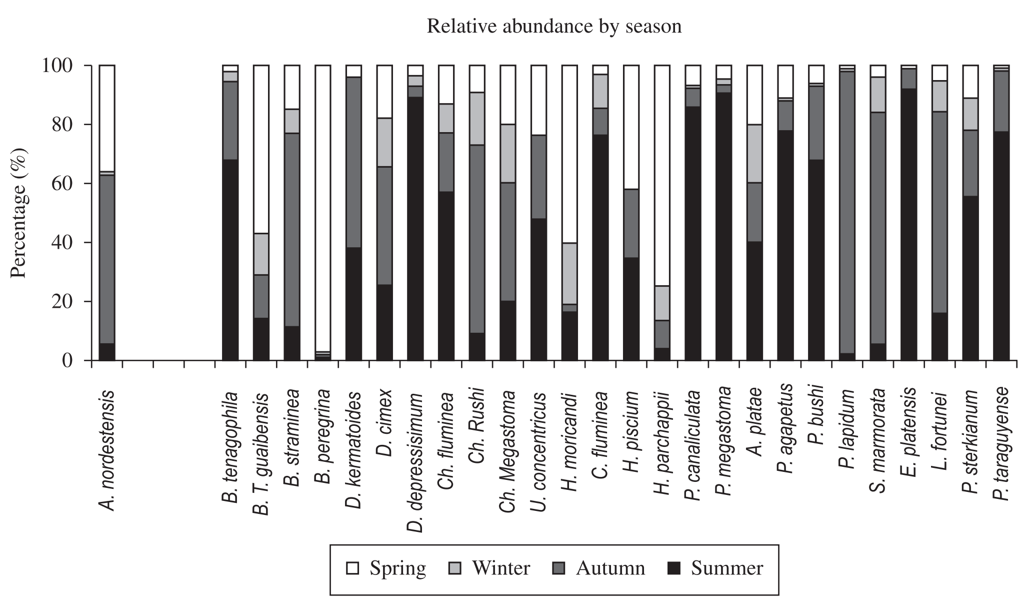

Figure 2. Mollusk relative abundance by season.

abundance in spring, followed by summer, though thereafter a decrease to slightly lower values; whereas no specimens were observed in winter. The latter species was recorded throughout the four seasons, with peak values in spring, minimum levels in summer, and similar intermediate abundances in autumn and winter.

The Ampullariidae family was represented by three species: *Pomacea canaliculata* (Lamark, 1822) was present throughout the year, with maximum values in summer that became minimum in winter, but passed through similar intermediate levels in autumn and spring; *P. megastoma* (Sowerby, 1825) evidenced a higher abundance in summer; while *Asolene platae* (Maton, 1809) passed through a low frequency of occurrence throughout the four seasons of the year.

The Lithoglyphidae family was represented by three species, *Potamolithus. agapetus* Pilsbry, 1911 and *P. buschii* (Fraunfeld, 1865); both with the highest values of relative abundance and presence throughout the sampling period, exhibiting a peak in summer though minimum values in winter. *P. lapidum* (D'Orbigny, 1835) displayed a peak of abundance in autumn, but had a low frequency of occurrence throughout the rest of the seasons.

Within the Bivalvia, the Sphaeridae family was represented: *Eupera platensis* Doello Jurado, 1921, exhibited a peak of abundance in summer that decreased in autumn to pass through minimum values in winter and spring; while *Pisidium sterkianum* Pilsbry, 1897 and *P. taraguyense* Ituarte, 2000 both evinced peak values of abundance in summer. Of the family Corbiculidae, *Corbicula fluminea* (Müller, 1774) exhibited the highest abundances in summer. Finally the family Mytilidae, represented by an invading species, *Limnoperna fortunei* (Dunker, 1857), showed a peak of abundance in autumn but manifested very low values in winter, spring, and summer.

The results from the species-clustering analysis (UPGMA) revealed two main groups of species (Figure 3). The first consisted in *S. marmorata*, *D. cimex*, *D. kermatoides* and *B. (t.) tenagophila*. The second comprised a subgroup composed of *P. canaliculata*, *D. depressissimum*, *H. parchappii*, and *P. megastoma* along with another subgroup composed of *P. agapetus*, *P. bushii*, *L. fortunei*, *H. piscium*, *H. moricandi*, and *U. concentricus*–all of which groupings gave the maximum coefficient of Jaccard: *Ch. fluminea* (J = 0.68) was included in the last group with a lower coefficient along with a third subgroup composed of *P. taraguyense*, *B. straminea*, and *A. nordestensis*.

In the CCA (Figure 4), the arrows depict the environmental variables and designate the maximum variation of the parameter. The length of each arrow is proportional to the significance of the variable in the ordination diagram. DO conductivity water temperature, and pH exhibited the highest fluctuations during the sampling period. The analysis suggests that the distribution of species was associated with the physicochemical conditions of the water. Axis 2 of the ordination diagram accounted for approximately 96% of the correlation between the species distribution and the environmental variables (cf. Table 2).

The dissolved oxygen, pH, and water temperatures were highly correlated among themselves. The electrical conductivity, however, was negatively related to the other physicochemical variables, but displayed a high correlation

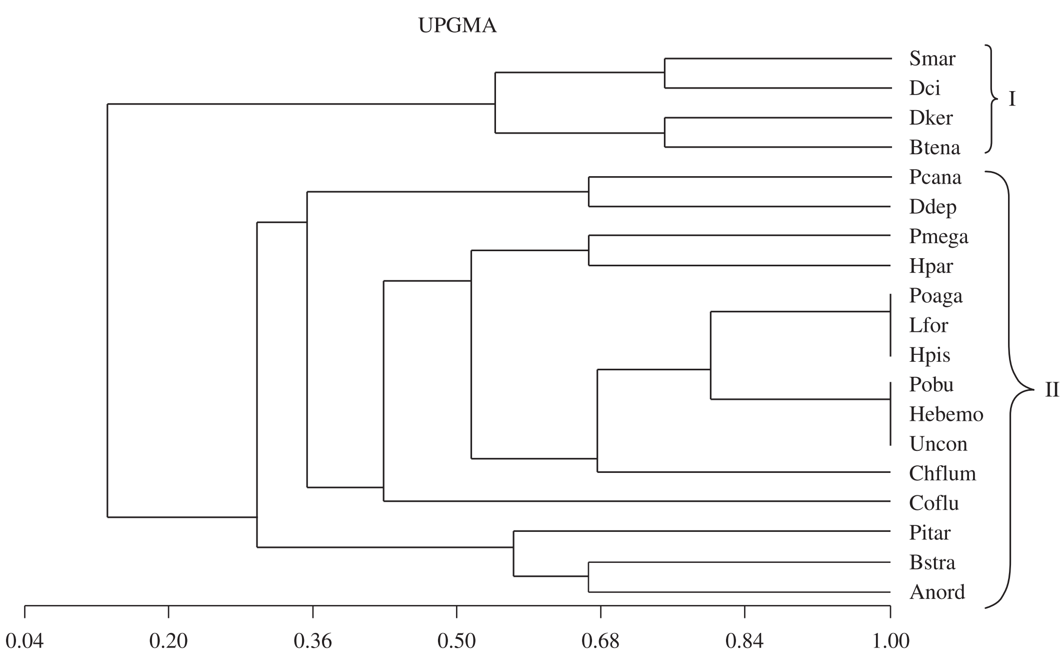

Figure 3. Species-clustering–analysis dendrogram (UPGMA) provided from binary (presence/absence) sampling. Based on their occurrence, two main groups are clustered. The first group comprised *Smar*, *Dci*, *Dker*, *Btena*. The second group comprised *Pcana*, *Ddep*, *Pmega*, *Hpar*, *Poaga*, *Lfor*, *Hpis*, *Pobu*, *Hebemo*, *Uncon*, *Chflum*, *Coflu*, *Pitar*, *Bstra*, and *Anord*.

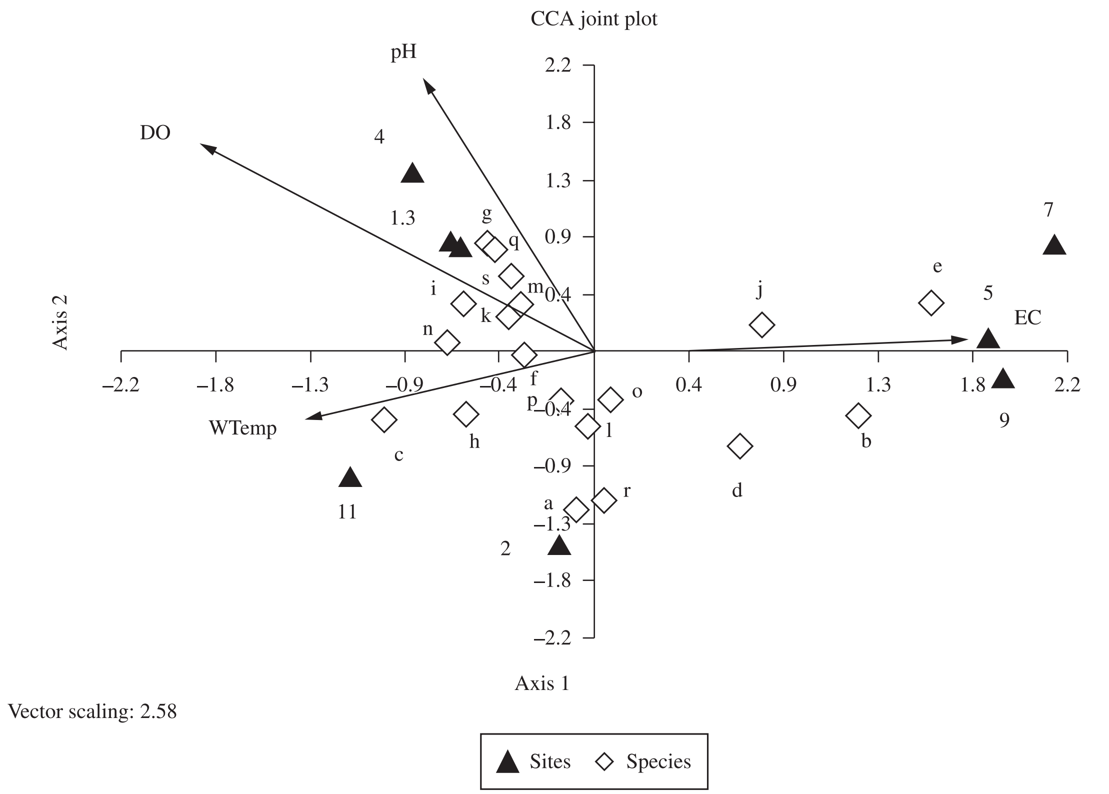

Figure 4. Canonical-correspondence-analysis diagram: nineteen species, and four environmental variables. Abbreviations: a) *A. nordestensis*; b) *B. (t.) tenagophila*; c) *B. straminea*; d) *D. kermatoides*; e) *D. cimex*; f) *D. depressissimum*; g) *Ch. fluminea*; h) *U. concentricus*; i) *H. moricandi*, j) *S. marmorata*, k) *H. piscium*, l) *H. parchappii*; m) *P. agapetus*; n) *P. buschii*; o) *P. canaliculata*; p) *P. megastoma*; q) *C. fluminea*; r) *P. taraguyense*; s) *L. fortunei*. Sampling stations: 1-8.

Table 2. Main results from the canonical-correspondence-analysis (CCA).

	Axis 1	Axis 2	Axis 3
Eigenvalues	0.6440	0.248	0.177
Percentage	37.769	14.525	10.358
Cum. percentage	37.769	52.295	62.653
Cum. constr. percentage	58.387	80.841	96.854
Spec .env. correlations	0.917	0.956	0.862

with certain environments – e.g., Cantera Basural (Site 5); Cantera Grande (Site 9); and to a lesser extent Cantera Tanque (Site 7), the inland ponds on the island.

The water temperature also correlated closely with the relative abundances of the mollusks within the environments – e.g., Puerto Viejo (Site 11) and Cantera Tanque (Site 7) – in the ordination diagram.

The dissolved oxygen and the pH exhibited a high correlation with the environments near the ponds – e.g., Casa Bomba (Site 1), Juncal (Site 4), and Playa de Arena (Site 3) along with the coastal drainage channels of Playa de Arena (Site 2).

With respect to the distribution of the species relative to the environmental variables, none were located at the centre of the ordination diagram. For the pulmonate gastropods (Table 3), the ordination diagram shows that species such as *D. cimex* were positively correlated with high values of conductivity but negatively so with temperature (r = –0.57), DO (r = –0.48) and pH (r = –0.38). Furthermore, in the ordination diagram *S. marmorata*, displayed a satisfactory association with conductivity, water temperature, and DO (r = –0.34); while *C. fluminea* was distributed at medium DO values and pH. *D. kermatoides* exhibited a negative correlation with DO (r = –0.44) and pH (r = –0.63); *B. tenagophila tenagophila*, was negatively associated with DO (r = –0.70); *B. straminea* was negatively correlated with conductivity (r = –0.32), but positively correlated with DO (r = 0.45); while *D. depressissimum* showed an excellent correlation with temperature (r = 0.56); *H. moricandi*, displayed a close positive correlation with DO (r = 0.43), though a negative one with conductivity (r = –0.32); *U. concentricus* was more closely associated

Table 3. Pearson correlations among four environmental variables, total number of species (NS), and the nineteen most abundant species analysed.

	T °C	DO	EC	pH	NS	Anord	Btena	Bstra	Dker	Dci	Ddep	Chflum	Uncon	Hebemo	Coflu	Hpis	Hpar	Pcana	Pmega	Poaga	Pobu	Smar	Lfor	Pitar
T °C	1																							
DO	0.16	1																						
EC	**-0.52	**-0.50	1																					
pH	0.19	**0.64	0.09	1																				
NS	**0.61	0.09	**-0.60	-0.16	1																			
Anord	0.20	*-0.37	-0.18	**-0.59	**0.69	1																		
Btena	0.11	**-0.70	0.22	*-0.41	*-0.34	-0.16	1																	
Bstra	0.02	**0.45	*-0.32	-0.19	0.08	-0.04	*-0.33	1																
Dker	0.18	**-0.44	-0.16	**-0.63	**0.66	1.00	-0.09	-0.08	1															
Dci	**-0.57	**-0.48	0.20	*-0.38	**-0.58	-0.24	**0.56	*-0.37	-0.17	1														
Ddep	**0.56	-0.04	-0.28	0.03	**0.68	**0.65	-0.28	-0.21	**0.64	*-0.36	1													
Chflum	0.08	0.25	-0.27	0.12	*0.42	-0.18	-0.26	0.23	-0.20	-0.29	-0.19	1												
Uncon	0.23	-0.20	-0.28	**-0.57	**0.67	**0.96	-0.26	0.21	**0.94	*-0.35	**0.62	-0.21	1											
Hebemo	0.15	**0.43	*-0.32	0.30	0.19	0.06	-0.29	-0.17	0.03	*-0.34	-0.11	0.00	0.06	1										
Coflu	0.04	0.25	-0.27	0.10	*0.40	-0.17	-0.26	0.23	-0.20	-0.28	-0.26	**0.99	-0.21	0.09	1									
Hpis	**0.62	0.14	*-0.33	0.25	**0.68	*0.41	*-0.34	-0.18	*0.38	*-0.42	**0.94	0.07	*0.38	-0.16	-0.02	1								
Hpar	0.20	*-0.32	-0.26	**-0.57	**0.82	**0.93	-0.23	0.05	**0.92	*-0.32	**0.57	0.19	**0.88	0.03	0.19	0.41	1							
Pcana	*0.37	*-0.39	-0.27	**-0.51	**0.72	**0.95	-0.05	-0.15	**0.96	-0.18	**0.80	-0.23	**0.90	-0.03	-0.25	**0.59	**0.87	1						
Pmega	0.29	*-0.32	-0.23	**-0.49	**0.76	**0.99	-0.20	-0.07	**0.98	-0.30	**0.77	-0.13	**0.94	0.02	-0.15	**0.56	**0.93	**0.98	1					
Poaga	0.13	0.17	-0.29	0.04	**0.53	-0.03	-0.28	0.23	-0.05	*-0.32	-0.03	**0.98	-0.07	-0.10	**0.96	0.20	*0.33	-0.06	0.03	1				
Pobu	0.05	0.27	-0.30	-0.01	*0.42	-0.11	-0.29	**0.47	-0.14	*-0.33	-0.20	**0.96	-0.09	-0.11	**0.95	0.03	0.24	-0.19	-0.08	**0.96	1			
Smar	0.05	*-0.34	-0.22	*-0.37	0.01	-0.26	**0.63	-0.06	-0.21	**0.47	*-0.38	**0.50	*-0.35	-0.27	**0.49	-0.26	-0.06	-0.18	-0.27	**0.47	**0.45	1		
Lfor	0.05	0.19	-0.24	0.05	*0.41	-0.14	-0.23	0.26	-0.16	-0.26	-0.19	1.00	-0.18	-0.08	**0.98	0.06	0.22	-0.20	-0.10	**0.99	**0.97	**0.52	1	
Pitar	0.20	*-0.38	-0.18	**-0.59	**0.69	1.00	-0.15	-0.04	1.00	-0.23	**0.65	-0.18	**0.96	0.06	-0.17	*0.41	**0.93	**0.96	**0.99	-0.03	-0.11	-0.25	-0.14	1

The numbers indicate strong correlations (*p < 0.05, **p < 0.01) where n = 48 for all variables. The abbreviations are the same as in Table 1.

with temperature; and *A. nordestensis* exhibited a negative correlation with both DO ($r = -0.37$) and pH ($r = -0.59$).

For the Caenogastropoda, *P. canaliculata* was negatively correlated with pH ($r = -0.51$) and DO ($r = -0.39$), but positively correlated with temperature ($r = 0.37$); *P. megastoma* exhibited a negative association with pH ($r = -0.49$) and DO ($r = -0.32$) as well as with water temperature; *H. parchappii*, however, was well correlated with temperature, while *H. piscium* was negatively associated with dissolved oxygen, pH, and conductivity. *P. agapetus* was correlated mainly with dissolved oxygen and pH, though to a lesser extent with temperature and conductivity; while *P. bushii* was found more closely associated with conductivity, on the negative side, and with temperature.

Both the infaunal (*C. fluminea*) and the epifaunal (*L. fortunei*) bivalves were positively correlated with the pH and the DO variables. Conversely, the infaunal bivalve *P. taraguyense* was negatively associated with both the pH ($r = -0.59$) and the DO.

The total number of species (NS) indicated relationships mainly with temperature and conductivity, with the latter on the negative side ($p < 0.05$).

4. Discussion

In all of Argentina, 158 mollusks, gastropods, and bivalves have been recorded; but the greatest richness and diversity has been found in the Del Plata basin of the Brazílic Subregion (Tassara et al., 2001; Rumi et al., 2008). That the biodiversity of the gastropods and bivalves from Martín García Island amounts to up to 26 species, even though the island is only 184 ha in area, is therefore not particularly surprising. Among the Gastropoda, the Planorbidae family made the most sizeable contribution. The Lithogliphidae *P. agapetus* (26.28%) and *P. buschii* (9.50%) showed the highest relative frequencies of occurrence within the littoral environments, while the Planorbidae *D. cimex* (23.83%) and *D. kermatoides* (11.59%) likewise did so in the inland ponds.

The results of the species-clustering analyses revealed two main groups of mollusk species (Figure 2). The first consisted in *S. marmorata*, *D. cimex*, *D. kermatoides*, and *B. tenagophila tenagophila*; which species are typical of Cantera Grande (Site 9). In this regard, studies by Bonetto et al. (1982) along both banks of the middle Paraná River revealed the association between *D. kermatoides* and *B. tenagophila tenagophila*. The second group and one of its subgroups consisted in the typical species *P. canaliculata*, *D. depressissimum*, *H. parchappii*, and *P. megastoma* from coastal habitats such as Playa de Arena (Site 3). Another subgroup onsisted in *P. agapetus*, *P. bushii*, *L. fortunei*, *H. piscium*, *H. moricandi*, and *U. concentricus* with the highest clustering coefficient along with *C. fluminea* ($J = 0.68$). These species, typically of coastal environments, inhabit rocky substrates. By contrast, the infaunal bivalve *C. fluminea*–it restricted to sandy substrates–joined the latter group with a lower clustering coefficient. Accordingly, Da Silva Gama (2004) had reported that the distribution of this latter bivalve was more associated with those same sandy substrates.

The final subgroup, consisting in *P. taraguyense*, *B. straminea*, and *A. nordestensis*, contained typical species from coastal environments. *P. taraguyense* was also found in Cantera Basural (Site 5). Since this latter site is an aquatic environment very close to the coast, the introduction of the species very likely occurred during floods from the river.

The ordination diagram shows the distribution of the mollusks with respect to the environmental variables. Although none of the species was located at the centre of the diagram, *P. canaliculata*, *P. megastoma* and *D. depressissimum* are the species closest to the average environmental variables. *S. marmorata*, *D. cimex*, *D. kermatoides* and *B. tenagophila tenagophila* were the most closely associated with medium and high values of conductivity. The same pattern has been observed for *B. (t) tenagophila* by Bonetto et al. (1982). This species was found exclusively in the inland ponds (Sites 5, 7 and 9) and was associated with floating vegetation.

Species of gastropods and littoral bivalves such as *H. piscium*, *H. parchappii*, *P. agapetus*, *P. bushii*, *U. concentricus* and *L. fortunei* were most closely associated with the variables pH, DO and water temperature as well as with hard substrates (basaltic rocks). *H. moricandi* was found on the surfaces of coastal vegetation; while *C. fluminea* and *P. taraguyense*, infaunal species, inhabited sandy loam substrates of the littoral sites. *B. straminea* and *A. nordestensis* were associated with aquatic macrophytes, such as *Ludwigia elegans*, *L. bonariensis* and *L. peploides*–plants typically found along the coasts of Martín García Island.

Rodrigues Capítulo et al. (2001) reported the presence of *P. canaliculata*, *D. kermatoides* and *S. marmorata* in streams of the pampean tributaries of the Río de la Plata River, at conductivity readings ranging from 705 to 878 $\mu S.cm^{-1}$. From the present results we can conclude that *P. canaliculata*, the closest species to the centre of the CCA diagram, should be poorly sensitive to conductivity; while the other two species should prefer environments with medium-to-high conductivities.

According to De Francesco and Isla (2003), salinity would constitute the most influential parameter determining the distribution of the *Heleobia* species. Those authors observed that *H. parchappii* demonstrated a conductivity-tolerance range of 4 to 34‰ and concluded that the species was highly resistant to the salinity of the estuarine and continental waters (Rodrigues Capítulo et al., 2001). This species is also abundant in the pampean region (Gaillard and Castellanos, 1976; Castellanos and Landoni, 1995). Ciocco and Scheibler (2008) recorded *H. parchappii* on the littoral benthos of a saline lake in Mendoza. Although Gaillard and Castellanos (1976) considered *H. piscium* a freshwater species, Darrigran (1995) stated that it was an eurihalin species because it was found in inland fluvial (salinities < 0.5‰) and intermediate-fluvial (salinities between 0.5 to 25‰) zones of the Río de la Plata River.

Our results agree with the observations of those authors regarding the distribution of both species on the Martín García Island, since the two are found in littoral environments associated with specific conditions of water temperature, dissolved oxygen and pH.

With respect to the species distribution of the *Potamolithus* genus on the island, the ordination diagram would indicate that *P. bushii* is negatively related to conductivity, it clearly being a freshwater species; while *P. agapetus* presents a higher tolerance to salinity; with that characteristic being in agreement with López Armengol and Darrigran (1998), who reported a distribution of the species up to as far as the Balneario Atalaya (the marine-fluvial zone of the Río de la Plata River). *H. moricandi*, *U. concentricus*, *Ch. fluminea* and the bivalve *C. fluminea* – those species cited by Lanzer and Schafer (1985) in coastal ponds in the south of Brazil–were found by them under similar conditions of conductivity and pH to those recorded for the littoral zone of Martín García Island.

During the sampling period of 1995-1997, the invasive bivalve *L. fortunei*, exhibited low densities on the island with an initial density recorded in 1991 of 4 to 5 individuals m^2 (Pastorino et al., 1993). Damborenea and Penchaszadeh (2006) reported that the species manifested a high flexibility during its reproductive cycle and that its dispersion was favored by human activity (Darrigran and Ezcurra de Drago, 2000; Manzur et al., 2003; Avelar et al., 2004; Brugnoli et al., 2005; Belz et al., 2005). This invasive species exhibits a great plasticity with respect to environmental variables, and this characteristic has been confirmed from the results of the analysis of correlation by Pearson, which data indicate special relationships to the physicochemical parameters examined in this present study.

On the island, the Sphaeridae family is represented by *P. sterkianum* with 3 individuals at Site 11 as well as by *P. taraguyense* with a greater abundance and an occurrence in sites 2 and 11. Although the morphology, taxonomy, and distribution of the species have been studied; little information is available regarding their ecology. For this reason, a comparison of the results obtained in the present paper with other references of the species cannot be made.

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References

ARMENDÁRIZ, LC. and CÉSAR, II., 2001. The distribution and ecology of litoral Oligochaeta and Aphanoneura (Annelida) of the Natural and Historical Reserve of Isla Martín García, Río de la Plata river, Argentina. *Hydrobiolgia*, vol. 463, p. 207-216.

ARMENDÁRIZ, LC., CÉSAR, II. and DAMBORENEA, MC., 2000. Oligoquetos en ambientes lénticos en la Reserva Natural e Histórica de la Isla Martín García, Río de la Plata Superior, Argentina. *Asociación Ciencias Naturales del Litoral*, vol. 31, no. 1-2, p. 73-79.

AVELAR, WEP., MARTIM, SL. and VIANNA, MP., 2004. A New occurrence of *Limnoperna fortunei* (Dunker, 1857) (Bivalvia, Mytilidae) in the State of São Paulo. *Brazilian Journal of Biology* (online), vol. 64, no. 4, p. 739-742. http://dx.doi.org/10.1590/S1519-69842004000500002

BELZ, C., PEREIRA BOEGER, WA., ALBERTI, SM., PATELLA, L. and TUBINO VIANA, R., 2005. Prospeção do molusco invasor *Limnoperna fortunei* (Dunker, 1857) em reservatórios e sistemas de usinas hidreletricas da companhia paranaense de energia-COPEL. *Acta Biologica Leopoldensia*, vol. 27, no. 2, p. 123-126.

BONETTO, AA., BECHARA, JA., and TASSARA, MP., 1982. Los moluscos de la familia Planorbidae en el área del río Paraná Medio. *Physis Sección B*, vol. 41, no. 100, p. 1-6.

BRAAK, CJF. and VERDONSCHOT, FM.,1995. Canonical correspondence anlysis and related multivariate methods in aquatic ecology. *Aquatic Sciences*, vol.57, no. 3, p. 255-289.

BRUGNOLI, E., CLEMENTE, JM., BOCCARDI, L. BORTHAGARAY, A. and SCARABINO, F., 2005. Golden mussell *Limnoperna fortunei* (Bivalvia: Mytilidae) distribution in the main hydrographical basins of Uruguay: update and predictions. *Anais da Academia Brasileira de Ciencias*, vol. 77, no. 2, p. 235-244. http://dx.doi.org/10.1590/S0001-37652005000200004

CASTELLANOS, ZJA. and LANDONI, N., 1995. Mollusca Pelecypoda Gastropoda. In LOPRETTO, EC. and TELL, G. *Ecosistemas de Aguas Continentales. Metodologías para su estudio*. La Plata: Ediciones Sur. p. 759-802.

CÉSAR, II., ARMENDÁRIZ, LC. and DAMBORENEA, C., 2001. Ostrácodos (Crustacea) de la Isla Martín García, Río de la Plata, Argentina. *Natura Neotropicalis*, vol. 32, no. 2, p. 147-151.

CÉSAR, II. and LIBERTO, R., 2008. Ostracoda ¿Posibles Indicadores de Deterioro Ambiental de la Reserva de Usos Múltiples Isla Martín García? *Ciencia*, vol. 3, no. 5, p. 99-108.

CÉSAR, II., MARTÏN, SM., GULLO, BS. and LIBERTO, R., 2009. Biodiversity and ecology of Hirudinea (Annelida) from the Natural Reserve of Isla Martín García, Río de la Plata, Argentina. *Brazilian Journal of Biology*, vol. 69, no. 4, p. 1107-1113.

CIOCCO, NF. and SCHEIBLER, EE., 2008. Malacofauna of the littoral benthos of saline lake in southern Mendoza, Argentina. *Fundamental and Applied Limnology. Archive für Hydrobiologie*, vol. 172, no. 2, p. 87-98.

CRISCI, JV. and LÓPEZ ARMENGOL, MF., 1983. *Introducción a la teoría y práctica de la taxonomía numérica* Washington: Ed. OEA. 132 p. Serie de Biología, no. 26.

DAMBORENEA, MC., CÉSAR, II. and ARMENDÁRIZ, LC., 1997. Especies de *Temnocephala* (Platyhelminthes: Temnocephalidae) de la Isla Martín García, Buenos Aires, Argentina. *Neotropica*, vol. 43, no. 109-110, p. 123-124.

DAMBORENEA, MC. and PENCHASZADEH, PE., 2006. Biología reproductiva de *Limnoperna fortunei*. In DARRIGRAN, GA. and DAMBORENEA, MC., (Eds.). *Bio-invasión del mejillón dorado en el continente americano*. La Plata: Edulp. p. 69-79.

DARRIGRAN, GA., 1995. Distribución de tres especies del género *Heleobia* Stimpson, 1865 (Gastropoda, Hydrobiidae) en el litoral argentino del Río de la Plata y arroyos afluentes. *Iheringia*, no. 78, p. 3-8.

DARRIGRAN, GA. and EZCURRA DE DRAGO, I., 2000. Invasion of *Limnoperna fortunei* (Dunker, 1857) (Bivalvia: Mytilidae) in America. *Nautilus*, vol. 114, no. 2, p. 69-74.

DA SILVA GAMA, AM., 2004. *Distribuição e abundância dos moluscos bentônicos da Lagoa do Araçá-RS, em função de parâmetros ambientais*. Porto Alegre: Pontifícia Universidade Católica do Rio Grande do Sul. Dissertação de Mestrado em Biociências - Zoologia.

DE FRANCESCO, CG. and ISLA, FI., 2003. Distribution and abundante of Hydrobiid snails in a Mixed Estuary and a Coastal Lagoon, Argentina. *Estuaries*, vol. 26, no. 3, p. 790-797.

FERNÁNDEZ, LA. and LÓPEZ RUF, M., 1999. Coleoptera y Heteroptera acuáticos y semiacuáticos de la Isla Martín García (Provincia de Buenos Aires). *Physis Secc B*, vol. 57, no. 132-133, p.1-4.

GAILLARD, C. and CASTELLANOS, ZJ A., 1976. *Mollusca Gasteropoda Hydrobiidae.* In RINGUELET, RA., (Ed.). *Fauna de Agua dulce de la República Argentina*. Buenos Aires: FECIC. vol. 15, no. 2, p. 7-40.

JUÁREZ, MC., 1995. Estatus de residencia y categorización trófica de las aves en la Reserva Natural Isla Martín García, Río de la Plata Superior. *Neotropica*, vol. 41, no. 105-106, p. 83-88.

KOVACH, W., 1998. Multi-Variate Statistical Package. version 3.01. Pentraeth.

KÜLKÖYLÜOĞLU, O., 2003. Ecology of freshwater Ostracoda (Crustacea) from Lakes and Reservoirs in Bolu, Turkey. *Journal Freshwater Ecology*, vol. 18, no. 3, p. 343-347.

KÜLKÖYLÜOĞLU, O., 2005. Ecology and phenology of freshwater ostracods in Lake Gölköy (Bolu, Turkey). *Aquatic Ecology*, vol. 39, no. 3, p. 295-304.

KÜLKÖYLÜOĞLU, O. and DÜGEL, M., 2004. Ecology and spatiotemporal patterns of Ostracoda (Crustacea) from Lake Gölcük (Bolu, Turkey). *Archive für Hydrobiolgie*, vol. 160, no. 1, p. 67-83.

LAHITTE, HB., HURRELL, JA., CANDA, G. and TRUCCO ALEMÁN, C., 1995. Poblaciones de *Tupinambis teguixin* (Sauria-Teidae) de la Isla Martín García (Buenos Aires, Argentina). I Etnobiología y Encuadre Metodológico-Cognitivo. *Pinaco*, vol. 2, p. 45-62.

LAHITTE, HB. and HURRELL, JA., 1996. *Plantas Hidrófilas de la Isla Martín García (Buenos Aires, República Argentina)*. La Plata: Ed. La Plata, CIC. 236 p. Serie informe, no. 52.

LAHITTE, HB. and HURRELL, JA., 1998. *Catálogo de las Aves de la Isla Martín García (Buenos Aires, Argentina*). La Plata: Ed. La Plata, CIC. p. 53-69. Serie informe, no. 53.

LANZER, RM. and SCHAFER, A., 1985. Padrões de distribução de Moluscos dulceaquícolas nas lagoas costeiras do Sul do Brasil. *Revista Brasileira de Biologia = Brazilian Journal of Biology*, vol. 45, no. 4, p. 535-545.

LÓPEZ ARMENGOL, MF. and DARRIGRAN, G., 1998. Distribución del género neotropical *Potamolithus* Pilsbry y Rush, 1896 (Gastropoda: Hydrobiidae) en el estuario del Río de la Plata. *Iberus*, vol. 16, no. 2, p. 67-74.

MALTCHIK, L., STENERT, C., KOTZIAN, CB. and PEREIRA, D., 2010. Responses of freshwater molluscs to environmental factors in Southern Brazil wetlands. Brazilian Journal of Biology, vol. 70, no. 3, p. 473-482. http://dx.doi.org/10.1590/S1519-69842010005000003

MANZUR, MCD., DOS SANTOS, CP., DARRIGRAN, G., HEYDRICH, I., CALLIL, C. and CARDOZO, FR., 2003. Primeros dados quail-quantitativos do mexilhao-dourado, *Limnoperna fortunei* (Dunker), no Delta do Jacuí, no Lago Guaíba e no Laguna dos Patos, Rio Grande do Sul, Brasil e alguns aspectos de sua invasao no novo ambiente. *Revista Brasileira de Biologia = Brazilian Journal of Biology*, vol. 20, p. 75-84.

MARTÍN, SM., 2008. Individual growth *Heleobia piscium* in natural populations (Gastropoda: Cochliopidae) from the Multiple Use Natural Reserve Isla Martín García, Buenos Aires, Argentina. *Brazilian Journal of Biology*, vol. 68, no. 4, p. 617-621.

MARTÍN, SM. and NEGRETE, LHL., 2006. Primer registro de *Heleobia guaranitica* (Doering, 1884) (Gastropoda: Cochliopidae) en la Reserva Natural de Usos Múltiples Isla Martín García. *Comunicaciones Sociedad Malacología Uruguay*, vol. 9, no. 89, p. 71-73.

MARTÍN, SM., CËSAR, II. and LIBERTO, R., 2009. Distribution of *Deroceras reticulatum* (Müller, 1774) (Pulmonata Stylommatophora) in Argentina with first record of the Reserva de Usos Múltiples Isla Martin Garcia, Río de la Plata superior. *Brazilian Journal of Biology*, vol. 69 no. 4, p. 1115-1119.

PASTORINO, G., DARRIGRAN, G., MARTÏN, SM. and LUNASCHI, L., 1993. *Limnoperna fortunei* (Dunker, 1857) (Mytilidae), nuevo bivalvo invasor en aguas del Río de la Plata. *Neotropica*, vol. 39, no. 101-102, p. 34.

RODRIGUES CAPÍTULO, A., TANGORRA, M. and OCÓN, CS., 2001. Use of Benthic macroinvertebrate to assess the ecological status of pampean rivers (Argentine). *Aquatic Ecology*, vol. 35, p. 109-119.

RUMI, A., MARTIN, SM., TASSARA, MP. and DARRIGRAN, GA.,1996. Moluscos de agua dulce de la Reserva Natural e Histórica Isla Martín García. Río de la Plata, Argentina. *Comunicaciones Sociedad Malacológica de Uruguay*, vol. 8, no. 70-71, p. 7-12.

RUMI, A., GUTIÉRREZ GREGORIC, D., ROCHE, A., and TASSARA, MP., 2004. Population structure in *Drepanotrema cimex* and *D. kermatoides* (Gastropoda, Planorbidae) in natural conditions. *Malacologia, Michigan, USA*, vol. 45, no. 2, p. 453-458.

RUMI, A., GUTIÉRREZ GREGORIC, DE. and ROCHE, A., 2007. Growth rates fitting using the von Bertalanffy model: analysis in natural populations of *Drepanotrema* spp. (Gastropoda: Planorbidae). *Revista Biología Tropical*, vol. 55, no. 2, p. 559-567.

RUMI, A., GUTIÉRREZ GREGORIC, DE., NÚÑEZ, V. and DARRIGRAN, GA., 2008. Malacología Latinoamericana. Moluscos de agua dulce de Argentina. Revista Biología Tropical, vol. 56, no. 1, p. 77-111.

TASSARA, MP., CËSAR, II., RUMI, A., GUTIËRREZ GREGORIC, DE., ROCHE, MA., MARTÏN, SM. and NÜÑEZ, V., 2001. Distributional patterns of freshwater Bivalvia in Argentina. In *Proceedings of the World Congress of Malacology-Unitas Malacologica*, 2001. Vienna, Austria. p. 348.

TER BRAAK, CJF., 1986. Cannonical Correspondance Analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecology*, vol. 67, p. 1167-1179. http://dx.doi.org/10.2307/1938672