MALACOLOGIA, 2010, 53(1): 47–60

FRESHWATER GASTROPOD PROVINCES FROM ARGENTINA

Verónica Núñez*, Diego E. Gutiérrez Gregoric & Alejandra Rumi

CONICET, División Zoología Invertebrados, Museo de La Plata, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900, La Plata, Argentina

ABSTRACT

Diverse biogeographic regions have been proposed in Argentina using different approaches of biogeography and different criteria. However, none of these proposals has considered freshwater gastropods in estimating biodiversity values, although gastropods from continental waters have great ecological importance and are a useful group to characterize freshwater environments. For this reason, our aim is to define freshwater gastropod provinces and to compare them with the available information on biogeographic regions previously defined using other data sets. The gastropod database comprises approximately 4,000 georeferenced records from museum collections, bibliographic records, and collections of our research team. A similarity analysis among basins was carried out using the species as characters and applying Jaccard's coefficient and UPGMA clustering with the MVSP program to obtain the resulting phenogram. Eight provinces were identified: I, Misionerean; II, Middle Paraná; III, Uruguay River; IV, Lower Paraná – Río de la Plata; V, Central; VI, Cuyo; VII, Northern Patagonia; and VIII, Southern Patagonia. Between Provinces V and VI lies a Transitional Zone that shows a higher faunal similarity with the Del Plata basin than with the Patagonian basins. The provinces with the highest diversity were I and IV (H = 1.92 and 1.89 respectively), while Province III shows the highest richness (S = 51) and quantity of endemic and vulnerable species. These provinces are the most densely populated in the country and therefore include the areas with the highest environmental degradation level.

Key words: Argentina, freshwater Gastropoda, diversity, endemism, provinces, richness.

INTRODUCTION

Gastropod faunas from continental waters are ecologically important in many aquatic ecosystems; more specifically, they have an essential trophic function in the dynamics of epicontinental aquatic environments. Because of their slow movements, adequate size, and large population numbers, they are an appropriate group to characterize freshwater environments. They constitute a group very rich in species with a tendency to local endemism. Moreover, freshwater gastropods are promising tools as pollution indicators by means of assessments of mollusk community composition and biological monitoring programs that rate water quality and status of aquatic biotopes based on invertebrate assemblages (Strong et al., 2008).

Recently, Strong et al. (2008) analyzed the world's gastropod fauna diversity and proposed a spatial distribution of species. Biogeography of Neotropical aquatic continental gastropods is poorly known. Unlike many terrestrial species, which can disperse widely in suitable habitats, the spatial range of freshwater species tends to correspond to present or formerly continuous river basins or lakes. In many instances, the range within a system will also be restricted by particular habitat requirements (*World Conservation Monitoring Centre* – WCMC, 1998).

Freshwater gastropods have been preliminarily used to define local or regional diversity in Argentina (Rumi et al., 2006, 2008). Since then, our knowledge about systematics and diversity of the Argentinean freshwater gastropod fauna has increased substantially, allowing us to adjust and improve those regional proposals.

Argentina covers an area of 2,780,403 km^2 of southern South America, and is about 3,900 km long from north to south. In addition, its variation in altitude favors the development of a great variety of environments, from subtropical rainforests to Patagonian steppes, being one of the countries in the world with the highest biogeographic diversity (Bertonatti & Corcuera,

*Corresponding author: nmariaveronik@yahoo.com.ar

2000). The Del Plata basin and the Patagonian System are the most important hydrographic systems of Argentina. According to estimates carried out by WCMC (1998), the Del Plata basin is identified as one of the 27 areas of special importance for freshwater mollusk diversity; they are key hotspots of diversity with high rates of endemism among freshwater gastropods.

Diverse divisions into biogeographic regions have been proposed for the Argentinean territory using different approaches of biogeography and other criteria. Such are the zoogeographic sketches of Morrone (2002, 2006) and the ecoregions described by Burkart et al. (1999) on the basis of climatic variables and particular ecologic functional features, mainly considering land flora and fauna. In all these schemes, the terms subregion, territory, unit or area are used indiscriminately. Freshwater gastropods are not taken into account in estimating biodiversity values. However, some of these proposals are related to the freshwater environments. According to Bonetto (1994), two biogeographic territories – with a Transitional Zone between them – are defined on hydrographic basins. Canevari et al. (1999) described six wetland regions. Based on fish distribution, Ringuelet (1975) proposed three ichthyologic provinces, whereas López et al. (2002) defined 11 ecoregions.

Our objective here is to define freshwater gastropod provinces and to compare them with the information available on biogeographic regions formerly defined for Argentina, mainly with those related to freshwater environments. This work is part of a long-range project, which also includes bivalves in similar regional analyses.

MATERIAL AND METHODS

Our database, with 101 species of gastropods, was assembled for research on the systematics, biogeography, and diversity of freshwater mollusks, and was published by Rumi et al. (2006, 2008). It comprises approximately 4,000 georeferenced records from: collections housed in the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Buenos Aires (MACN), Museo de La Plata, La Plata (MLP), and Fundación “Miguel Lillo”, Tucumán (FML), bibliographic citations, and collections of our research team.

Three species included in this database were not considered for this study: (a) *Laevapex* sp. (Ancylidae), because it is unidentified; (b) *Heleobia australis* (d’Orbigny, 1835), and (c) *H. conexa* (Gaillard, 1974) (Cochliopidae), both of which inhabit mainly seawater environments. On the other hand, two species were added to the database, a recently published species – *Chilina iguazuensis* Gutiérrez Gregoric & Rumi, 2008; Chilinidae – and another with a recent record for Argentina (*Galba truncatula* (Müller, 1774) – Lymnaeidae) (Bargues et al., 2006).

Because this work deals with freshwater organisms, we used hydrographic basins as operational geographical units. The basins used are those defined by the *Sistema Nacional de Información Hídrica de la Argentina* (2002), with some modifications; names of each basin and their description are given also by López et al. (2002). Two more basins were added due to their particular characteristics: basin no. 102 (streams in the Somuncurá System, Province of Río Negro) as in the work of López et al. (2002) and basin no. 103 (Martín García Island, Province of Buenos Aires) (Fig. 1). On the other hand, some basins were divided: no. 67 in 67a (small streams of SE Chubut Province) and 67b (small streams of E Santa Cruz Province), and no. 60 in 60a (upper Colorado River) and 60b (lower Colorado River). Only one of the three parts of basin no. 61 was considered (61a: small streams of SE Buenos Aires, to the N of Colorado River), because the rest of this basin has few records. Some basins were united to others, because they represent small adjacent basins of several independent drainage streams.

To recognize similarities between hydrographic basins, we performed a similarity analysis based on the native fauna of freshwater gastropods following the methodology used by López et al. (2002) for fish. A basic matrix of binary data (presence/absence) was laid out; basins were treated as Operational Taxonomic Units and species as characters. Basins with no records (38, 52, 58, 78, 81, 87 and 92) and basins with one or with two records (32, 60a, 61b–c, 71, 77, 80, 90, 95, 96 and 99; 70 and 101, respectively) were not included in the analysis. A total of 69 basins was used. Likewise, species found in only one basin were not included (Table 1). Thus, a total of 77 species of the 100 present in Argentina was considered. A resulting phenogram was obtained applying Jaccard’s coefficient (Real

FIG. 1. Division of the Argentinean territory into its hydrographic basins.

TABLE 1. List of species and their distribution by provinces. *: Species that inhabits only one basin; +: Exotic species; both were not considered in similarity analysis; Provinces: I. Misionerean, II. Middle Paraná, III. Uruguay River, IV. Lower Paraná – Río de la Plata, V. Central, VI. Cuyo, VII. Northern Patagonia, VIII. Southern Patagonia; TZ: Transitional Zone; E: Endemic species of Argentina; V: Vulnerable species; EV: Endemic and vulnerable species; P: Non-endemic species present in each province. S: Species of sanitary importance.

Species/Provinces	I	II	III	IV	V	VI	VII	VIII	TZ
Ampullariidae Gray, 1824									
Asolene platae (Maton, 1809)			P	P					
A. pulchella (Anton, 1839)	P	P	P	P					
A. spixii (d'Orbigny, 1835)	P	P	P	P					
Felipponea elongata (Dall, 1921)			V						
F. iheringi (Pilsbry, 1933)			V						
F. neritiniformis (Dall, 1919)			P						
Marisa planogyra Pilsbry, 1933	P	P		P	P				
Pomacea canaliculata (Lamarck, 1822)	P	P	P	P	P	P			P
P. insularum (d'Orbigny, 1835)	P	P	P	P					
P. scalaris (d'Orbigny, 1835)		P	P	P					
Pomella americanista (Ihering, 1919)	P	P	P						
P. megastoma (G. B. Sowerby I, 1825)	P		P	P					
Thiaridae Troschell, 1857									
Aylacostoma chloroticum Hylton Scott, 1954*	EV								
A. guaraniticum (Hylton Scott, 1951)*	EV								
A. stigmaticum Hylton Scott, 1954*	EV								
Melanoides tuberculatus Müller, 1774+	P								
Cochliopidae Tryon, 1866									
Heleobia castellanosae (Gaillard, 1974)*				EV					
H. guaranitica (Doering, 1884)	P	P	P	P					
H. hatcheri (Pilsbry, 1911)						P	P	P	P
H. isabelleana (d'Orbigny, 1835)*				V					
H. kuesteri (Strobel, 1874)						EV			
H. montana (Doering, 1884)					EV				EV
H. occidentalis (Doering, 1884)		EV				EV			
H. parchappii (d'Orbigny, 1835)	P	P	P	P	P	P	P		P
H. peiranoi (Weyrauch, 1963)*					EV				
H. piscium (d'Orbigny, 1835)		P	P	P					
H. rionegrina (Gaillard, 1974)*									
H. sublineata (Pilsbry, 1911)*								EV	
H. tucumana (Gaillard, 1974)		EV			EV				EV
H. vianai (Parodiz, 1960)		EV				EV			
Lithoglyphidae Troschel, 1857									
Potamolithus agapetus Pilsbry, 1911			EV	EV					
P. buschii (Frauenfeld, 1865)			EV	EV					
P. callosus Pilsbry, 1925			P						
P. catharinae Pilsbry, 1911			V						
P. concordianus Parodiz, 1966			EV						

(continues)

(continued)

Species/Provinces	I	II	III	IV	V	VI	VII	VIII	TZ
P. conicus (Brot, 1867)			EV						
P. dinochilus Pilsbry, 1896			EV						
P. doeringi Pilsbry, 1911	V								
P. hidalgoi Pilsbry, 1896			EV						
P. iheringi Pilsbry, 1896			P						
P. lapidum (d'Orbigny, 1835)	P		P	P					
P. microthauma Pilsbry, 1896			V						
P. orbignyi Pilsbry, 1896			V	V					
P. paranensis Pilsbry, 1911	E	E	E						
P. peristomatus (d'Orbigny, 1835)	P	P	P						
P. petitianus d'Orbigny, 1840	P		P	P					
P. philipianus Pilsbry, 1911	P		P						
P. quadratus Pilsbry & Ihering, 1911			V						
P. rushii Pilsbry, 1896			E						
P. simplex Pilsbry, 1911			EV						
P. tricostatus (Brot, 1867)*			EV						
P. valchetensis Miquel, 1998*									
Glacidorbidae Ponder, 1986									
Gondwanorbis magallanicus (Meier-Brook & Smith, 1976)							V	V	
Chilinidae Gray, 1828									
Chilina aurantia Marshall, 1924*							V		
C. dombeiana (Bruguiere, 1789)							P		
C. fluminea (Maton, 1809)			P	P	P				
C. fulgurata Pilsbry, 1911							E	E	
C. gallardoi Castellanos & Gaillard, 1981			E	E					
C. gibbosa G. B. Sowerby I, 1841							P		
C. guaraniana Castellanos & Miquel, 1980*	EV								
C. iguazuensis Gutiérrez Gregoric & Rumi, 2008*	EV								
C. megastoma Hylton Scott, 1958*	EV								
C. mendozana Strobel, 1874						E			
C. neuquenensis Marshall, 1933							EV		
C. parchappii (d'Orbigny, 1835)					E	E			E
C. patagonica Sowerby, 1874							P	P	
C. perrieri Mabille, 1833							EV	EV	
C. portillensis Hidalgo, 1880		EV							EV
C. rushii Pilsbry, 1911			E	E					
C. strebeli Pilsbry, 1911							EV	EV	
Lymnaeidae Rafinesque, 1815									
Galba truncatula (Müller, 1774)*+						S			
Lymnaea columella Say, 1817+	S	S	S	S					
L. diaphana King, 1830							P	P	

(continues)

(continued)

Species/Provinces	I	II	III	IV	V	VI	VII	VIII	TZ
L. pictonica Rochebrune & Mabille, 1885								P	
L. plicata Hylton Scott, 1953*							EV		
L. viatrix (d'Orbigny, 1835)		S		S	S	S	S	S	S
Planorbidae Rafinesque, 1815									
Acrorbis petricola Odhner, 1937	V								
Antillorbis nordestensis (Lucena, 1954)	P	P	P	P	P				
Biomphalaria intermedia (Paraense & Deslandes, 1962)	P	P							
B. occidentalis Paraense, 1981		P							
B. oligoza Paraense, 1974		P			P				
B. orbignyi Paraense, 1975	P	P	P	P	P	P			P
B. peregrina (d'Orbigny, 1835)	S	S	S	S	S	S	S		S
B. straminea (Dunker, 1848)	S	S	S	S	S				
B. tenagophila (d'Orbigny, 1835)	S	S	S	S	S				S
Drepanotrema anatinum (d'Orbigny, 1835)	P	P	P	P	P				
D. cimex (Moricand, 1839)	P	P	P	P					
D. depressissimum (Moricand, 1839)	P	P	P	P					P
D. heloicum (d'Orbigny, 1835)	P	P		P	P				
D. kermatoides (d'Orbigny, 1835)	P	P	P	P	P		P		P
D. lucidum (Pfeiffer, 1839)	P	P	P	P					
Ancylidae Rafinesque, 1815									
Anisancylus obliquus (Broderip & Sowerby, 1832)					P		P		
Gundlachia ticaga (Marcus & Marcus, 1962)	V								
Hebetancylus moricandi (d'Orbigny, 1837)	P	P	P	P	P				
Uncancylus concentricus (d'Orbigny, 1835)	P	P	P	P	P		P		P
Physidae Fitzinger, 1833									
Physa aspii Holmerg, 1909*		EV							
P. loosi Holmerg, 1909*		EV				EV			
P. acuta Draparnaud, 1805+	P	P		P	P	P	P		P
Physella venustula (Gould, 1848)+					P	P	P		
Stenophysa marmorata (Guilding, 1828)	P	P	P	P	P	P			P

& Vargas, 1996) ($J = a/N$, in which a is the number of species present in two determinate basins and N is the total number of species found in both basins together) and UPGMA clustering. These analyses were run with the Multivariate Statistical Program, MVSP 3.13 (Kovach, 2006). Provinces were defined on the basis of groups of basins sharing at least 50% of their species ($J \geq 0.5$), and the basins related to these clusters, although at a lower similarity. Basins that were not included in the original analysis were later tentatively grouped with another because of hydrological or geographical features. We tentatively assigned provinces that are bounded by other countries to the political boundary because there is not enough information to extend them beyond that artificial limit.

Each province was characterized according to:

- Gastropod diversity: it was estimated using the total number of native and exotic species (Table 1), by means of the Shannon diversity index ($H = -\Sigma\ p_i \ln p_i$). Thus, for each prov-

TABLE 2. Values of Richness (S) and Diversity (H) obtained in each Province. Provinces: I Misionerean, II Middle Paraná, III Uruguay River, IV Lower Paraná - Río de la Plata, V Central, VI Cuyo, VII Northern Patagonia, and VIII Southern Patagonia. TZ: Transitional Zone. Hmax and Smax: maximum values of diversity and richness in each basin of each province. Hmin and Smin: minimum values of diversity and richness in each basin of each province. V: number of vulnerable species. E: number of species endemic to Argentina. EP: number of species endemic to the Province. EX: number of exotic species. IB: basins not used in the similarity analysis but tentatively included in each province.

	Provinces								
	I	II	III	IV	V	VI	VII	VIII	TZ
H	1.92	1.77	1.63	1.89	1.73	1.66	1.72	1.28	1.77
Hmax	1.92	1.67	1.66	1.9	1.82	1.75	1.75	1.33	1.73
	(b10)	(b19)	(b39)	(b33+35)	(b94)	(b55)	(b62)	(b82)	(b28)
Hmin	1.48	0.9	1.44	1.59	1.36	0.64	0.5	0.64	0.95
	(b12)	(b13)	(b43)	(b46)	(b30–31)	(b93)	(b79)	(b68)	(b84)
S	41	38	51	38	24	16	20	10	15
Smax	35	27	45	32	17	10	15	7	8
	(b10)	(b17)	(b39)	(b37)	(b48)	(b54–56)	(b63)	(b69)	(b28, 90–91)
Smin	21	13	23	15	10	3	3	3	4
	(b11)	(b25–26)	(b42)	(b46)	(b30+31)	(b93)	(b67a)	(b68)	(b60b, 61, 85)
V	9	6	14	5	3	4	6	4	1
E	7	7	12	5	4	6	5	4	3
EP	6	0	7	1	1	2	2	1	0
EX	3	2	1	2	2	3	2	0	1
Protected Areas	30	47	17	20	18	30	30	15	
Ramsar Sites	No	3	No	2	1	3	1	2	No
IB		32	38		101	58	77, 78, 61c, Part of 99	70, 71, 80, 81, Part of 99	28, 60b, 61a, 84, 85, 88, 90, 91, 98

ince and basin we did not evaluate specific diversity in the usual manner, in which each species is weighed by the relative number of individuals, but rather we considered the distribution of species among families (Rabinovich & Rapoport, 1975; Rumi et al., 2006), so that p*i* = (number of species of family *i*) / (total number of species of province or basin). Richness (S) is the total number of species for each province and for each of the basins.

- Biological value: taking into account species that are endemic (present only in one province), vulnerable (species with a limited distribution in particular areas and those not recorded since 1975), exotic and species of cattle and human sanitary importance, according to Rumi et al. (2006, 2008).
- Number of protected areas and Ramsar sites defined by The Ramsar Convention of Wetlands (Table 2).

RESULTS

From the similarity analysis, eight provinces were identified (Figs. 2–4): I, Misionerean; II, Middle Paraná; III, Uruguay River; IV, Lower Paraná – Río de la Plata; V, Central; VI, Cuyo; VII, Northern Patagonia; and VIII, Southern Patagonia.

Eight basins located in central and northwestern Argentina cluster at a low similarity index (0.23) (Fig. 2). These, together with basins with scarce records and not included in the similarity analysis (52, 87, 92, 95 and 96) and basins 83, 89 and 93 (all with three records), constitute a Transitional Zone between Provinces V and VI (Fig. 4).

Basins 102 and 93 cluster with Province VI at a low similarity value (0.32). However, they are not considered part of this province because they are very distant geographically.

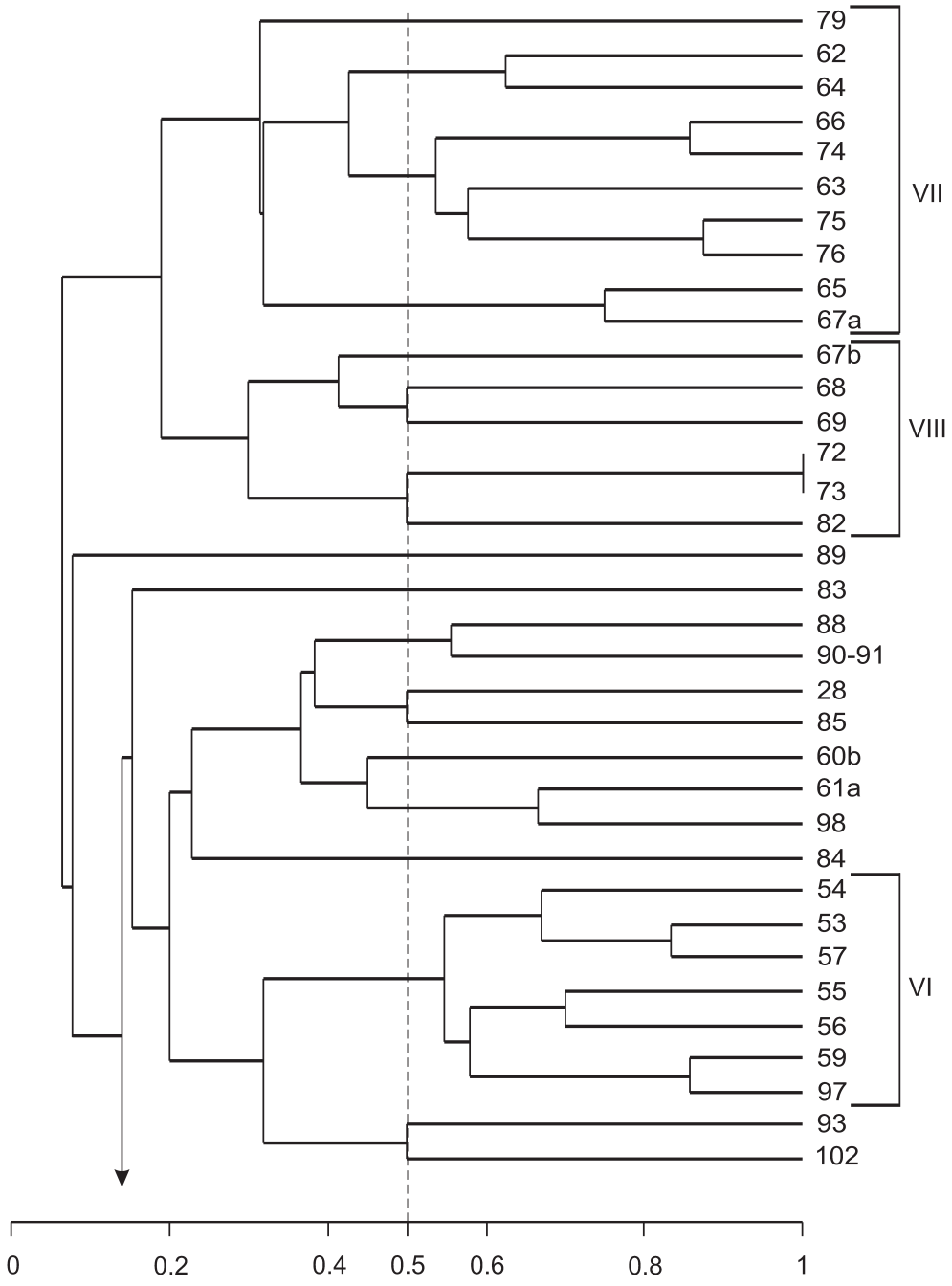

FIG. 2. Phenogram obtained from the similarity analysis among basins. Identification of provinces: VI. Cuyo; VII. Northern Patagonia; VIII. Southern Patagonia. Arrow indicates continuity with figure 3.

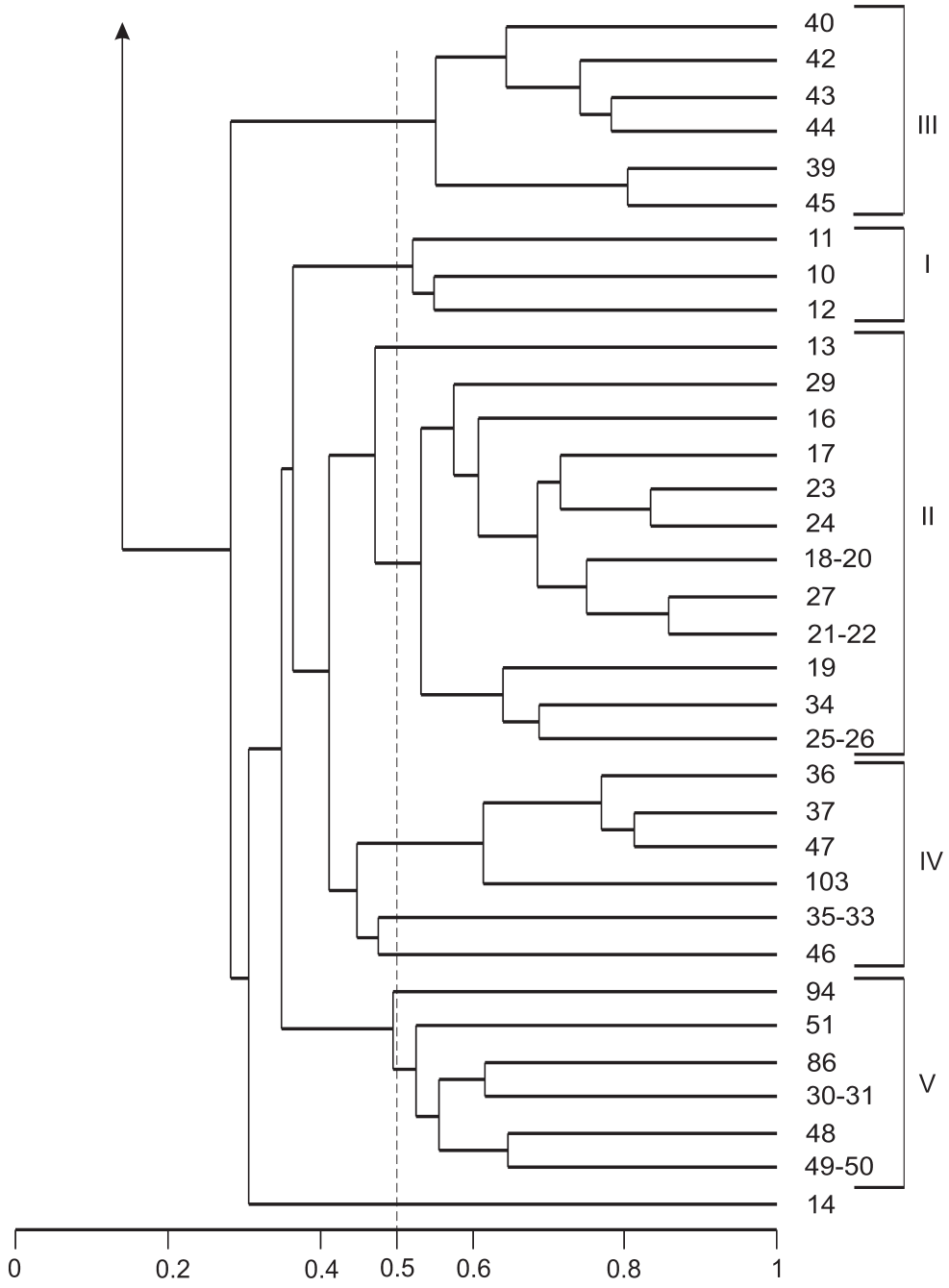

FIG. 3. Phenogram obtained from the similarity analysis among basins. Identification of provinces: I. Misionerean; II. Middle Paraná; III. Uruguay River; IV. Lower Paraná – Río de la Plata; V. Central. Arrow indicates continuity with figure 2.

Basin 102 has only six species, but two of them are endemic and considered vulnerable because they are only recorded at their type locality (*Heleobia rionegrina* and *Potamolithus valchetensis*).

Basin 14 was not assigned to any province in particular, as it clusters at a low similarity index with several provinces (Fig. 3). Perhaps, the species of this basin are more closely associated to those of basins of the neighboring countries, Bolivia and Paraguay.

Province I: Misionerean

This province shows the highest value in freshwater gastropod diversity and at the same time includes the basin with the highest diversity value for Argentina. Regarding richness, it is the second of Argentina (Table 2). The six endemic species of this province are considered vulnerable, and are found only at their type localities. *Chilina megastoma* and *C. iguazuensis* (Chilinidae) live in the Iguazú River environment, and are currently recorded frequently. *Chilina guaraniana* and *Aylacostoma* spp (Thiaridae) are endemic of the High Paraná River. Records of the former are few, while the latter has several records, but all of them before the flooding of the Yacyretá reservoir during the early 1990s. Three more species are found only in this province in Argentina but their distribution extends into neighboring countries: *Gundlachia ticaga* (Ancylidae), *Potamolithus doeringy*, and *Acrorbis petricola* (Planorbidae), the last two with a restricted distribution (Table 1).

Province II: Middle Paraná

The basin with the highest gastropod diversity of this province corresponds to part of the Cloud Forest or Yungas but the highest richness for a basin occurs in the Paraná basin (Table 2). The six vulnerable species recorded in this province have no current records (Table 1). Some of them have a restricted continuous range (*Chilina portillensis*) and others a discontinuous distribution (*Heleobia occidentalis* and *Physa loosi*). *Physa aspii* was recorded for Formosa and Salta political provinces (exact localities unknown) and has not been recorded again (Table 1).

Province III: Uruguay River

Although this is the province with the second lowest gastropod diversity, it has the highest specific richness (Table 2). This province has 20 of the 22 species of the Lithoglyphidae, which comprise almost 50% of the species present in the province. Of the 14 vulnerable species recorded in this province (Table 1), *Potamolithus concordianus* is mentioned for its type locality only and has no current records. The remaining 13 vulnerable species present a restricted discontinuous distribution. *Potamolithus tricostatus* and *P. quadratus* have no current records.

Province IV: Lower Paraná – Río de la Plata

This province receives faunal influence from Provinces II and III and therefore has mixed features. Even though *Heleobia castellanosae* and *H. isabelleana* have scarce records and there therefore vulnerable species, these are from areas where sampling was frequent.

Province V: Central

This province runs across the country diagonally from the northwest to the center-east and has numerous small and middle-sized endorrheic water courses that become salt pans during the dry season. Part of the Cloud Forest or Yungas is located in this province. The gastropod diversity index is higher and richness is almost half than in Province III (Table 2). Three vulnerable species are recorded (Table 1) and none of these have current records. *Heleobia peiranoi* is recorded only at its type locality.

Province VI: Cuyo

Gastropod diversity of this province is one of the lowest in the country (Table 2). Of the four vulnerable species in this province (Table 1), *Heleobia vianai, H. occidentalis*, and *Physa loosi* have no current records, the latter also with a restricted, discontinuous range (they are recorded also in Province II). The remaining vulnerable species, *Heleobia kuesteri*, shows restricted continuous range.

Province VII: Northern Patagonia

This province has the highest gastropod diversity of southern Argentina (Table 2). Six vulnerable species are recorded in this province (Table 1). Two of these have a restricted discontinuous range (*Chilina strebeli* and *Gondwanorbis magallanicus*), two have a restricted continuous range and no current records (*Chilina aurantia* and *C. perrieri*), one has a restricted continuous range (*Chilina*

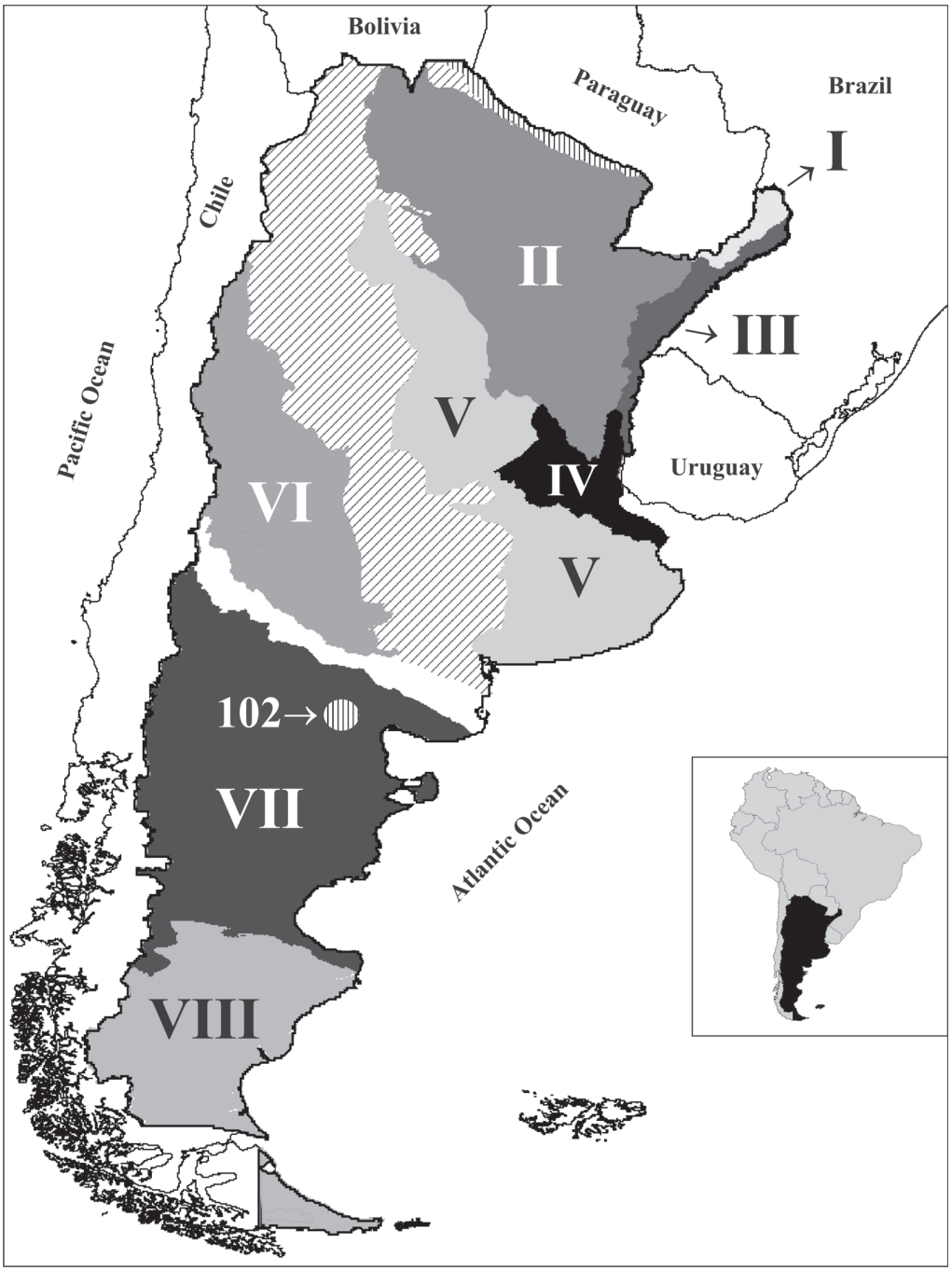

FIG. 4. Provinces identified in the map: I. Misionerean; II. Middle Paraná; III. Uruguay River; IV. Lower Paraná – Río de la Plata; V. Central; VI. Cuyo; VII. Northern Patagonia; VIII. Southern Patagonia. Diagonal patern: Transitional Zone. Vertical pattern: Basins not associated to any province. White area: Basins with no records and not associated to any province.

neuquenensis), and one is recorded only at its type locality and has no current records (*Lymnaea plicata*). *Chilina gibbosa* and *Chilina aurantia* occur only in this province in Argentina, but are also found in Chile (Castellanos & Miquel, 1980; Castellanos & Gaillard, 1981).

Province VIII: Southern Patagonia

Gastropod diversity and richness in this province are the lowest of Argentina. Gastropods are represented by a few families (Tables 1, 2). *Heleobia sublineata* is a vulnerable species endemic to this province recorded only from its type locality and has no current records. *Lymnaea pictonica* is found in Tierra del Fuego and at the southern tip of Santa Cruz; Picton Island in Chile is its type locality. There are no exotic species in this province.

Examination of the obtained phenogram reveals three large clusters. The first includes the Patagonian Provinces (VII and VIII) (Fig. 2). *Gondwanorbis magallanicus* is a species known in only two sites in Argentina, one in Province VII and the other in Province VIII. Species of Chilinidae are predominant. *Chilina strebeli* is endemic of this area. There are no species of Ampullariidae or Thiaridae.

The second large cluster is formed by Province VI and the Transitional Zone and shows greater similarity with the third cluster than with the first (Fig. 2). Species of Cochliopidae and Planorbidae are predominant over the seven families recorded (Table 1). It is worth noting the absence of Thiaridae, Glacidorbidae, and Lithoglyphidae and the presence of only one species each of Ampullariidae and Ancylidae.

The third great cluster – including provinces I to V (Fig. 3) – is the area with the highest richness values in Argentina because three different distribution patterns of freshwater gastropods overlap there. The first includes widely distributed species of Ampullariidae, Ancylidae, Physidae, Planorbidae, and Thiaridae (only in this area). Most of these species reach their southern limit in this area. The second group comprises the Chilinidae, which has a southern distribution, with its greatest richness in Patagonia, but with its northern limit in northeastern Argentina around the Tropic of Capricorn. The Lithoglyphidae constitute the third group and are almost entirely endemic to the Uruguay River basin.

DISCUSSION

Of the different biogeographic patterns mentioned in the Introduction, the pattern of freshwater gastropod provinces presented here is very similar to the ichthyological pattern (López et al., 2002):

Misionerean Province

Gastropods of this province differ from those present in streams flowing into the Uruguay River. However, according to ichthyologic classifications (Ringuelet, 1975; López et al., 2002), the whole of Misiones political province behaves as an ecoregion or province. This province is inhabited by species of *Aylacostoma* which, according to Quintana & Mercado Laczkó (1997), can be considered extinct in their natural habitat. However, Ostrowski & Quintana (2008) carried out a parasitological study on a natural population of *Aylacostoma chloroticum*.

Middle Paraná Province

It largely agrees with the wetland of Chaco (Canevari et al., 1999) and includes two ichthyologic ecoregions (4 and northern part of 2) (López et al., 2002).

Uruguay River Province

Malacologically, this province can be very well defined and is coincident with the ichthyologic proposal of López et al. (2002). No other schemes recognized this province as a single biogeographic unit. According to Bonneto (1994), the Uruguay River is part of the Del Plata basin. However, in this analysis gastropod fauna of these provinces showed a low similarity index ($J = 0.28$).

Lower Paraná – Río de la Plata Province

Gastropods of the Lower Paraná and Río de la Plata rivers receive influence of the middle Paraná and Uruguay rivers, Provinces II and III respectively. Such an influence confers the area characteristics of its own that warrant definition of a province. This does not happen in the rest of the classifications, in which this area does not conform to a separate province.

Central Province

It includes ichthyologic ecoregions 5, 7, and 8 (López et al., 2002) and coincides with the southern part of the pampas and the Chaco wetlands (Canevari et al., 1999).

Cuyo Province

It coincides with ichthyologic ecoregion 9 (López et al., 2002), while hydrographic (Bonetto, 1994) and wetland (Canevari et al., 1999) classifications include it within Patagonia. However, the fauna of gastropods of this province presents a higher similarity to the one of the Del Plata basin than to the fauna from Patagonia.

Northern and Southern Patagonia Provinces

Gastropod fauna of northern Patagonia (Province VII) differs from that of Southern Patagonia (Province VIII). Contrary to gastropods, in ichthyologic (Ringuelet, 1975; López et al., 2002), hydrographic (Bonetto, 1994), and wetland (Canevari et al., 1999) classifications, Patagonia conforms one single region. Besides, except in the ichthyologic classification of López et al. (2002), Patagonia extends to the north to include part of the Desaguadero System. In our similarity analysis, it is shown that this system defines a separate province (Cuyo) and it is more closely related to northern provinces.

Gastropod Transitional Zone

Coincides with the area of the same name defined by Bonetto (1994) based on hydrography, and it shows higher similarity to the Del Plata basins than to Patagonian basins.

On the other hand, the three great clusters of provinces of freshwater gastropods are partly coincident with the provinces proposed by Ringuelet (1975) based on ichthyology. The main difference is the conformation – for freshwater gastropods – of a central-western area (which includes Province VI and Transitional Zone), with Paraná-Plata affinities; in the ichthyologic classifications, part of the area corresponding to gastropods Province VI is included in the Patagonian Province. The cluster including provinces I to V is equivalent to the Brazilian Subregion of Bonetto (1994), and to the Paranense Dominio of Ringuelet (1975).

Analyzing the biological value, Burkart et al. (1999) showed that the highest values of biodiversity and endemism of Argentina are in the rainforests of Misiones and the Cloud Forest or Yungas. For gastropods, the highest values of diversity recorded for basins are found in the rainforest environments of Misiones (Province I) but not in the Yungas. The second most diverse place was in basins of Province IV. On the other hand, López et al. (2002) recorded the highest richness of fish species in the Middle and Lower Paraná River and in the rainforest of Misiones. In turn, Misionerean ecoregion of fish recorded a great amount of endemism. According to this classification, the Uruguay River – together with the Somuncuará System – shows the least endemism. The highest values of gastropod richness (51) occurred in Province III (Uruguay River), which also records the highest number of vulnerable (14) and endemic species (seven of the province and another five of Argentina), most of them belonging to Lithoglyphidae and to *Felliponea* spp. (Ampullariidae).

Proposals for management and protection areas at a world-wide level are established on the basis of diverse sources of information. However, invertebrates in general and gastropods in particular are not frequently used. Regrettably, most areas important for mollusk diversity have not been recognized by inclusion in the Ramsar List of Wetlands of International Importance (Strong et al., 2008). Besides, areas of highest diversity are not necessarily the same for different taxa, and some areas low biodiversity could still have an important fauna, such as the Uruguay River, with its peculiar gastropods.

Finally, it is worth noting that within the provinces it is important to identify the areas with a greater risk of degradation, either due to the construction of dams, to deforestation, or to agricultural or cattle-related activities. For example, the provinces with the greatest gastropod diversity (Provinces I and IV), according to Bertonati & Corcuera (2000), are in areas with the highest degradation level. It is important to note that Province IV is the most densely populated province of the country (more than 50%). Besides, the Uruguay River (Province III with the highest richness and number of endemic and vulnerable species of gastropods) lies within the political limits among three countries: Brazil, Uruguay and Argentina. Along its course there are at least five hydroelectric dams, and on its margin there are several industries that dispose of waste products into the river. Despite the fact that there are 17 protected areas in the province, only two of them are actually located on the Uruguay River. However, their objective is restricted to the protection of some terrestrial environments. As Suski & Cooke (2007) mention, no plans exist for the protection of aquatic environments in most of the protected areas. In addition, there are no protected areas in neighboring countries adjacent to these reserves in Argentina. Therefore, it is essential to focus the conservation plans on the basis of adequate faunal studies.

ACKNOWLEDGEMENT

This study was funded by Facultad de Ciencias Naturales y Museo, UNLP (PN: 470).

LITERATURE CITED

BARGUES, M. D., S. MAS COMA, R. L. MERA y SIERRA, H. G. GÓMEZ & P. ARTIGAS, 2006, Ribosomal DNA ITS-1 sequencing of *Galba truncatula* (Gastropoda, Lymnaeidae) and its potential impact on fascioliasis transmission in Mendoza, Argentina. *Animal Biodiversity and Conservation*, 29(2): 191–194.

BERTONATTI, C. & J. CORCUERA, 2000, *Situación ambiental Argentina 2000*. Fundación Vida Silvestre Argentina, Buenos Aires, Argentina, 2nd ed., 440 pp.

BONETTO, A. A., 1994, Austral rivers of South America. Pp. 425–472, in: R. MARGALEFF, ed., *Limnology now: a paradigm of planetary problems.* Elsevier Science, Amsterdam, The Netherlands, xvii + 553 pp.

BURKART, R., N. BÁRBARO, O. SÁNCHEZ & D. A. GÓMEZ, 1999, *Eco-regiones de la Argentina*. Programa Desarrollo Institucional Ambiental Administración de Parques Nacionales. Secretaría de Recursos Naturales y Desarrollo Sustentable, Buenos Aires, Argentina, 42 pp.

CANEVARI, P., D. E. BLANCO, E. BUCHER, G. CASERO & E. I. DAVIDSON, 1999, *Los humedales de la Argentina. Clasificación, situación actual, conservación y legislación.* Wetlands International, SRNYDS, Buenos Aires, Argentina, 208 pp.

CASTELLANOS, Z. A. de & M. C. GAILLARD, 1981, Mollusca Gasterópoda: Chilinidae. *Fauna de Agua Dulce de la República Argentina*. PROFADU (CONICET), Buenos Aires, 15(4): 23–51.

CASTELLANOS, Z. A. de & S. MIQUEL, 1980, Notas complementarias al género *Chilina* Gray (Mollusca Pulmonata). *Neotrópica*, 26(76): 171–178.

KOVACH COMPUTING SERVICE, 2006, *A multi variate statistical package for Windows*. Version 3.13. Kovach Computing Services, Wales, U.K.

LÓPEZ, H. L., C. MORGAN & M. J. MONTENEGRO, 2002, Ichthyological ecoregions of Argentina. *Probiota*, 1: 1–70.

MORRONE, J. J., 2002, Biogeographical regions under track and cladistic scrutiny. *Journal of Biogeography*, 29: 149–152.

MORRONE, J. J., 2006, Biogeographic areas and transition zones of Latin America and the Caribbean islands based on panbiogeographic and cladistic analyses of the entomofauna. Annual *Review of* Entomology, 51: 467–494.

OSTROWSKI de NÚÑEZ, M. & M. G. QUINTANA, 2008, The life cycle of *Stephanoprora aylacostoma n. sp.* (Digenea: Echinostomatidae), parasite of the threatened snail *Aylacostoma chloroticum* (Prosobranchia, Thiaridae) in Argentina. *Parasitology Research*, 102: 647–655.

QUINTANA, M. G. & A. C. MERCADO LACZKÓ, 1997, Biodiversidad en peligro. Caracoles de los rápidos en Yaciretá. *Ciencia Hoy*, 7(41): 22–31.

RABINOVICH, J. E. & E. H. RAPOPORT, 1975, Geographical variation of diversity in Argentina passerine birds. *Journal of Biogeography*, 2: 141–157.

REAL, R. & J. M. VARGAS, 1996, The probabilistic basis of Jaccard's index of similarity. *Systematic Biology*, 45: 380–385.

RINGUELET, R. A., 1975, Zoogeografía y ecología de los peces de aguas continentales de la Argentina y consideraciones sobre áreas ictiológicas de América del Sur. *Ecosur*, 2(3): 1–122.

RUMI, A., D. E. GUTIÉRREZ GREGORIC, V. NÚÑEZ, I. I. CESAR, M. A. ROCHE, M. P. TASSARA, S. M. MARTÍN & M. F. LÓPEZ ARMENGOL, 2006, Freshwater Gastropoda from Argentina: species richness, distribution patterns, and an evaluation of endangered species. *Malacologia*, 49: 189–208.

RUMI, A., D. E. GUTIÉRREZ GREGORIC, V. NÚÑEZ & G. A. DARRIGRAN, 2008, Malacología latinoamericana. Moluscos de agua dulce de la República Argentina. *Revista Biología Tropical*, 56(1): 77–111.

SISTEMA NACIONAL de INFORMACIÓN HÍDRICA, 2002, Atlas digital de los recursos hídricos superficiales de la República Argentina. Subsecretaría de Recursos Hídricos, Instituto Nacional del Agua. http://www.hidricosargentina.gov.ar/MapaCuencas.html [Consulted 19 March 2008].

STRONG, E. E., O. GARGOMINY, W. F. PONDER & P. BOUCHET, 2008, Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. *Hydrobiologia*, 595: 149–166.

SUSKI, C. D. & S. J. COOKE, 2007, Conservation of aquatic resources through the use of freshwater protected areas: opportunities and challenges. *Biodiversity and Conservation*, 16: 2015–2029.

WORLD CONSERVATION MONITORING CENTRE (WCMC), 1998, *Freshwater biodiversity: a preliminary global assessment*. Ed. by B. GROOMBRIDGE & M. JENKINS. World Conservation Press, Cambridge, U.K., 104 pp.

Revised ms. accepted 9 February 2010