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Identifying priority areas for invertebrate conservation using land snails as models

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ABSTRACT

Mollusca are a megadiverse phylum with an estimated number of 70,000 to 76,000 described species which can inhabit a wide variety of environments. Among them, land snails are a main component of terrestrial ecosystems and they play a pivotal role in ecosystem functioning. They are suffering habitat loss, overexploitation and competition from introduced species, but are regarded as a “non-charismatic” group for conservation purposes. Orthalicoidea is a dominant faunal element in the Neotropics and in Argentina includes 104 species that inhabit a variety of environments. Their abundance, diversity, comprehensive taxonomy and widespread representation in different ecoregions makes this molluscan group an excellent model for biodiversity assessments. The database used here consisted of 985 unique geographic records of 104 species. Species distribution models were generated using the Maximum Entropy method and Zonation v 3.1 was used to evaluate the proposed conservation goals. Three analyses including species distributions, the current protected areas system (PAs) and the Human print layer were carried out. This allowed the identification of priority areas for conservation, the percentage of the species distribution under PAs and analysis of the potential impacts under current land uses and in the priority areas detected above. Sixty-one species were modeled, and 59 of them were included in the priority area selection process due to their high area under curve (AUC) scores. Five high priority areas located in the different ecoregions, were identified: 1-dry Chaco, 2-humid Pampas, 3-Southern Andean Yungas, 4-Alto Paraná Atlantic Forests and 5-high Monte. A small percentage of the average distribution range of Orthalicoidean species (3%) was within the current protected areas. Highest-ranked priority areas for land snails are outside the current protected areas system. When human impact is considered, the priority areas are reduced in size and appear as small patches. However, highest priority areas for conservation continue being those detected in the above analyses. Most of the areas detected are used for economic purposes, creating conflicts of interest between the development of human activities and conservation. This study represents one of the first attempts to identify ecoregion level priority areas for a terrestrial invertebrate group. Further analyses, including new predictors and other molluscan taxa, would improve planning the conservation of poorly known invertebrate groups.

Keywords: Mollusca; Orthalicoidea; Protected areas; Species distribution modelling; Zonation.

Introduction

Invertebrates represent the largest proportion of terrestrial and freshwater biodiversity and, despite their minute size, they play a pivotal role in ecosystem functioning (Fontaine et al., 2007; McGeoch et al., 2011; New, 2011). However, most conservation strategies focus on vertebrate protection and there is considerable uncertainty as to how these strategies translate to invertebrates (Kerr, 1997; Fontaine et al., 2007; McGeoch et al., 2011). Mollusks are considered a megadiverse group containing an estimated 70,000 to 76,000 described species (Rosenberg, 2014) comprising about 25,000 terrestrial species worldwide (Bouchet, 2007). Land snails form an important component of terrestrial ecosystems by recycling nutrients, and many of them are food resources for many small mammals, birds, reptiles, amphibians and other invertebrates, including carnivorous snails (Deepak et al., 2010). In calcium poor habitats land snails can form an important source of calcium for other animals (Jurickova et al., 2007) and play a key role in soil generation and water filtration (Cuttelod et al., 2011). Land snails also serve as an indicator of ecological condition, and are very sensitive to climatic and ecological change (Sen et al., 2012). Globally, land snails are facing an unprecedented survival crisis resulting from habitat loss, overexploitation and competition with introduced species (Lydeard et al., 2004; Solymos & Feher, 2005; Regnier et al., 2009; Cowie et al., 2017). However, land snails have traditionally been considered a "non-charismatic" group and usually have not been included in lists of priority species for conservation.

Biodiversity loss makes ecosystems vulnerable, alters processes and changes the resilience of ecosystems to environmental change (Chapin et al., 2000). The main drivers that cause biodiversity decline are climate change, land use change, invasive species, overexploitation, pollution and changes in human population (Sala et al., 2000). Aiming at halting biodiversity loss, the Convention on Biological Diversity (CBD, 2010) proposed that at least 17 per cent of terrestrial and inland waters, especially areas of special importance for biodiversity and ecosystem services, are conserved through effective and balanced management. The aim is to have ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures globally by 2020 (CBD, 2010).

Argentina has 360 protected areas that cover approximately 6.7% of the national territory (Tognelli et al., 2011). During 1934-1960 the territorial integrity and sovereignty were the main motivations for the establishment of the first protected areas. By the mid-60’s, the focus was redirected to protection of ecoregions and some charismatic vertebrate species (Marinaro et al.,

2012) without taking into account invertebrate taxa as a priority for conservation. More recently the effectiveness of the current system of protected areas to conserve vertebrate species (Arzamendia & Giraudo, 2004; Tabeni et al., 2004; Tognelli et al., 2011; Corbalán et al., 2011; Nori et al., 2013) and plants (Ortega Baes et al., 2012) is being evaluated.

The land snail superfamily Orthalicoidea is a dominant faunal element in the Neotropics (Breure & Mogollón, 2010). In Argentina, this superfamily includes 104 species that inhabit a variety of environments ranging from humid subtropical and cold forests to nearly desert areas (Cuezzo et al., 2013; Salas Oroño et al., 2007; Miranda & Cuezzo, 2010). The systematics, taxonomy and distribution of Argentinean Orthalicoidean are well known and have been studied by several authors over time (Parodiz, 1946; Cuezzo et al., 2013; Miranda & Cuezzo, 2014; Miranda, 2015). The abundance, diversity, comprehensive taxonomic information and widespread representation in different ecoregions make the Orthalicoidea an excellent model group for biodiversity assessments. Our goal was to: (1) test the effectiveness of the current protected areas network in safeguarding land snail species; (2) identify priority areas for land snail conservation; (3) analyze priority areas with respect to anthropogenic impacts.

Methods

Study area

Argentina, located in southern South America (from 21º-55º S to 53º-73º W), has the ninth largest land mass in the world, with a total area of 2,791,810 km^2 (Fig. 1A). It is divided into twenty-three political provinces and the Ciudad Autónoma de Buenos Aires (Fig. 1B). The latitudinal position of Argentina between Tropic of Capricorn and Antarctica confers the region a great climatic and ecoregional diversity (Brown & Pacheco, 2006). According to Olson et al. (2001), the Argentinean territory is divided into seventeen ecoregions (Fig. 1A). An ecoregion is a relatively large unit of land or water containing a characteristic set of natural communities that share a large majority of their species, dynamics and environmental conditions.

Data collection

The database used for this study consisted of 985 unique geographic records of 104 species (Table 1), obtained from the following malacological collections: Instituto de Biodiversidad Neotropical (IBN), Tucumán, Argentina; Instituto-Fundación Miguel Lillo (IFML-Moll), Tucumán, Argentina; Museo de La Plata (MLP), Buenos Aires, Argentina; Museo de Ciencias Naturales "Bernardino Rivadavia" (MACN-In), Buenos Aires, Argentina; Museo de Ciencias Naturales "José Lorca" (MCNL), Mendoza, Argentina; Field Museum of Natural History (FMNH), Chicago, USA; Academy of Natural Sciences of Philadelphia (ANSP), Philadelphia, USA, plus relevant literature. Extensive field work was conducted over the last 20 years by Instituto de Biodiversidad Neotropical (IBN) where the sampling effort was standardized over time. The time window spanned 30 min at each site.

Locations without geographical coordinates were georeferenced using GEOLocate (http://www.museum.tulane.edu/geolocate/web/webgeoref.aspx). Digital layers of ecoregions were obtained from Olson et al. (2001); the National System of Protected Areas was taken from protectedplanet.net and www.parquesnacionales.gob.ar, Biosphere reserves were not considered in the analyses as their focus is on managing ecosystem changes linked to human activity. All data obtained were analyzed using QGIS 2.8 software (http://qgis.osgeo.org) to evaluate the distribution of the species included in the analysis. Species records were plotted and overlapped with layers of different types of information such as political subdivisions and ecoregions. The Human Influence Index (HII) dataset of 1-kilometer grid cells was used in Zonation. This dataset was created from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover), and human access (coastlines, roads, railroads) (WCS & CIESIN, 2005).

Species Distribution Modeling

Species distribution models were generated using the Maximum Entropy method (MaxEnt version 3.3.3k; Phillips et al., 2006, 2009). Default parameters for MaxEnt were used, including a maximum of 500 iterations, with a convergence threshold of 0.00001, and 10,000 randomly generated background localities. The logistic output format was chosen for the selected model value because it provides an estimated probability of presence between 0 (unsuitable for species presence) and 1 (highly suitable for species presence). A layer corresponding to topographic variable (altitude) was obtained from DIVA resource (http://www.diva-gis.org/gdata). Additionally, nineteen bioclimatic variables were used in the algorithm. The bioclimatic information was derived from monthly min/max temperature and precipitation data taken from the WorldClim database (Hijmans et al., 2005) averaged to calculate annual trends for the period 1950–2000 with a spatial resolution of 2.5 arc min (4.65 km).

As the lower limit strongly depends on the species' prevalence and the specific features of the targeted study area (Proosdij et al., 2015), we did not model those species with ≤ three geographical records and the remaining species were divided into two groups: Low - four to ten records; High - ≥11 records. The validation of the models in the first group was performed using the Jackknife validation approach (Pearson et al., 2007; Corbalán et al., 2011; Rinnhofer et al., 2012). The jackknife validation approach proposed enabled assessment of the predictive ability of models built using very small sample sizes (Pearson et al., 2007). The number of iterative runs was set as equal to the number of records available and resulting models were tested using ValueCompute software (Pearson et al., 2007). For the second group, we used a random percentage test, in which 75% of the records were randomly selected to generate models and the remaining 25% were used to test them. The performance of each model was also assessed using the Area Under the Curve (AUC) method of the Receiver Operating Characteristic (ROC). The AUC is a threshold independent index used to assess prediction maps, which is expressed in values between 0.5 (no predictability) and 1 (perfect prediction). This study followed the parameters established in Elith et al. (2006) and Loo et al. (2007), in which models that have an AUC value of > 0.75 are considered to have a useful amount of discrimination.

Conservation prioritization analysis

Zonation v 3.1 (Moilanen & Kujala, 2008) was used to identify priority areas for the conservation of Orthalicoidean species. This software uses large grids of probabilistic data as input files and provides a correlation between species distribution modeling data and spatial conservation prioritization (Moilanen et al., 2005; Taberlet et al., 2012). Also, it produces a hierarchical prioritization of the landscape based on the occurrence levels of biodiversity features (species, land cover types, etc.) in grid cells (a pixel on a map). Zonation uses a raster for each biodiversity feature, where each cell (pixel) contains a number for the occurrence level of that feature. The way loss of conservation value is aggregated across features (occurring in a cell) depends on the so-called cell-removal rule. Iterative priority ranking starts from the full landscape and removes cells stepwise, minimizing loss, until no more remain. Least valuable cells (e.g. a few common species occurring) are removed first, while the most important cells for biodiversity (e.g. high species richness and species occurrence) are kept till last. The ranking enables easy identification and visualization as a prioritized rank map with colors indicating different rank values (Lehtomäki & Moilanen, 2013).

To established the priority ranking, the Core-area Zonation (CAZ) removal rule was selected. This procedure bases ranking on "the most important occurrence of a feature in the cell". Therefore, it is able to identify those areas that have a high occurrence level for a single rare and/or highly weighted feature as high-priority (Moilanen et al., 2012; Di Minin et al., 2014). Differential weights were assigned to analyzed species; endemic species (selected by their condition at country level) were assigned a weight of two, while the remaining species were given a weight of one. An "unconstrained" analysis was carried out considering only the species distribution to identify the areas with the highest priority conservation areas. We used the following ranking in the priority map: top 1.47% (equivalent to percentage of the area protected by National Parks), top 6.7% (equivalent to percentage of the total PAs in the country) and top 17% (equivalent to that 17% target recommended by CBD). A second analysis included the existing PAs using a hierarchical mask, and we tested the proportion of Orthalicoidean species distribution within them. Finally, we used as negative variable the Human Footprint V 2.0 (WCS & CIESIN, 2005) "penalizing" the pixels with high human influence according the proposal of Nori et al. (2016). This variable was included in Zonation the same way as the layers of the species distribution and was weighted as a negative value, while species distribution had a positive weight so that the sum of the individual weights of each species and negative variable equals zero.

Endemic species that were not modeled, together with those not found statistically significant using the Jackknife validation approach, were categorized in the prioritization analysis as Species of Special Interest (SSI) (Table 1, 2). For each performed analysis, the only predicted distributions that were used were those of the Orthalicoidean species that had been validated in their primary input.

After running the prioritization analysis, performance curves were plotted which quantify the proportion of the original occurrences retained for each biodiversity feature (Di Minin et al., 2014; Moilanen et al., 2014) at each top fraction of the landscape chosen for conservation. This allowed us to determine the representativeness of the current PAs network and the top priority 17% of the available territory.

Results

Based on the current distribution of Orthalicoidea (Fig. 1A), 56 species (55 %) are ecologically rare, meaning endemic species restricted to a single ecoregion, and 72 (70 %) are geographically rare, meaning species endemic to Argentina with restricted distributional areas. The dry Chaco is the ecoregion with the highest endemism, with 39 endemic species (36 %). On the other hand, only 37 species (35%) were recorded within the current protected areas system, including four species considered as SSI in our analyses (Table 1, 2).

Models that were evaluated with the Jackknife validation method (average success rate=0.71; $p<0.05$) demonstrated that almost all species with a low number of records obtained statistically significant results, as well as an excellent discrimination of occurrence, including an average AUC score of 0.954 (range:0.758 -0.998). Species with a high number of records ($n>11$) also obtained a high average AUC score (0.967; range 0.892 - 0.996). Consequently, all modeled species were included in the priority area selection process. Sixty-one species were modeled, and 59 of them were included in the priority area selection process due to their high AUC scores. The "unconstrained" analysis showed five areas with highest priority for conservation located in the different ecoregions, 1-dry Chaco (mainly north-western Córdoba province), 2-humid Pampas (southeastern Buenos Aires province), 3-Southern Andean Yungas (northwestern portion of the country), 4-Alto Paraná Atlantic Forests (northeastern portion of the country) and 5-high Monte (central part of La Rioja and eastern San Juan provinces) (Fig. 2A). In this initial analysis, considering the top 1.47% fraction area (equivalent to the percentage of the National Parks system area) would protect, on average, 6.44% (range: 1.2–17.4%) of the geographic range of the analyzed Orthalicoidean species (Fig. 2B). Species with limited distribution ranges would receive greater protection than species with wider distribution areas (Fig. 2B). Similarly, non-endemic species made up a higher percentage of protection than endemics (Fig. 2B). Among endemic species, *Clessinia tucumanensis* (Parodiz, 1941) and *Plagiodontes daedaleus* (Deshayes, 1851) would have the highest percentage of protection coverage (15.9%), followed by *Clessinia martensii* (Doering, 1874b [1875]) (12.4%) (Fig. 2B). For the remaining endemic species, less of the 10% of their distribution would be protected under this scenario (Fig. 2B). When we take into account the 6.7% top fraction of the landscape (percentage of total protected areas), the average species' ranges protected increased to 23.9% (range: 5.5–52.7) (Fig. 2C). Less than 30% of the distribution of most endemic species would be protected (Fig. 2C). Considering the 17% target, the number of priority areas does not increase relative to the previous analysis (considering the 1.47%) but an expansion of those areas covering more territory was observed. In the top fraction of the landscape, the average species distribution protection would increase to 45% (Fig. 2D). The distribution of nineteen endemic species would be between 40% to close to 60% protected (Fig. 2D).

When we consider the existing protected areas in Argentina, only a small percentage of the average distribution range of Orthalicoidean species (3%) is within the current protected areas. Highest-ranked priority areas for land snails in the unconstrained analyses are outside of most PAs (Fig. 3A). In Northwestern Argentina there are seven National Parks that protect part of the ecoregions of Southern Andean Yungas and dry Chaco (Baritú, Calilegua, Copo, Pizarro and El Rey), Monte and Central Andean dry Puna (Los Cardones) and Southern Andean Yungas and Central Andean Puna (Campo de Los Alisos) (Fig. 1B). In the central part of Argentina (Córdoba province) there is only one National Park (Quebrada del Condorito) that protects the dry Chaco while in southwestern Buenos Aires one national park (Campos del Tuyú) protects part of Humid Pampas ecorregion (Fig. 1B). The priority areas obtained in the "unconstrained" analysis and those considering the existing protected areas analysis, occupy the same total area, although a high level of fragmentation of these areas in the "unconstrained" analysis can be seen (Fig. 3A).

To protect 17% of the study area, the current protected areas would require an increase of 7.6% in their total surface. Under this scenario, an average of 45.9% (range: 78.5–14.1) of all species distributions would be represented. As an example, *Plagiodontes daedaleus*, would have almost 78.5% of its distribution range under protection. On the other hand, the endemic *Discoleus ameghinoi* von Ihering, 1908, would only have 16.4% of its distribution range under protection (Fig. 3B).

The human footprint superimposed on species distribution significantly modified the previous analyses. Surprisingly, the priority areas suffered a dramatic reduction in their extension in comparison with the previous results. Many of the areas appear isolated from each other, mainly located in the Northwestern Argentina (Fig. 3C) and the species distributions are also affected (Fig. 3D). Despite this, the highest priority areas continue to be within the dry Chaco, Southern Andean Yungas, Alto Paraná Atlantic Forests and humid Pampas (Fig. 3C). A significant portion of these ecoregions are currently occupied by agriculture and cattle production creating a potential conflict of interest between the development of economic activity and the protection of mollusks.

DISCUSSION

Conservation prioritization areas in different ecoregions

All the conservation prioritization analyses carried out showed areas that protect part of five ecoregions of Argentina. Some of these ecoregions are treated as “Vulnerable” or “Critical/Endangered” by World Wide Fund for Nature (WWF) such as the dry Chaco, Southern Andean Yungas and humid Pampas (Olson et al., 2001). The cloud forests of Yungas, as well as the dry Chaco, are being destroyed at one of the fastest rates in the world and dry Chaco is the ecoregion with the lowest level of protection (Izquierdo & Grau, 2008; Persson et al., 2014). The dry Chaco has suffered from the effects of human population increase (Roig, 1991), the advance of the agricultural frontier, especially soya beans, wheat and other crops that have replaced native forests; domestic animal populations have also remained high (Izquierdo & Grau, 2008; Gasparri et al., 2013). The situation in the Southern Andean Yungas is also critical as it has been estimated that more than one-half of the original forest has disappeared due to logging, agriculture and urbanization. The humid Pampas is one of the most highly human populated areas in Argentina and is extensively used for agriculture and cattle grazing (Dinerstein et al., 1995). The northwestern portions of the country are being affected by climate change and anthropogenic activities and the presence of cattle (grazing), erosion, industrial activity, mining and contamination of water supplies (Gonzales, 2009; Godoy-Bürki et al., 2013).

Areas within the Southern Andean Yungas and dry Chaco (Chaco Serrano sub-ecoregion) identified here as having high priority for land snail conservation are consistent with previous studies, both for groups of vertebrates and invertebrates. For example, for the protection of several xenarthra species, the Southern Andean Yungas and the Alto Paraná Atlantic Forests ecoregions were set up as priority areas (Tognelli et al., 2011) in the same way they were to macroinvertebrates, the basins located in the Southern Andean Yungas (Nieto et al., 2017).

Land gastropods of the dry Chaco merit special attention because they comprise a highly diverse group of mostly endemic species to this ecoregion. *Clessinia* inhabits the dry Chaco of Argentina and contains endemic rare species (Cuezzo et al., 2018). Also, *Bostryx peristomatus* (Doering, 1879) (Bulimulidae) is endemic to north western Córdoba. Nori et al. (2011, 2013) also identified that these dry Chaco areas are of significant conservation value for amphibians and reptiles. At the same time, the dry Chaco of Córdoba has high crop production and yields per planted area and suffers uncontrolled deforestation; frequent forest fires are also causing significant losses of habitats (Britos & Barchuk, 2008; Izquierdo et al., 2011). Within the high Monte in the central part of La Rioja and eastern San Juan provinces, priority areas for conservation identified here are coincident with priority areas for vascular plants (Godoy-Bürki et al., 2013).

Current Protected Areas

A small percentage of the Orthalicoidean land snail average distribution ranges are safeguarded within current protected areas, showing that the existing protected areas system is not effective at all for the protection of land snail species. Some large priority areas for conservation occur adjacent to (or in buffer) areas of current PAs, mainly in the Northwestern Argentina (Fig. 2A). Several studies carried out in Argentina have shown strong evidence that the existing protection system of Argentina is not effective for safeguarding vertebrates (Arzamendia & Giraudo, 2004; Tabeni et al., 2004; Corbalán et al., 2011; Tognelli et al., 2011; Nori et al., 2013), plants (Chehebar et al., 2013; Godoy-Bürki et al., 2013) or invertebrate species (Chehebar et al., 2013; Nieto et al., 2017).

When considering the percentage recommended by CBD (2010) for conservation, the analyses identified the same areas of interest as the "unconstrained" analysis (Fig. 2A). The only difference was an expansion of the priority areas when calculating the ideal percentage of protection (17%). However, a mere increase in the extent of terrestrial Protected Areas does not necessarily guarantee the protection of more species. Despite the increase in the extent of terrestrial PAs in the last decade, the proportion of animal species outside PAs has also increased (Nori et al., 2015).

Human footprint and conservation

The impact of the growing extent and intensity of human influences on landscapes is reflected in of loss and degradation of natural habitats and in the species that they contain (McGowan, 2016). The analysis identified that some areas continue to be classified within the highest conservation priorities, despite the fact that they are under the human pressure. The reduction in the extension of the priority areas and fragmentation into small disconnected patches could bring about a decrease in dispersion rates, population survival and species richness in these areas as a consequence. Also, we highlighted how the dearth of protected areas and excess human pressure may lead to the extinction of both SSIs and species with limited distribution ranges that inhabit these areas. Patches of land that are not currently under agriculture could be used for conservation and serve as a refuge for molluscs and other invertebrates. For example, some small patches of dry Chaco in Córdoba (from the Northwestern to the southwestern) and close to the political limits with Santiago del Estero province are areas of high conservation value that still hold many living endemic species. To the south, in the low Monte ecoregion, land patches close to the limit between Córdoba and San Luis provinces are still available for conservation purposes. New strategies for invertebrate conservation should focus on the protection of these small patches and, if possible, restore those modified habitats that are a priority for the conservation of Orthalicoidean species.

Habitat fragmentation is considered as one of the major drivers of biodiversity loss world-wide (Bailey et al., 2010). When a continuous habitat is transformed into many smaller patches a reduction in migration rates, dispersal success, abundance and species richness follow (Fischer & Lindenmayer, 2010). A real conflict exists between the human development and conservation and some authors have proposed strategies to reconcile such conflicts (Henle at al., 2008). However agricultural policies, expansion in the agricultural activities and interests (mostly geared towards economic gains) clash with the conservation of biodiversity in agricultural landscapes (Henle et al., 2008).

In Argentina, the following ecoregions suffer strong impact of agriculture: humid Chaco and Espinal, located in the central-eastern part of the country, from Corrientes and Entre Rios to southern Buenos Aires province; the dry Chaco, from Formosa to northern Córdoba; the Southern Andean Yungas ecoregion, from Jujuy to Tucumán provinces (Cabido et al., 2005; Britos & Barchuk, 2008; Gonzáles, 2009). On the contrary, the Low Monte and the Patagonian Steppe ecoregions within the central-southern portions of the country are more affected by livestock production (Guevara et al., 2009).

A narrow strip was identified as priority for conservation in Northwestern Argentina, as it has the largest continuous area of Yungas in the country and hosts a high diversity, including endemic and endangered species. It is coincident with the "Reserva de Biosfera de Las Yungas" recognized by UNESCO, with the aim is to promote solutions reconciling the conservation of biodiversity with its sustainable use in the Yungas Area (Le Ster et al., 2015). Only national parks and provincial reserves included in it truly constitute areas with total protection (also known as the "Core area"), among them the Baritú and Calilegua National Parks and Pintascayo and Potrero de Yala Provincial Parks (Lomáscolo et al., 2010). In buffer areas the main activities are sustainable forestry, livestock and agriculture (potato, corn, peanuts, chili) in small areas. Most peripheral areas correspond to transition areas, mostly within private properties. These are used for large scale agriculture (sugar cane, soybean, corn, banana, citrus and vegetable plantations), livestock, forestry, industrial activities and human settlements (Lomáscolo et al., 2010). Orthalicoidean species are, however, also distributed outside the core areas, which makes them vulnerable to continued economic activities in those areas without protected status.

When land uses are taken into account, small areas of the humid Pampas ecoregion of southern Buenos Aires have high conservation priority for land snails. The Humid Pampas is almost completely affected by agriculture, but contain a rich endemic fauna and are inhabited by various SSIs (i.e. *Plagiodontes rocae* Doering, 1881, *P. patagonicus* and *Cyclodontina (Ventania*) *avellanedae*) that should be protected. Furthermore, these areas are located in two mountainous systems identified as areas of endemism for other invertebrate groups (Ferretti et al., 2012).

This study represents one of the first attempts to identify priority areas, at the ecoregion level, for a terrestrial invertebrate group, also analyzing the influence of land uses on biodiversity conservation. Although our results pinpoint potential areas for mollusks conservation, it is important to recognize some limitations of our analyses. Our results are based on distribution modelling and we focused on those rare and endemic species, which are generally the strongest predictors of the extinction risk of species (Isik, 2011), but we cannot know how well other species are represented. Thus, we believe that two steps are central to the evaluation of biodiversity conservation in order to obtain robust conclusions: first, the application of expertise of taxonomists and natural history museums that offer a wealth of data suitable for the study; second, the availability of reproducible Model-based analyses that can be rigorously evaluated.

Additional studies, including new information regarding other mollusks groups, should be performed. It is clear from our results that areas currently protected, mainly designed for vertebrates, are not effective in protecting biodiversity, especially in the light of mollusks. Moreover, global climatic change, together with changing land use, are affecting the distribution areas of invertebrates in a way not yet completely understood. For these reasons, analyses including new predictors and the refinements of models would be useful tools for future conservation decisions in order to protect the poorly known groups.

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References

Arzamendia, V., & Giraudo, A. R. (2004). Usando patrones de biodiversidad para la evaluación y diseño de áreas protegidas: las serpientes de la provincia de Santa Fe (Argentina) como ejemplo. *Revista Chilena de Historia Natural*, *77*, 335–348.

Bailey, D., Schmidt- Entling, M. H., Eberhart, P., Herrmann, J. D., Hofer, G., Kormann, U. & Herzog, F. (2010). Effects of habitat amount and isolation on biodiversity in fragmented traditional orchards. *Journal of Applied Ecology*, 47, 1003–1013.

Bouchet, P. 2007 Inventorying the molluscan fauna of the world: how far to go? In: K. Jordaens, N. van Houtte, J. Van Goethem, and T. Backeljau. (eds) Abstracts of the World Congress of Malacology, Antwerp, Belgium

Breure, A. S. H., & Mogollon, V. (2010). Well-known and little-known: miscellaneous notes on Peruvian Orthalicidae (Gastropoda, Stylommatophora). *Zoologische Mededelingen*, *84*, 15–35.

Britos, A. H., & Barchuk, A. H. (2008). Cambios en la cobertura y en el uso de la tierra en dos sitios del Chaco Árido del noroeste de Córdoba, Argentina. *Agriscientia*, *25*, 97–110.

Brown, A.D., & Pacheco, S. (2006). Propuesta de actualización del mapa ecorregional de la Argentina. In A. D., Brown, U., Martinez Ortiz, Acerbi, & J. Corcuera (Eds.), *La situación ambiental argentina 2005*. Fundación Vida Silvestre Argentina. Buenos Aires, pp 1–587.

Cabido, Marcelo & Zak, Marcelo & Cingolani, Ana & Cáceres, Daniel M. & Diaz, Sandra. (2005). Cambios en la cobertura de la vegetación del centro de Argentina. ¿Factores directos o causas subyacentes?.

CBD (2010). Convention on Biological Diversity. https://www.cbd.int/2010-target/

Chapin, F. S., Zavaleta, E. S., Eviner, V. T., Rosamond, L. N., Vitousek, P. M., Reynolds, H. L., Hooper, D. U., Lavorel, S., Sala, O. E., Hobbie, S. E., Mack, M. C., & Díaz, S. (2000). Consequences of changing biodiversity. *Nature*, *405*, 234–42.

Chehebar, C., Novaro, A., Iglesias, G., Walker, S., Funes, M., Tammone, M., & Didier, K. (2013). *Identificación de áreas de importancia para la biodiversidad en la estepa y el monte de Patagonia-Valoración en base a distribución de especies y ecosistemas,* pp. 112. APN/WCS/TNC.

Corbalán, V., Tognelli, M. F., Scolaro, J. A., & Roig-Juñent, S. A. (2011). Lizards as conservation targets in Argentinean Patagonia. *Journal of Nature Conservation*, *19*, 60–67.

Cowie, R. H., Regnier, C., Fontaine, B., & Bouchet, P. (2017). Measuring the Sixth Extinction: what do mollusks tell us?. *The Nautilus, 131*(1), 3–41.

Cuezzo, M. G., Miranda, M. J., & Ovando, X. C. M. (2013). Catalogue of the nominal taxa of Orthalicoidea in Argentina (Gastropoda: Stylommatophora). *Malacologia, 56*, 135–191.

Cuezzo, M. G., Miranda, M. J., Vogler, R. E., & Beltramino, A. A. 2018. From morphology to molecules: A combined source approach to untangle the taxonomy of *Clessinia* (Gastropoda, Odontostomidae), endemic land snails from the Dry Chaco ecoregion. *PeerJ* 6:e5986 DOI 10.7717/peerj.5986

Deepak, V., Vasudevan, K., & Pandav, B. (2010). Preliminary observation on the diet of the cane turtle (*Vijayachelys silvatica*). *Hamdaryad, 34*, 166–168.

Di Minin, E., Veach, V., Lehtomäki, J., Pouzols, F.M. & Moilanen, A. (2014). A quick introduction to Zonation. Unigrafia OY, Helsinki.

Dinerstein, E., Olson, D. M., Graham, D. J., Webster, A. L., Primm, S. A., Bookbinder, M. P., & Ledec, G. (1995). *Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean*. The World Bank: Washington, D.C, USA.

Elith, J., Graham, C. H., Anderson, R. P., Dudík, M., Ferrier, S., Robert, A. G., Hijmans, J., Huettmann, F., Leathwick, J. R., Lehmann, A., Li, J., Lohmann, L. G., Loiselle, B. A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., McC. Overton, J., Townsend Peterson, A., Phillips, S. J., Richardson, K., Scachetti-Pereira, R., Schapire, R. E., Soberón, J., Williams, S., Wisz, M. S., & Zimmermann, N. E. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, *29*, 129–151.

Ferretti, N. E., Gonzalez, A., & Perez-Miles, F. (2012). Historical biogeography of mygalomorph spiders from the peripampasic orogenic arc based on track analysis and PAE as a panbiogeographical tool. *Systematics and Biodiversity*, *10*: 179–193.

Fontaine, B., Bouchet, P., Van Achterberg, K., Alonso-Zarazaga, M. A., Araujo, R., Asche, M., Aspöck, U., Audisio, P., Aukema, B., Bailly, N., Balsamo, M., Bank, R. A., Barnard, P., Belfiore, C., Bogdanowicz, W., Bongers, T., Boxshall, G., Burckhardt, D., Camicas, J. L., Chylarecki, P., Crucitti, P., Deharveng, L., Dubois, A., Enghoff, H., Faubel, A., Fochetti, R., Gargominy, O., Gibson, D., Gibson, R., Gómez López, M. S., Goujet, D., Harvey, M. S., Heller, K.-G., Van Helsdingen, P., Hoch, H., De Jong, H., De Jong, Y., Karsholt, O., Los, W., Lundqvist, L., Magowski, W., Manconi, R., Martens, J., Massard, J. A., Massard-Geimer, G., Mcinnes, S. J., Mendes, L. F., Mey, E., Michelsen, V., Minelli, A., Nielsen, C., Nieto Nafría, J. M., Van Nieukerken, E. J., Noyes, J., Pape, T., Pohl, H., De Prins, W., Ramos, M., Ricci, C., Roselaar, C., Rota, E., Schmidt-Rhaesa, A., Segers, H., Zur Strassen, R., Szeptycki, A., Thibaud, J. M., Thomas, A., Timm, T., Van Tol, J., Vervoort, W., & Willmann, R. (2007). The European union´s 2010 target: Putting rare species in foccus. *Biological Conservation*, *139*, 167–185.

Fischer, J. & Lindenmayer, D.B. (2007). Landscape modification and habitat fragmentation: a synthesis. *Global Ecology and Biogeography*, *16*, 265–280.

Gasparri, I., Grau, H. R., & Gutierrez Angonese, J. (2013). Linkages between soybean and neotropical deforestation: Coupling and transient decoupling dynamics in a multi-decadal analysis. *Global Environmental Change*, *23*, 1605–1614.

Godoy-Bürki, A. C., Ortega-Baes, P., Sajama, J. M., Aagesen, L. (2013). Conservation priorities in the Southern Central Andes: mismatch between endemism and diversity hotspots in the regional flora. *Biodiversity and Conservation*, *23*(1), 81–107

Gonzales, J. A. (2009). Climatic change and other anthropogenic activities are affecting environmental services on the Argentina Northwest (ANW). *Earth and Environmental Science*, *6*, 1–2.

Guevara, J., Grünwaldt, E., Estevez, O., Bisigato, A., Blanco, L., Biurrun, F. N., Ferrando, C., Chirino, C., Morici, E., Fernández, B., Allegretti, L. I., & Passera, C. (2009). Range and livestock production in the Monte Desert, Argentina. *Journal of Arid Environments*, *73*, 228–237. 10.1016/j.jaridenv.2008.02.001.

Henle, k., Alardb, D., Clitherowc, J., Cobbd, P., Firbanke, L., Kullf, T., McCrackeng, D., Moritzh, R. F. A., Niemeä, J., Rebanej, M., Wascherk, D., Wattl, A. & Young, J. (2008), Identifying and Managing the Conflicts between Agriculture and Biodiversity Conservation in Europe—A Review. *Agriculture, Ecosystems and Environment*, 124, 60–71.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. (2005). Very high-resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, *25*, 1965–978.

Isik, K. (2011). Rare and endemic species: Why are they prone to extinction?. *Turkish Journal of Botany*, *35*, 411–417.

Izquierdo, A. E., & Grau, H. R. (2008). Agriculture adjustment, land-use transition and protected areas in Northwestern Argentina. *Journal of Environmental Management*, *90*, 858–865.

Izquierdo, A. E., Grau, H. R., & Mitchel Aide, T. (2011). Implications of Rural–Urban migration for Conservation of the Atlantic Forest and Urban growth in Misiones, Argentina (1970–2030). *Ambio*, *40*, 98–309. doi 10.1007/s13280-010-0095-3.

Jurickova, L., Horsák, M., Cameron, R., Hylander, K., Míkovcová, A., Hlaváčfg, J. C. & Rohovec, J. (2007). Land snail distribution patterns within a site: The role of different calcium sources. *European Journal of Soil Biology*, *44*(2), 172-179.

Kerr, J. T. (1997). Species Richness, Endemism, and the Choice of Areas for Conservation. *Conservation Biology*, *11*, 1094–1100.

Lehtomäki, J., & Moilanen, A. (2013). Methods and workflow for spatial conservation prioritization using Zonation. *Environmental Modelling & Software*, *47*, 128–137.

Le Ster, A., Reid Rata, Y., Bergesio, L. & Malizia, L. R. (2015). Las reservas de biosfera como instrumentos de gestión territorial: el caso de RBYungas (Argentina). *Revista de Estudios Regionales*, *11*, 61–79.

Lomáscolo, T., Brown, A. D., & Malizia, L. R. (2010). *Guía visual de la Reserva de biosfera de las Yungas*. Argentina: Tucumán, Yerba Buena.

Loo, S.E., Mac Nally, R., & Lake, P.S. (2007). Forecasting New Zealand mud snail invasion range: Model comparisons using native and invaded ranges. *Ecological Applications*, *17*, 181–189.

Lydeard, C, Cowie, R. H., Ponder, W. F., Bogan, A. E., Bouchet, P., Clark, S. A., Cummings, K. S., Frest, T. J., Gargominy, O., Herbert, D. G., Hershler, R., Perez, K. E., Roth, B., Seddon, M., Strong, E. E., & Thompson, F. G. (2004). The Global Decline of Nonmarine Mollusks. *BioScience*, *54*, 321–330.

Marinaro, S., Grau, H. R., & Aráoz, E. (2012). Extensión y originalidad en la creación de parques nacionales en relación a cambios gubernamentales y económicos de la Argentina. *Ecologia Austral*, *22*, 1–10.

McGeoch, M. A., Sithole, H., Samways, M. J., Simaika, J. P., Pryke, J. S., Picker, M., Uys, C., Armstrong, A. J., Dippenaar-Schoeman, A. S., Engelbrecht, I. A., & Hamer, M. (2011). Conservation and monitoring of invertebrates in terrestrial protected areas. *Koedoe, 53*, 1–13. doi:10.4102/koedoe.v53i2.1000.

Miranda, M. J., & Cuezzo, M. G. (2010). Biodiversidad de gasterópodos terrestres (Mollusca) en el Parque Biológico Sierra de San Javier, Tucumán, Argentina. *Revista de Biología Tropical*, *58*, 1009–1029.

Miranda, M. J., & Cuezzo, M. G. (2014). Taxonomic revision of the *Bostryx stelzneri* species complex (Gastropoda, Orthalicidae, Bulimulidae). *American Malacological Bulletin*, *32*, 74–93.

Miranda, M. J. (2015). *Bostryx tortoranus* (Doering, 1879) species complex (Gastropoda: Stylommatophora: Bulimulidae), a review of taxonomy and distribution of endemic species from Argentina. *Journal of Natural History*, *49*, 995–1022. doi: 10.1080/00222933.2014.981313.

Moilanen, A., Franco, A. M. A., Early, R., Fox, R., Wintle, B., & Thomas, C. D. (2005). Prioritizing multiple use landscapes for conservation: methods for large multi species planning problems. *Procceedings of the Royal Society B, 272*, 1885–1891.

Moilanen, A., & Kujala, H. (2008). Zonation Spatial conservation planning framework andsoftware. User manual. Version 2. www.helsinki.fi/BioScience/ConsPlan

Moilanen, A., Anderson, B. L., Eigenbrod, F., Heinemeyer, A., Roy, D. B., Gillings, S., Armsworth, P. R., Gaston, K. J., & Thomas, C. D. (2011). Balancing alternative land uses in conservation prioritization. *Ecological Applications*, *21*, 1419–1426.

Moilanen, A., Meller, L., Leppänen, J., Montesino, Pouzol, F., Arponen, A., & Kujala, H. (2012). Zonation Spatial conservation planning framework and software. User manual. Version 3.1

New, T.R. (2011). Strategic planning for invertebrate species conservation-how effective is it?. *JoTT Essays*, *3*, 2033–2044.

Nieto, C., Ovando, X. M. C., Loyola, R., Izquierdo, A., Romero, F., Molineri, C., Rodríguez, J., Rueda Martín, P., Fernández, H., Manzo, V., Miranda, M. J. (2017). The role of macroinvertebrates for conservation of freshwater systems. *Ecology and Evolution*, *7*(14), 5502-5513. doi: 10.1002/ece3.3101.

Nori, J., Diaz Gomez, J. M., & Leynaud, G. C. (2011). Biogeographic regions of Central Argentina based on snake distribution: evaluating two different methodological approaches. *Journal of Natural History*, *45*, 1005–1020.

Nori, J., Lescano, J. N., Illoldi Rangel, P., Frutos, N., Cabrera, M. R., & Leynaud, G. C. (2013). The conflict between agricultural expansion and priority conservation areas: Making the right decisions before it is too late. *Biological Conservation, 159*, 507–513.

Nori, J., Lemes, P., Urbina-Cardona, N., Baldo, D., Lescano, J., & Loyola, R. (2015). Amphibian conservation, land-use changes and protected areas: A global overview. *Biological Conservation*, *191,* 367–374.

Nori, J., Torres, R. Lescano1, J. N., Cordier, J. M., Periago, M. E. &and Baldo, D. (2016). Protected areas and spatial conservation priorities for endemic vertebrates of the Gran Chaco, one of the most threatened ecoregions of the world. *Diversity and Distributions*, 1–8.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess Neil, D., Powel, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., & Kassem, K. R. (2001). Terrestrial Ecoregions of the world: a new map of life on earth. *Bioscience*, 51, 933–938.

Ortega Baes, P., Bravo, S., Sajama, J., Sühring, S., Arrueta, J., Sotola, E., Alonso-Pedano, M., Godoy-Bürki, A. C., Frizza, N. R., Galíndez, G., Gorostiague, P., Barrionuevo, A., & Scopel, A. (2012). Intensive field surveys in conservation planning: Priorities for cactus Diversity in the Saltenian Calchaquíes Valleys (Argentina). *Journal of Arid Environments*, *82*, 91–97.

Parodiz, J. J. (1946). Los géneros de los Bulimulinae Argentinos. *Revista Museo de La Plata, 4,* 303–371.

Pearson, R. G., Raxworthy, C. J., Nakamura, M., & Peterson, A. T. (2007). Predicting species distributions from small numbers of occurrence records: A test case using cryptic geckos in Madagascar. *Journal of Biogeography*, *34*, 102–117.

Persson, M., Henders, S., & Kastner, T. (2014). Trading forest: Quantifying the contribution of global commodity markets to emissions from Tropical deforestation. CGD Working Paper 384. Washington, DC: Center for Global Development.

Phillips, S.J., Anderson, R.P., & Schapire, R.E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*, 231–259.

Phillips, S. J., Dudík, M., Elith, J., Graham, C. H., Lehmann, A., Leathwick, J., & Ferrier, S. (2009). Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. *Ecological Applications*, *19*, 181–197.

Quantum GIS Development Team (2009). Quantum GIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

Regnier, C., Fontaine, B., & Bouchet, P. (2009). Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. *Conservation Biology, 23*, 1214–1221.

Rinnhofer, L. J., Roura Pascual, N., Arthofer, W., Dejaco, T., Thaler-Knoflach, B., Wachter, G. A., Florian, E. C., Steiner, M., & Schlick-Steiner, B. C. (2012). Iterative species distribution modelling and ground validation in endemism research: an Alpine jumping bristletail example. *Biodiversity and Conservation*, *21*, 2845–2863.

Roig, V. G. (1991). Desertification and distribution of mammals in the Southern Cone of South America. In: M. A. Mares, & D. J. Schmidly (Eds.), *Latin American Mammalogy: History, Biodiversity and Conservation*, pp. 239-279. Norman: University of Oklahoma Press.

Rosenberg, G. (2014). A new critical estimate of named species-level diversity of the recent Mollusca. *American Malacological Bulletin*, *32*(2), 308–322.

Sala, O. E., Chapin III, F. S., Armesto, J. J., Berlow, R., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D., Mooney, H. A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H. (2000). Global Biodiversity Scenarios for the Year 2100. *Science*, 287, 1770–1774.

Salas Oroño, E., Cuezzo, M. G., & Romero, F. (2007). Land snail diversity in subtropical rainforest mountains (Yungas) of Tucumán, northwestern Argentina. *American Malacolacological Bulletin*, *22*, 17–26.

Secretariat of the Conservation on Biological Diversity .2010. Global Biodiversity Outlook 3. Montréal. http://www.cbd.int

Sen, S., Ravikanth, G., & Aravind, N. A. (2012). Land Snails (Mollusca: Gastropoda) of India: Status, Threats and Conservation Strategies. *Journal of Threatened Taxa, 4*, 3029–3037.

Solymos, P., & Fehér, Z. (2005). Conservation prioritization based on distribution on land snails in Hungary. *Conservation Biology*, *19*, 1084–1094.

Tabeni, M. S., Bender, J. B., Ojeda, R. A. (2004). Puntos calientes para la conservación de mamíferos en la provincia de Tucumán, Argentina. *Mastozoologia Neotropical*, *11*, 55–67.

Taberlet, P., Zimmermann, N. E., Englisch, T., Tribsch, A., Holderegger, R., Alvarez, N., Niklfeld, H., Coldea, G., Mirek, Z., Moilanen, A., Ahlmer, W., Marsan, P. A., Bona, E., Bovio, M., Choler, P., Cieślak, E., Colli, L., Cristea, V., Dalmas, J. P., Frajman, B., Garraud, L., Gaudeul, M., Gielly, L., Gutermann, W., Jogan, N., Kagalo, A. A., Korbecka, G., Küpfer, P., Lequette, B., Letz, D. R., Manel, S., Mansion, G., Marhold, K., Martini, F., Negrini, R., Niño, F., Paun, O., Pellecchia, M., Perico, G., Piękoś-Mirkowa, H., Prosser, F., Puşcaş, M., Ronikier, M., Scheuerer, M., Schneeweiss, G. M., Schönswetter, P., Schratt-Ehrendorfer, L., Schüpfer, F., Selvaggi, A., Steinmann, K., Thiel-Egenter, C., van Loo, M., Winkler, M., Wohlgemuth, T., Wraber, T., Gugerli, F., & Vellend, M. (2012). Genetic diversity in widespreadspecies is not congruent with species richness in alpine plant communities. *Ecology Letters*, 15, 1439–1448.

Tognelli, M. F., Abba, A. M., Bender J. B., & Seitz, V. P. (2011). Assessing conservation priorities of xenarthrans in Argentina. *Biodiversity and Conservation*, *20*, 141–151.

Wildlife Conservation Society - WCS, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2005. Last of the Wild Project, Version 2, 2005 (LWP-2): Global Human Footprint Dataset (Geographic). Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4M61H5F. Accessed 23 January 2019.

Figure legends

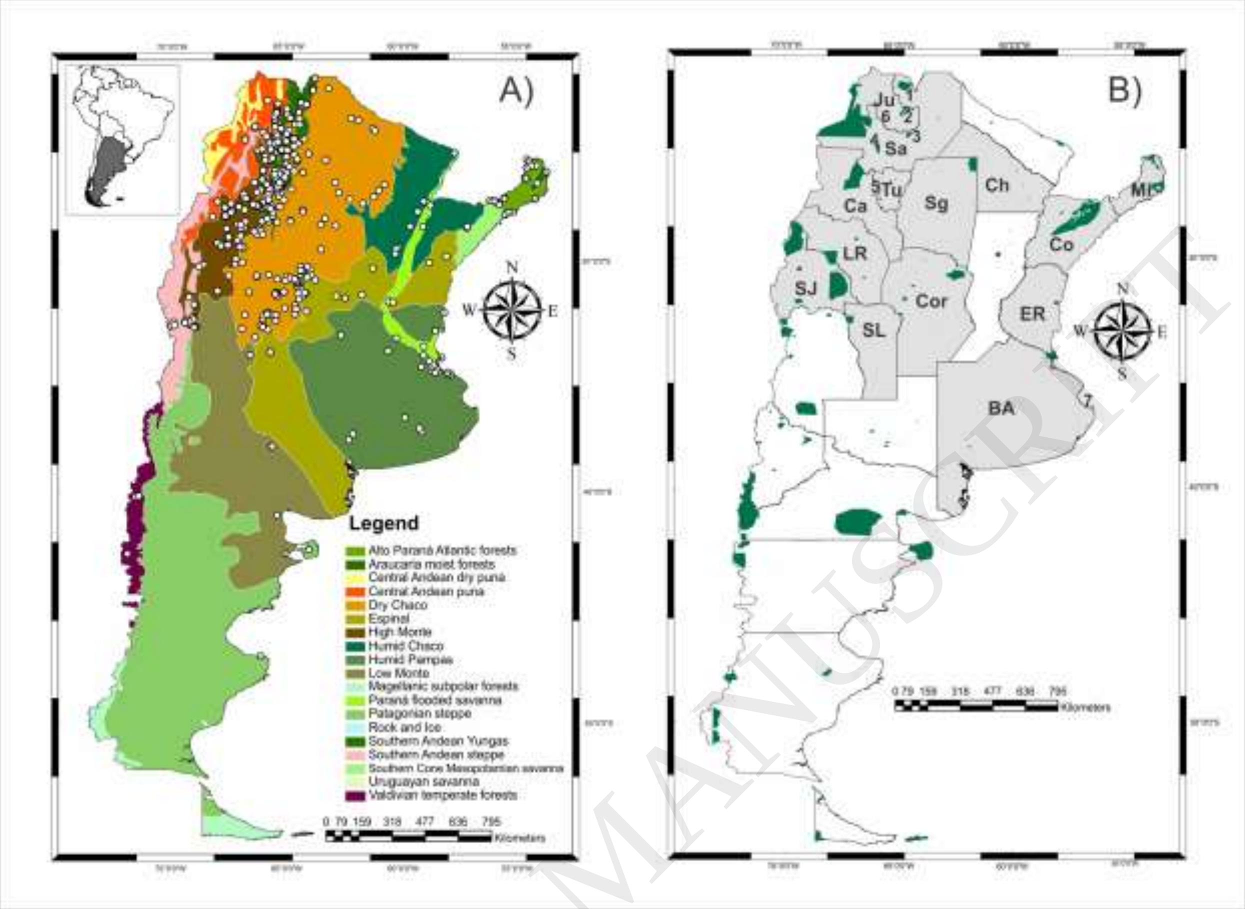

Figure 1. (A) Map showing the known distribution for Orthalicoidea in the seventeen ecoregions present in Argentina. The white points correspond to the known distribution of Orthalicoidean species in the study area. (B). Adminitrative division and protected areas of Argentina. Legend: BA: Buenos Aires, Ca: Catamarca, Co: Corrientes, Ch: Chaco, Cor: Córdoba, ER: Entre Ríos, Ju: Jujuy, LR: La Rioja, Mi: Misiones, Sa: Salta, Sg: Santiago del Estero, SJ: San Juan, SL: San Luis, Tu: Tucumán.

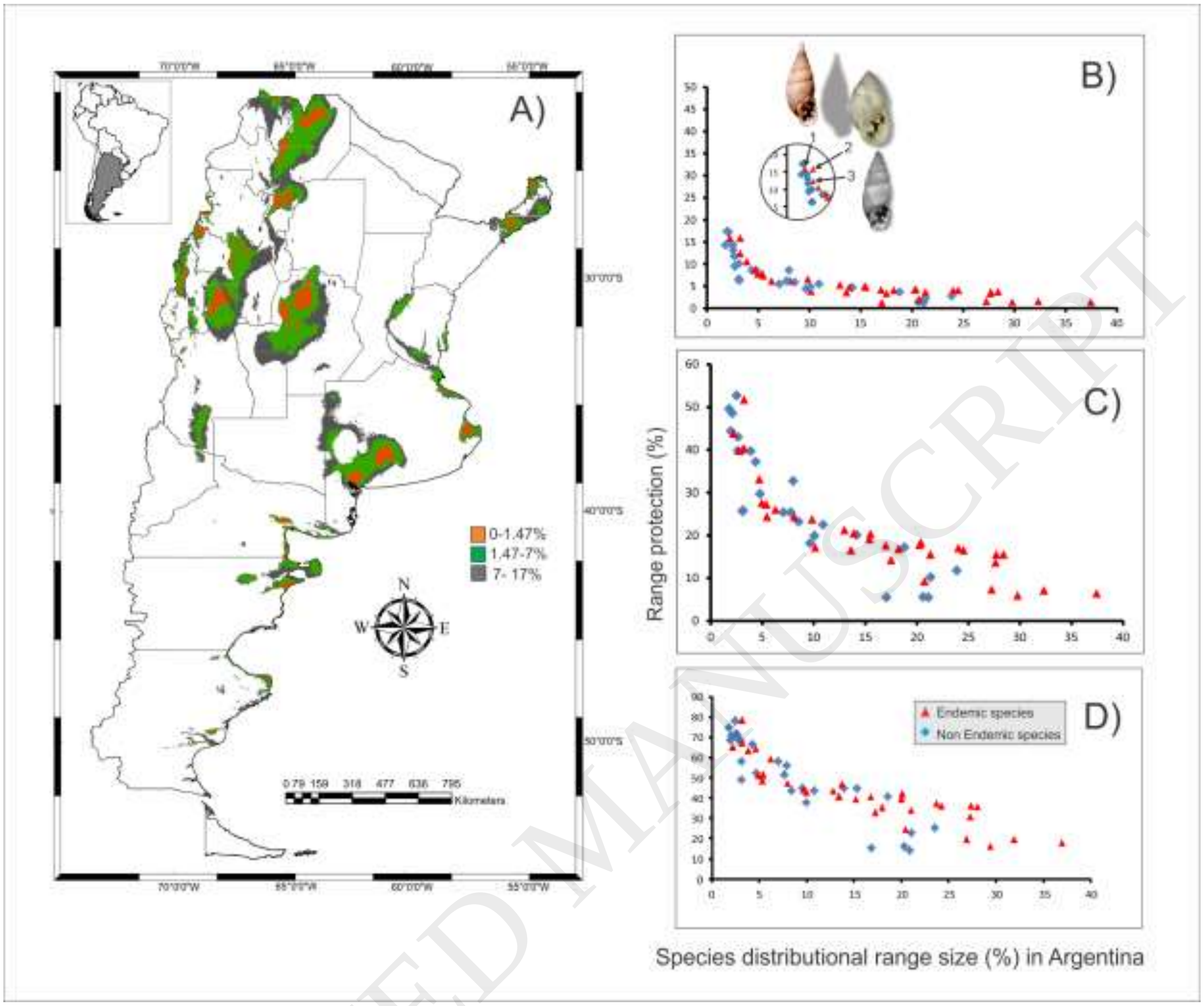

Figure 2. Priority Maps (A) “Unconstrained” map showing priority areas considering species distribution and assuming a ranking of 1.47% (areas in orange tone), 6.7% (areas in green tone) and 17% respectively (areas in grey tone), (B) Comparisons between the distributional range protection for species percentages (*y*-axis) versus distributional range size percentage in the study area (*x*-axis) considering 1.47% of priority of the total area, (C) the same comparations considering 6.7%, (D) the comparation 17% respectively. In (B) number 1 corresponds to *Clessinia tucumanensis*, number 2 to *Plagiodontes daedaleus*, and number 3 *Clessinia martensii*.

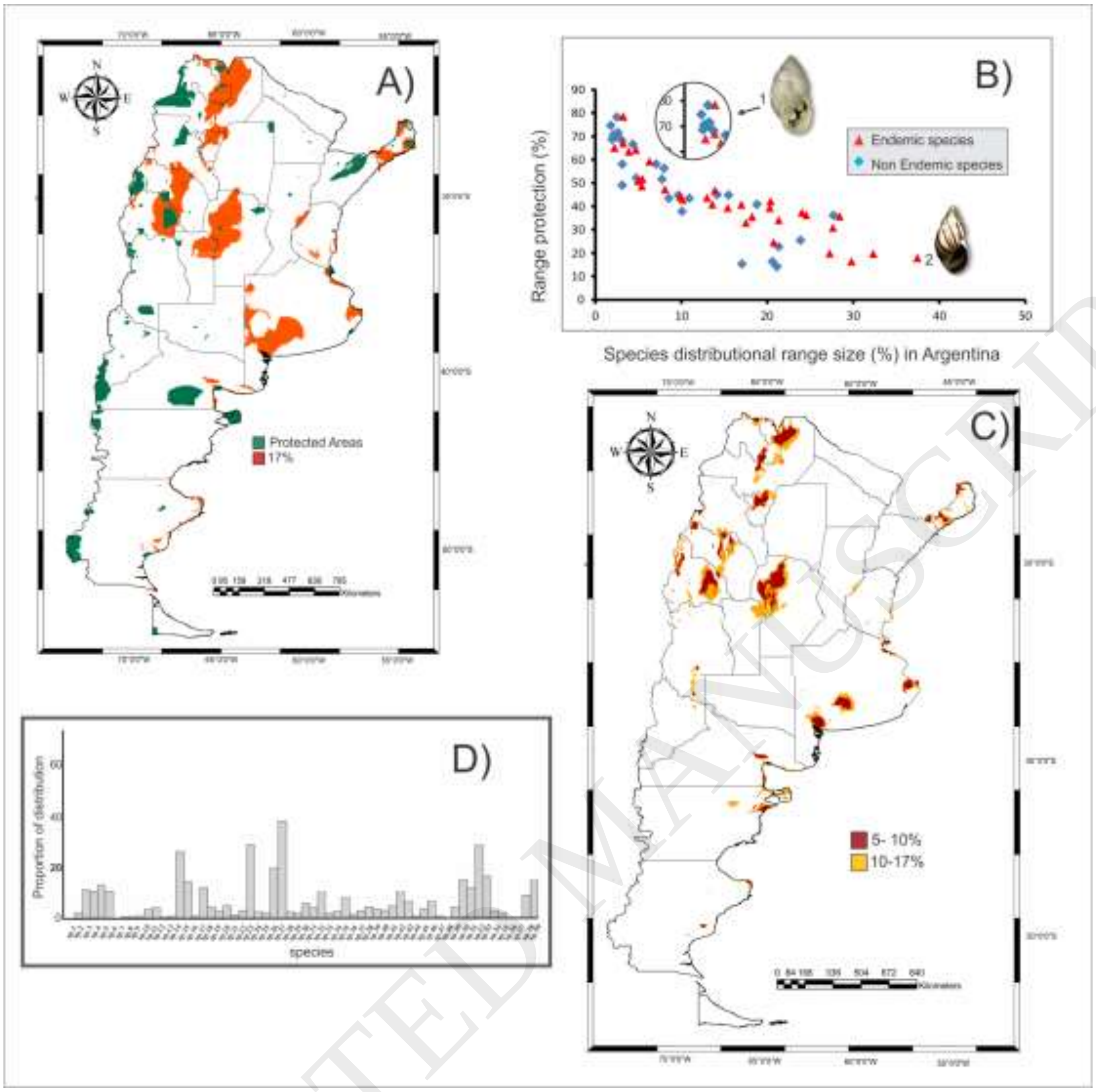

Figure 3. (A) Map showing the protected areas (as green polygons) and priority areas for conservation, (B) Comparisons between the distributional range protection for species percentages (*y*-axis) versus distributional range size percentage in the study area (*x*-axis) considering 17%. In (G) number 1 corresponds to *Plagiodontes daedaleus* and number 2 *Discoleus ameghinoi*, (C)Map with the results of land uses analyses (human footprint) and species distributions, (D) Histogram with the proportion of the distributions per species when land uses are considered.

Table 1

Distribution per Ecoregion, altitudinal range and endemisms (**ee**= ecologic endemism, **E**= endemic of Argentina) of the Bothriembryontidae, Simpulopsidae and Bulimulidae species from Argentina. In the table, species marked with (*) are species considered as SSI in the Zonation Analyses, **n** correspond to number of records for each and **PAs** point out the species recorded in Protected Area.

Genus	**Species**	**Ecoregion**	**Altitudinal range (m)**	**ee**	**E**	**PAs**	**n**
Discoleus	*aguirrei*	Humid Pampas, Low Monte	135-415		X	X	5
Discoleus	*ameghinoi*	Humid Pampas, Low Monte, Patagonian Steppe	60-160		X	X	5
Plectostylus	*mariae**	Valdivian Temperate Forests	460-740	X		X	3
Simpulopsis	*citrinovitrea*	Alto Parana Atlantic Forest, Southern Andean Yungas	308-950				4
Simpulopsis	*eudioptus*	Alto Parana Atlantic Forest, Araucaria Moist Forest, Southern Andean Yungas	170-480			X	4
Bostryx	*birabenorum*	Central Andean Puna	3000-3042	X	X		2
Bostryx	*catamarcanus*	Dry Chaco, High Monte			X		2
Bostryx	*cordillerae*	High Monte, Southern Andean steppe	1900-3500		X	X	9
Bostryx	*costellatus*	High Monte		X	X		1
Bostryx	*cuyanus*	High Monte, Southern Andean steppe	2000-5000		X		7
Bostryx	*famatinus**	High Monte	2000	X	X		1
Bostryx	*martinezi*	Dry Chaco	600-1440	X	X	X	9
Bostryx	*mendozanus*	High Monte, Southern Andean steppe	1500-1800		X		4
Bostryx	*pastorei*	Dry Chaco, Espinal, Low Monte	555-1600		X		5
Bostryx	*peristomatus*	Dry Chaco	920-1300	X	X	X	6
Bostryx	*reedi**	High Monte	3000-3400	X	X		3
Bostryx	*roselleus*	Dry Chaco, Central Andean Puna	1550-3200		X		5
Bostryx	*rudisculptus*	High Monte	1630-2760	X	X		2
Bostryx	*scaber*	High Monte	2160-3200	X	X		3
Bostryx	*stelzneri*	Central Andean Puna, Dry Chaco, Espinal, High Monte, Southern Andean Steppe	555-4000			X	120

Bostryx	*strobeli*	Dry Chaco, Espinal	1500		X		3
Bostryx	*torallyi*	Dry Chaco, High Monte, transition with Southern Andean Yungas	259-1500			X	43
Bostryx	*tortoranus*	Central Andean Puna, Dry Chaco, High Monte	944-3200		X	X	27
Bostryx	*willinki*	High Monte	1210	X	X		2
Bulimulus	*apodemetes*	Dry Chaco, Espinal, High Monte, Parana flooded savanna, Southern Andean Yungas	200-2000			X	66
Bulimulus	*bonariensis*	Alto Parana Atlantic forest, Araucaria moist forest, Dry Chaco, Espinal, Humid Chaco, Humid Pampas, Parana flooded savanna, Southern Andean Yungas, Southern Cone Mesopotamian Savanna	100-900			X	59
Bulimulus	*elatior**	Dry Chaco	200-350	X	X		2
Bulimulus	*fourmiersi*	Alto Parana Atlantic Forest		X	X		2
Bulimulus	*gracilis**	Dry Chaco		X	X		1
Bulimulus	*prosopidis*	Humid Chaco	100-400	X			1
Bulimulus	*rushii*	Espinal, Humid Pampas	100				4
Bulimulus	*vesicalis*	Espinal, Humid Pampas	50-100				2
Drymaeus	*abyssorum*	Southern Andean Yungas	1450-1780	X		X	7
Drymaeus	*flossdorfi*	Dry Chaco, Southern Andean Yungas			X		2
Drymaeus	*hygrohylaeus*	Dry Chaco, Southern Andean Yungas	355-1980			X	11
Drymaeus	*hyltoni*	Southern Andean Yungas	495	X	X		4
Drymaeus	*interpunctus*	Alto Parana Atlantic Forest, Southern Cone Mesopotamian Savanna	105-260			X	6
Drymaeus	*papyraceus*	Alto Parana Atlantic Forest, Espinal, Humid Chaco, Southern Cone Mesopotamian Savanna	1-250			X	11
Drymaeus	*poecilus*	Dry Chaco, High Monte, Southern Andean Yungas	160-1180			X	49
Naesiotus	*calchaquinus**	Dry Chaco	1268	X	X		2
Naesiotus	*crepundia*	Dry Chaco, Southern Andean Yungas	290-710				3
Naesiotus	*deletangi*	Dry Chaco, Southern Andean Yungas	290-1090			X	13

Naesiotus	*montivagus*	Dry Chaco, Southern Andean Yungas	297-1075			X	9
Naesiotus	*munsterii*	Dry Chaco, Southern Andean Yungas	290-600				5
Naesiotus	*oxylabris*	Dry Chaco, Espinal	110-1340				22
Naesiotus	*pollonerae*	Southern Andean Yungas		X			1
Naesiotus	*rocayanus*	Dry Chaco	360-1950	X			1
Naesiotus	*willinki**	Dry Chaco		X	X		2
Scutalus	*tupacii*	Dry Chaco, High Monte, Southern Andean Yungas	180-2400			X	50

Table 2

Distribution per Ecoregion, altitudinal range and endemisms (**ee**= ecologic endemism, **E**= endemic of Argentina) for Odontostomidae species in Argentina. In the table, species marked with (*) are species considered as SSI in the Zonation Analyses, **n** correspond to number of records for each and **PA** point out the species recorded in Protected Area.

Genus	**species**	**Ecoregion**	**Altitudinal range (m)**	**ee**	**E**	**PA**	**n**
Clessinia	*cordovana*	Dry Chaco	279-1231	X	X		10
Clessinia	*stelzneri*	Dry Chaco	900	X	X		3
Clessinia	*nattkemperi*	Dry Chaco	645-1900	X	X		2
Clessinia	*pagoda**	Dry Chaco	600-900	X	X		4
Clessinia	*tulumbensis*	Dry Chaco	628-645	X	X		3
Clessinia	*achalana*	Dry Chaco, High Monte, Espinal	750-850		X		10
Clessinia	*aconjigastana*	Dry Chaco	600-1050	X	X	X	9
Clessinia	*albostriata*	Dry Chaco	694-870	X	X		2
Clessinia	*alvarezii*	Dry Chaco	241-970	X	X		5
Clessinia	*bergii*	Dry Chaco	688-755	X	X		2
Clessinia	*cala*	Dry Chaco	870	X	X		2
Clessinia	*champaquiana*	Dry Chaco, High Monte	500-850		X	X	27
Clessinia	*chancanina*	Dry Chaco	373-1230	X	X	X	5
Clessinia	*charpentieri*	Dry Chaco	800-1200	X	X		9
Clessinia	*columellaris*	Dry Chaco	870	X	X		2
Clessinia	*costellifer*	Dry Chaco	620-950	X	X		4
Clessinia	*cuezzoae*	Dry Chaco	795-944	X	X		8
Clessinia	*doellojuradoi*	Dry Chaco, Espinal	620-1050			X	20
Clessinia	*dubia*	Dry Chaco	550	X	X		1
Clessinia	*holmbergi*	Dry Chaco	750-977	X	X		5
Clessinia	*kobeltiana**	Dry Chaco	370-770	X	X	X	4

Clessinia	*marmorata*	Dry Chaco		X	X		2
Clessinia	*martensii*	Dry Chaco, Espinal, High Monte	600-1225		X		29
Clessinia	*minor*	Dry Chaco	819-1178	X			9
Clessinia	*multispirata*	Dry Chaco	393-1058	X	X	X	9
Clessinia	*olainensis*	Dry Chaco		X	X		1
Clessinia	*parodizi*	Dry Chaco	682	X	X		3
Clessinia	*paucidenta*	Dry Chaco	200	X	X		2
Clessinia	*pervarians*	Dry Chaco	650	X	X		2
Clessinia	*philippii*	Dry Chaco, Espinal	556-913		X		6
Clessinia	*profundidens*	Dry Chaco, Espinal	593-1130		X		10
Clessinia	*pucurana*	Dry Chaco, Espinal	663-910		X		4
Clessinia	*pyrgula*	Dry Chaco	702-928	X	X		4
Clessinia	*pyriformis**	Dry Chaco	700-1100	X	X		4
Clessinia	*reticulata*	Dry Chaco	760-1030	X	X		7
Clessinia	*riojana*	High Monte, Dry Chaco	745-1725		X		5
Clessinia	*striata*	Alto Parana Atlantic forest, Espinal					1
Clessinia	*subsexdentata*	Dry Chaco	597-777	X			10
Clessinia	*tridens*	Dry Chaco	623	X	X		3
Clessinia	*tucumanensis*	Dry Chaco	700-1150	X	X		9
Clessinia	*tumulorum*	Dry Chaco	258-1969	X	X		11
Cyclodontina	*guarani*	Alto Parana Atlantic forest	140-200	X	X		2
Cyclodontina	*avellanedae**	Humid Pampas	250-380	X	X		2
Odontostomus	*gargantua*	Alto Parana Atlantic forest	150-350	X			6
Pilsbrylia	*paradoxa*	Southern Andean Yungas	300-1300	X	X		7
Pilsbrylia	*hyltonae*	Southern Andean Yungas	1000	X	X	X	1
Plagiodontes	*brackebuschii*	Dry Chaco, Southern Andean Yungas	650-1300		X		3
Plagiodontes	*daedaleus*	Dry Chaco, Espinal, Southern Andean Yungas	500-1500		X		32
Plagiodontes	*dentatus*	Humid Pampas, Paraná flooded savanna	9-100			X	6
Plagiodontes	*multiplicatus*	High Monte, Dry Chaco	200-1000		X		15
Plagiodontes	*patagonicus*	Humid Pampas, Espinal	25-200		X		10
Plagiodontes	*rocae**	Humid Pampas	200-550	X	X		2
Plagiodontes	*strobelii*	Dry Chaco, Espinal			X		17
Plagiodontes	*weyenberghii*	Dry Chaco, Humid Pampas	200-1200		X	X	5

Plagiodontes	*weyrauchi*	High Monte, Dry Chaco, Southern Andean Yungas	800-1455	X	4