

SHORT REPORT

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# Density and abundance of *Rhea pennata garleppi* (Struthioniformes: Rheidae) in the Puna ecoregion of Argentina

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## Abstract

**Background:** *Rhea pennata* is classified internationally as a near-threatened species, with the subspecies *R. p. garleppi* being listed as endangered.

**Finding:** The aim of this study was to provide updated information on the density and abundance of *R. p. garleppi* in the southern Puna ecoregion of Argentina. Density was estimated indirectly on the basis of monthly feces counts during 2011 and 2012, using line-transect surveys. Monthly abundance was calculated by multiplying the density of each month by the area of the reserve (400 km<sup>2</sup>). Population size range was calculated considering the average of the months with the highest abundance (and density) as the upper limit and the average of the months with the lowest abundance (and density) as the lower limit. The population size of this subspecies varied between 300 individuals ( $\pm 60$ ), with a density of 0.75 individuals/km<sup>2</sup> ( $\pm 0.15$ ) during the non-breeding season, and 188 individuals ( $\pm 40$ ), with a density of 0.47 individuals/km<sup>2</sup> ( $\pm 0.10$ ), during the reproductive season.

**Conclusion:** This work shows the highest density record for *R. p. garleppi* so far and highlights changes in population size related to life history characteristics of rheas, as well as human factors that negatively affect the survival of wild populations.

**Keywords:** *Rhea pennata garleppi*; Puna; Conservation; Andean precordillera

## Findings

The family Rheidae is endemic to the Neotropics and comprises two species of large flightless birds: *Rhea americana* and *Rhea (Pterocnemia) pennata* (Blake 1977). *R. pennata* includes three subspecies: *R. p. pennata*, present in southern Chile and west-central and southern Argentina, in the Andean Precordillera steppes and Patagonian plateaus up to 2,000 m above sea level (a.s.l.); *R. p. tarapacensis*, which is distributed throughout northern Chile; and *R. p. garleppi*, occurring in southern Peru, southwestern Bolivia, and northwestern Argentina. The latter two subspecies inhabit open plains with grasslands, shrublands, and in the intermountain valleys of the Puna plateau above 3,500 m a.s.l. (Plenge 1982; Cajal 1988; Folch 1992).

Wild populations of *R. p. garleppi* are found in low densities, with severe fluctuations throughout the species' distribution range, and with a tendency to decrease or become locally extinct in many cases (Cajal 1988; Chebez 2008). In the Puna, the main factors that negatively affect wild populations of this ratite are hunting for meat consumption and egg harvesting as subsistence resources (Barbarán 2004; Hernandez 2011). Another threat is the use by local people of by-products, such as feathers, skin, fat, and bones (Barbarán 2004). In this scenario, and in order to ensure their long-term conservation, the subspecies *R. p. garleppi* is considered at risk of extinction (CITES 2014) and *R. pennata* has been categorized as near-threatened (IUCN 2014). However, the lack of knowledge regarding the current status of wild populations of *R. p. garleppi* hinders the conservation of this subspecies. The aim of this study was to provide updated information on the density and abundance of *R. p. garleppi* in the southern Puna ecoregion of Argentina.

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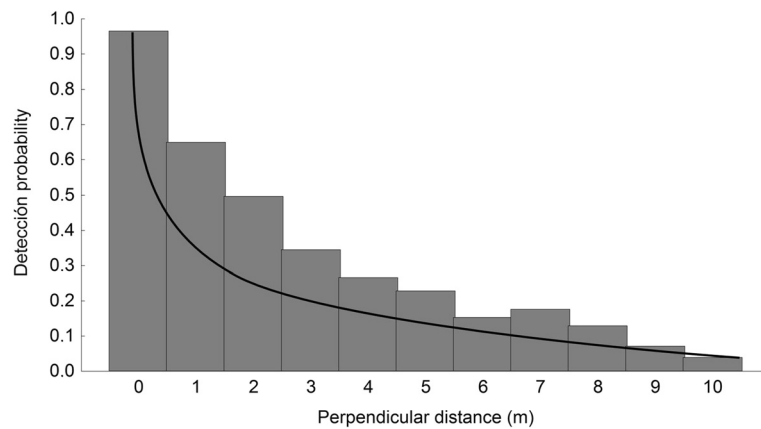
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This study was conducted in Don Carmelo Private Reserve (400 km<sup>2</sup>), located on the Andean Precordillera of San Juan province in Argentina (30°56'52" S, 69°05'02" W; 3,100 m a.s.l.). The Reserve is located in the Argentine Puna ecoregion, in the southeastern border of the Altiplano in the central Andes (Bonaparte 1978). The climate is arid and cold, with intense solar radiation, strong winds, and daily temperature fluctuations that may exceed 30°C (Reboratti 2006). Precipitations are scarce and occur between November and February, decreasing to the west and south of the Puna (Cabrera and Willink 1973). The reserve is located in the subregion known as dry Puna due to the lack of permanent rivers and lakes (Cabrera 1976). The dominant habitat is the shrub-steppe, with a mean altitude of 13.9 cm ( $\pm 0.72$ ), and the vegetation is xerophilous, with 88% of bare soil (Cappa et al. 2014). Wild populations of *R. p. garleppi* inhabiting similar environments use indistinctly both the grassland plains of *Stipa* spp. and low shrublands of *Adesmia* spp, as well as the rocky and non-rocky mountain slopes with shrubs of *Lycium* spp. and *Adesmia* spp. and low cover of *Stipa* spp. (Cajal 1998). Don Carmelo Private Reserve is a suitable site for the subspecies *garleppi* because it is not fragmented or disturbed by mining or agricultural activities, and massive tourism is banned.

It is difficult to perform direct observation or monitoring of *R. p. garleppi* in the study area because these birds run long distances at great speed, their plumage color allows them to mimic the environment, and the topography of the area is irregular. Therefore, we decided to use the fecal count technique as an indirect method for estimating population density (Ojasti and Dallmeier 2000). This method has been used effectively in other studies on wild populations of rheas (Bazzano et al. 2002; Herrera et al. 2004; Kusch and Henríquez 2011). Six samplings were conducted between 2011 and 2012 (September and November 2011; March, April, July, and November 2012). In each sampling, 20 randomized transects were spaced at least 400 m apart. This randomized design ensured sample independence, allowing us to consider each transect as true replicates by avoiding repetition of a single transect in successive monthly samplings. Transects of 500 m long were walked by a single observer in search of feces. The exact perpendicular distance from the path to each encountered feces was measured with metric tape by an assistant. Thus, the observer never left the transect, avoiding the record of additional feces. All encountered feces were collected to avoid double counting. Density of *R. p. garleppi* was calculated monthly using Distance 6.0 software (Thomas et al. 2009), which requires entering data on individuals' defecation rate and feces permanence in the study area (Buckland et al. 2001). As we did not have defecation rate data for *R. p. garleppi*, we used data from a similar

species *R. americana*, following Buckland et al. (2001). These species are phylogenetically closely related (Delsuc et al. 2007), have similar body weight and size (Fowler 1991; Navarro et al. 1998; Navarro et al. 2005), and exhibit a primarily herbivorous diet (Bonino et al. 1986; Martella et al. 1996). The defecation rate used was 13.5 feces/individual/day ( $\pm 3.1$ ;  $n = 8$ ) and the permanence time of the feces was 88.15 days ( $\pm 6.4$ ;  $n = 14$ ) (NV Marinero, personal observation). To calculate monthly density, we used the negative exponential model with cosine extension (Figure 1). The monthly abundance of *R. p. garleppi* was determined by multiplying density value of each month by the reserve area (400 km<sup>2</sup>), following Ojasti and Dallmeier (2000). Population size range of *R. p. garleppi* was calculated considering the average of months with highest density as the upper limit and the average of months with lowest density as the lower limit. Abundance (dependent variable) as a function of months (fixed effect) was calculated using a heteroscedastic mixed model, considering the sampling years (2011 and 2012) as random effect. In addition, given the heteroscedasticity of our data, we indicated that error variance of abundance was different for each month (grouping criterion) in the mixed model, using the function *VarIdent* (Di Rienzo 2011). An *a posteriori* comparison of means of monthly abundance was performed using the Fisher's least significant difference (LSD) test, when differences were significant at  $P \leq 0.05$  (Balzarini et al. 2008). Data were Log<sub>10</sub>-transformed for normalization of residuals. Non-transformed data were expressed as mean  $\pm$  standard error of the mean. Statistical analyses were performed using Infostat (Di Rienzo et al. 2014).

Population size of the subspecies *R. p. garleppi* presented significant variations among months ( $F_{5,84} = 3.61$ ;  $P = 0.002$ ). The upper limit of the population was 0.75 ind/km<sup>2</sup> ( $\pm 0.15$ ) and was recorded in March, April, and July (2012) ( $P \leq 0.05$ ) (Figure 2). This density is the highest published until now, but close to other records obtained in Argentina: 0.67 ind/km<sup>2</sup> (29°25'60" S, 66°50'60" W, La Rioja) and 0.52 ind/km<sup>2</sup> in Laguna de Pozuelo Biosphere Reserve (22°28' S, 66°02' W, Jujuy) (Cajal 1988; Cajal 1998; and references therein). The differences in density estimates might be due to the different methods used, considering that Cajal (1988) states that the use of a motor vehicle to conduct the surveys of *R. p. garleppi* might have led to density underestimation. By contrast, we used the line-transect method and fit a detection function of probability of signs, which decreases with distance to the observer. This method reduces the potential bias of the density estimator (Buckland et al. 2001) and provides a more realistic value of a population's density and abundance in a given area (Thomas et al. 2013). The lower limit of *R. p. garleppi* population density was 0.47 ind/km<sup>2</sup> ( $\pm 0.10$ ) in November (2011 and 2012) ( $P \leq 0.05$ ) (Figure 2).

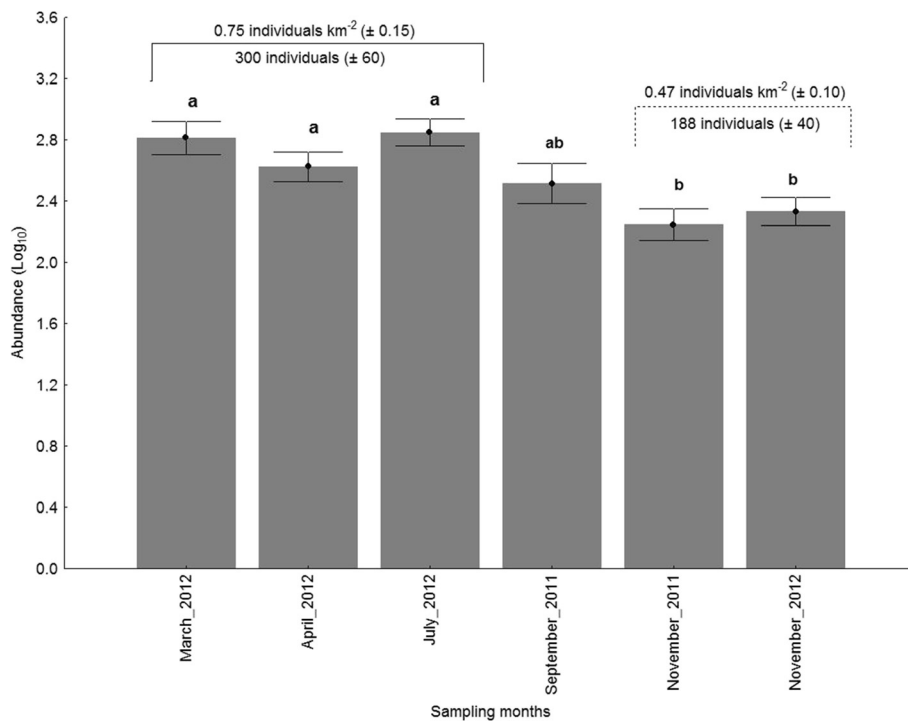


**Figure 1** Histogram of the perpendicular distance of feces of *R. p. garleppi* recorded at Don Carmelo Private Reserve, San Juan, Argentina. The line represents the fit of the negative exponential function with cosine extension.

Although this record is the lowest for our study population, it is still higher than records reported for other wild populations inhabiting Argentina and Perú: 0.41 ind/km<sup>2</sup> in Olaroz (23°43' S, 66°48' W, Jujuy) (Cajal 1998 and references therein), 0.12 ind/km<sup>2</sup> in Laguna Blanca Biosphere Reserve (26°28' S, 66°48' W, Catamarca), 0.03 ind/km<sup>2</sup> in San Guillermo Biosphere Reserve (29°25' S, 69°15' W, San Juan) and 0.01 ind/km<sup>2</sup> in Tacna (16°44' S, 70°16' W) (Cajal 1988; Llellish et al. 2007). Taking into account the important wild population of the subspecies *garleppi*

present in the study area, it is necessary to promote its *in situ* conservation because it might become a source of individuals for possible recolonization and/or reinforcement of other populations undergoing higher conservation threat.

The higher abundance values of *R. p. garleppi*, with 300 individuals (±60), were recorded during March, April, and July 2012 ( $P \leq 0.05$ ) (Figure 2). The record of this upper limit in population size coincided with the occurrence of social groups of *R. p. garleppi* composed



**Figure 2** Variation of monthly abundance of *R. p. garleppi* in 2011 and 2012 in Don Carmelo Private Reserve, San Juan, Argentina. Solid line, upper limit of population size; dashed line, lower limit of population size. Different letters indicate significant differences (Fisher's LSD,  $P \leq 0.05$ ).

of juveniles, females with juveniles, and males in the reserve (NVM, pers. obs.); this group composition is characteristic of the non-reproductive season of rheas (Hanford and Mares 1985; Sarasqueta 1990; Carro and Fernandez 2008). Thus, the observed increase in population size might be due to a reduction of aggressive behaviors among individuals during the non-breeding season, favoring the formation of groups of numerous individuals that tend to move together (Sarasqueta 1990). However, it is also very important to consider that the upper limit in the population size of *R. p. garleppi* could be due to the movements made by the individuals to the reserve in search of refuge from poaching and livestock production, two activities that are more intensively conducted in the surrounding fields during the non-breeding season of the subspecies *garleppi* (Ordoñez 2006). This perception of a protected area as refuge from the surroundings has also been described for other native herbivores, such as *Lama guanicoe* in the Monte arid ecoregion in Argentina (Acebes et al. 2010). Moreover, abundance fell to 188 individuals ( $\pm 40$ ) in November (2011 and 2012) (Figure 2). This lower limit of population size corresponds to the breeding season of *R. p. garleppi*. While there was a record of an orphan egg in September 2012, no nest was found, despite the intensive search made inside the reserve. This drop in the number of individuals may be related to the species' nesting preferences, since individuals tend to select sites with high shrub cover, instead of pastures, which favors concealment and protection against predators and severe climate conditions (Bellis et al. 2006; Barri et al. 2009a). These sites are scarce in the study area, where shrub cover is only 16%, and pastures are 24%, whereas the remaining cover corresponds to bare soil (NV Marinero, unpublished data). Therefore, it is likely that during the reproductive season, *R. p. garleppi* individuals move toward surrounding areas about 14 km away from the reserve and below 2,500 m a.s.l. (NVM personal observation), where the habitat is dominated by an open shrubland of *L. divaricata* (Márquez 1999). Indeed, reproductive groups of males with females, males with chicks, and juveniles have been observed in this environment adjacent to the reserve (NV Marinero, unpublished data).

We were not able to compare our results with wild populations from Bolivia because there are no studies published on the density of *R. p. garleppi* in that country, despite the heavy use of this subspecies by local communities, to the extent that wild populations may be decimated (Balderrama 2009).

Our density records of *R. p. garleppi* (Figure 2) are higher than density values of *R. p. tarapacensis* present in different protected areas of Chile, which vary between 0.002 ind/km<sup>2</sup> (Isluga Volcano National Park, 19°9'5" S, 68°49'27" W) and 0.022 ind/km<sup>2</sup> (National Monument Salar Surire,

18°49'41" S, 69°3'39" W) (Acuña et al. 2008). However, our estimations are lower than the values recorded for *R. p. pennata* in the Patagonia of Chile and Argentina, with records of 8 ind/km<sup>2</sup> (50°46' S, 74°6' W, Ultima Esperanza, Chile), 2.93 ind/km<sup>2</sup> (Santa Cruz, Argentina), 2.51 ind/km<sup>2</sup> (Chubut, Argentina), 2.06 ind/km<sup>2</sup> and 1.55 ind/km<sup>2</sup> (Rio Negro, Argentina), and 1.94 ind/km<sup>2</sup> (Neuquén, Argentina), although higher than in some areas of its northern distribution in Neuquén province, Argentina (Servicio Agrícola y Ganadero SAG 2002; Navarro et al. 1999; Secretaría de Ambiente y Desarrollo de la Nación SAYDS 2000; Novaro et al. 2000; Barri et al. 2009b). In Argentina, in general, *R. p. garleppi* would occur at lower densities than *R. p. pennata*, which could be related to the primary productivity of the ecosystems. Specifically, the subspecies *R. p. garleppi* is distributed throughout the Puna ecoregion, where the low biomass production in the environment determines a lower carrying capacity. By contrast, the Argentine Patagonia, where *R. p. pennata* occurs, comprises a wider range of environments; the Monte and the Patagonia phytogeographic provinces, the Monte-Patagonia ecotone as well as 'mallines' (patchily distributed wetland areas), which provide habitat this ratite with important food resources (Oosterheld et al. 1998; Bellis et al. 2006; Guevara et al. 2006; Bianchi and Bravo 2008).

This work provides the highest density record for *R. p. garleppi* so far and highlights changes in population size related to the characteristics of the life history of rheas and human factors that negatively affect the survival of wild populations.

#### Competing interests

The authors declare that they have no competing interests.

#### Authors' contributions

NVM designed the study, collected the data, carried out the statistical analysis, and drafted the manuscript. RCO contributed to data acquisition and drafted the manuscript. JLN participated in the analysis and interpretation of results and in writing the manuscript. MBM conducted the fund raising, participated in the design of the study, the analysis, and interpretation of results, and in writing the manuscript. All authors read and approved the final manuscript.

#### Authors' information

NVM is a fellow and JLN and MBM are researchers of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and teachers of the Universidad Nacional de Córdoba.

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