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POPULATION FLUCTUTATIONS OF LESSER RHEA (*RHEA PENNATA PENNATA*) IN PENÍNSULA VALDÉS, PATAGONIA ARGENTINA

Martín G. Frixione[1,2] · Daniel De Lamo[2]

[1]Centro de Investigaciones Biológicas del Noroeste S.C., Mar Bermejo No. 195, Col. Playa Palo de Santa Rita, 23090 La Paz, Baja California Sur, México.

[2]Universidad Nacional de la Patagonia San Juan Bosco. Brown 3700, U9120ACX Puerto Madryn, Chubut, Argentina.

E-mail: Martín G. Frixione · mfrixione@pg.cibnor.mx

Abstract · Most populations of large flightless birds have declined since the last century. In arid ecosystems, overgrazing and climate change are particularly detrimental to soil health. In arid Patagonia these processes may lead to a reduction in primary productivity, potentially affecting the populations of herbivorous flightless birds, such as rheas (family Rheidae). We surveyed Lesser Rhea (*Rhea pennata pennata*) abundance during the breeding and post-breeding seasons of 2012/2013 and 2013/2014 in Península Valdés Protected Area, Province of Chubut, Patagonia, Argentina. Linear transect surveys were conducted in September and December (breeding) and in late summer (post-breeding). Density estimates were corrected by detectability in each kind of habitat. Density was substantially lower for the 2012/2013 season than 2013/2014, probably due to the combination of severe drought and ash-deposition from the eruption of the Puyehue-Caulle volcano in 2011. Lesser Rhea adult group size increased with food abundance estimates (EVI, Enhanced Vegetation Index) within the season, suggesting food offer is an important factor affecting Lesser Rhea group size in Península Valdés.

Resumen · Fluctuaciones poblacionales del Choique (*Rhea pennata pennata*) en Península Valdés, Patagonia Argentina

Gran parte de las poblaciones de aves no voladoras de gran porte han disminuido en el último siglo. El sobrepastoreo y el cambio climático promueven el deterioro de los suelos en ecosistemas áridos. En la Patagonia árida una reducción de la productividad primaria puede afectar las poblaciones de aves herbívoras no voladoras. Se estimó la abundancia del Choique (*Rhea pennata pennata*) durante las temporadas 2012/2013 y 2013/2014 en el Área Protegida Península Valdés, Provincia del Chubut, Patagonia, Argentina. Los muestreos fueron llevados a cabo en septiembre y diciembre durante el estadío de cría de pichones y al final del verano en la temporada post-reproductiva. Las densidades estimadas fueron ajustadas por la variación en la detectabilidad en los diferentes hábitats. Las estimaciones de densidades fueron sustancialmente menores para la temporada 2012/2013 en comparación con la temporada 2013/2014, probablemente en respuesta a la combinación de una severa sequía y la deposición de cenizas provenientes de la erupción del volcán Puyehue-Caulle en 2011. Los tamaños de grupo de Choique aumentaron con el incremento de las estimaciones en la abundancia de alimento (EVI, Índice de Vegetación Mejorado) para cada muestreo, sugiriendo que la oferta alimenticia es un factor importante que afecta el tamaño de grupo de Choique en Península Valdés.

Key words: Density · Drought · Península Valdés · Primary productivity · *Rhea pennata pennata*

INTRODUCTION

The Lesser Rhea (*Rhea pennata pennata*), also known as Darwin's Rhea, is a large and flightless bird adapted to the arid South American environments (del Hoyo et al. 1992). Populations of this species are declining in most arid and semi-arid ecosystems, and it is considered ecological extinct in northwestern Patagonia (Novaro et al. 2000). The most important threats for the species are habitat degradation, poaching and egg collection for human consumption (Bellis et al. 2006, Barri et al. 2008a).

Habitat degradation and desertification in arid Patagonia are due to the combination of overgrazing and extreme meteorological conditions (Ares et al. 1990). Extreme droughts have been affecting South America

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(Watterson 2009, Garreaud et al. 2009, Aravena & Luckmann 2009) and some areas in Patagonia during the last 50 years (Agosta & Compagnucci 2008, Lara et al. 2009, Villalba et al. 2012). Extreme climatic events could exacerbate habitat degradation affecting the structure and function of Patagonian ecosystems (Paruelo et al. 1998, Gaitán et al. 2017). Food availability in arid ecosystems is one of the most important factors determining population abundance and distribution of large size flightless birds such as Lesser Rheas (Bellis et al. 2006, Pedrana et al. 2011).

Lesser Rhea group sizes range generally from five to 20 individuals (Davies 2002). Adults start breeding during winter; their mating system includes polygyny and sequential polyandry (Oring 1982, Hanford & Mares 1985). Nests are built by males who incubate clutches of 12-30 eggs (Barri et al. 2008b). After 42 days, chicks hatch synchronically, throughout late September and early November (Sarasqueta 1988; Barri et al. 2008a, b). The male takes care of all parental duties during chick rearing as well (Figure 1; Hanford & Mares 1985, Sarasqueta 1990). Chicks become independent in early January (summer) forming large groups of just fledged juveniles from several breeding groups. Juveniles are capable of moving long distances towards better sites where food is abundant (Bellis et al. 2006). The survival of adults, juveniles and chicks depends on several factors such as, food availability and predation (Barri et al. 2009).

The aims of the current study were to: 1) estimate Lesser Rhea densities in Península Valdés during breeding and post-breeding stages, and 2) evaluate group size variation in relation to food availability, estimated as primary productivity. Studies of group size variation in ratites (Sommer 2000, Boland 2003, Fernández et al. 2003, de Azevedo et al. 2010), suggest that gregarious behavior is affected by predation risk or food availability. Hence, we predict a reduction of individuals per group in response of a strong intragroup competition during drier seasons when food scarce, reflecting food availability as an important factor to explain group size in Península Valdés.

METHODS

Study area. The study was conducted in Península Valdés Protected Area, located in northeastern Chubut province (42°53'–42°03'S; 64°43'–63°34'W), Patagonia, Argentina (Figure 2). This area has been declared a World Natural Heritage site by UNESCO (1999), and is categorized as a class VI (Managed Resource Protected Area). Sheep ranching and tourism are the most important socio-economic activities in the area. Sheep ranching comprises more than 90% of the protected area. Sheep density averages 64.4 (± 19.6 SD) individuals per km^2, being more abundant in the southeastern part of the peninsula where primary productivity is higher (Nabte et al. 2013).

The climate is arid and semiarid with an average annual rainfall between 200 and 220 mm with an autumn–winter peak, and average annual temperature of 12.6°C (Barros & Rivero 1982, Roveta 2008). The vegetation within the area is classified as transitional between Monte and Patagonian steppe (Soriano 1956). Monte is found in the western side of the peninsula throughout the Ameghino isthmus, the soil is poor and plant cover can be extremely reduced during droughts (Soriano 1956). On the eastern side of the peninsula forb cover is higher and Patagonian steppe species dominate. For the sake of this study the sampled area has been classified in shrub, shrub-herbaceous and herbaceous types (coastal herbaceous and mosaic herbaceous) based on the floristic classification of Península Valdés by Bertiller et al. (1981).

Density estimation. During 2012, 2013, and 2014 line transects were used to assess Lesser Rhea abundance. Surveys were carried out systematically over 61 transects in 17 ranches on 6 occasions. Prior to the start of the study, we evaluated the availability of potential roads within ranches, we divided the potential transects, and for each vegetation type these were numbered and randomly selected. The surveys were conducted in the same transects during breeding in September and December 2012/2013 and post-breeding on March 2013 and February 2014. We grouped transects in four types by vegetation characteristics and plant cover checked *in situ*: shrub-land, shrub-herbaceous, coastal herbaceous and mosaic herbaceous (Figure 2). Line transects (total length: 128.9 km) were distributed proportionally to each area size, (shrub = 25 transects, shrub-herbaceous = 19 transects, coastal herbaceous = 8 transects, mosaic herbaceous = 9 transects). Surveys were conducted using a four-wheel drive pickup, with two observers in the back. The car stopped once a Lesser Rhea group or an isolated individual was observed. We georeferenced each observation (Figure 2) and measured perpendicular distances from the vehicle to the rhea groups with a laser rangefinder (Bushnell 10x25/5–700). Density estimations for September and December surveys (breeding seasons) were calculated for adults, sub-adults, and chicks. During the breeding stage (September and December), when solitary males take care of chicks, densities were calculated as the sum of total individuals per km^2. During post-breeding densities were estimated as the sum of adults, sub-adults and just fledged juveniles per km^2. To increase precision of density estimates and to avoid the unrealistic assumption of constant detection (Rosenstock et al. 2002) and the underestimation of abundance in areas with lower detection rates (Thomas et al. 2005), we estimated the effective strip width (ESW, distance in which the individuals are mostly detected) for each vegetation type (Caughley et al. 1984). We fitted key functions and series expansion (cosine, simple polynomial, polynomial hermite) to perpendicular distance data and

Figure 1. Male and group of chicks (n = 11) of Lesser Rhea (*Rhea pennata pennata)* in the southern area of Caleta Valdés in November 2012, in Península Valdés Protected Area, Chubut, Patagonia, Argentina.

used Akaike's Information Criterion to select the best model and adjustments (AIC, Akaike 1973). Estimates and their coefficients of variation (%CV) were calculated using Distance 6.2 software (Thomas et al. 2003). Additionally, we applied a log transformation to density values and run a general linear model to test for differences between breeding and post-breeding stages (2012/2013 and 2013/2014).

Group size analysis. To determine the association between food availability and group size we carried out two analyses: one analysing groups size of groups composed by adults and subadults and the other breeding groups (male with offspring). The Enhanced Vegetation Index (EVI) can be used as a good proxy to estimate primary productivity and plant cover (Wallace & Thomas 2008). We extracted EVI values derived from 250 m MODIS satellite images distributed by the Land Processes Distributed Active Archive Center (LP DAAC) (lpdaac.usgs.gov), and rescaled these by 10,000 (Huete et al. 2002). Values were extracted from satellite images from September 2012 and 2013, December 2012 and 2013 (corresponding to breeding surveys), and March 2013 and February 2014 (post-breeding surveys). EVI values were extracted from equidistant points every 100 meters along each transect where groups were detected. To assess the relationship between group size and food availability in the different stages we fit a GLM model with Poisson distribution and EVI and season as predictor variables. To process geospatial information we used QGis open source software (version 2.16.3). We used R version 3.2.5 for all statistical analysis.

RESULTS

Density estimation. We detected a total of 80 groups, 31 groups in 2012/2013 and 49 in 2013/2014 surveys. The effective strip size for detection differed between vegetation types, being larger in open grasslands (coastal and mosaic herbaceous). The shrub vegetation category had the shortest detection distances (121.4 m, cosine 1, CV% 14.7), followed by shrub-herbaceous vegetation (291.8 m, cosine 1, CV% 8.2), coastal herbaceous (324 m, simple polynomial, CV% 0), and mosaic herbaceous (330 m, hermite polynomial, CV% 40.2).

Lesser Rhea densities were at its lowest during the first breeding season (Sep–Dec 2012), increased slightly during the post-breeding period (March), and showed a marked increase during the following breeding season (Sep–Dec 2013), followed by a slight decrease post-breeding (Feb 2014, Table 1). These

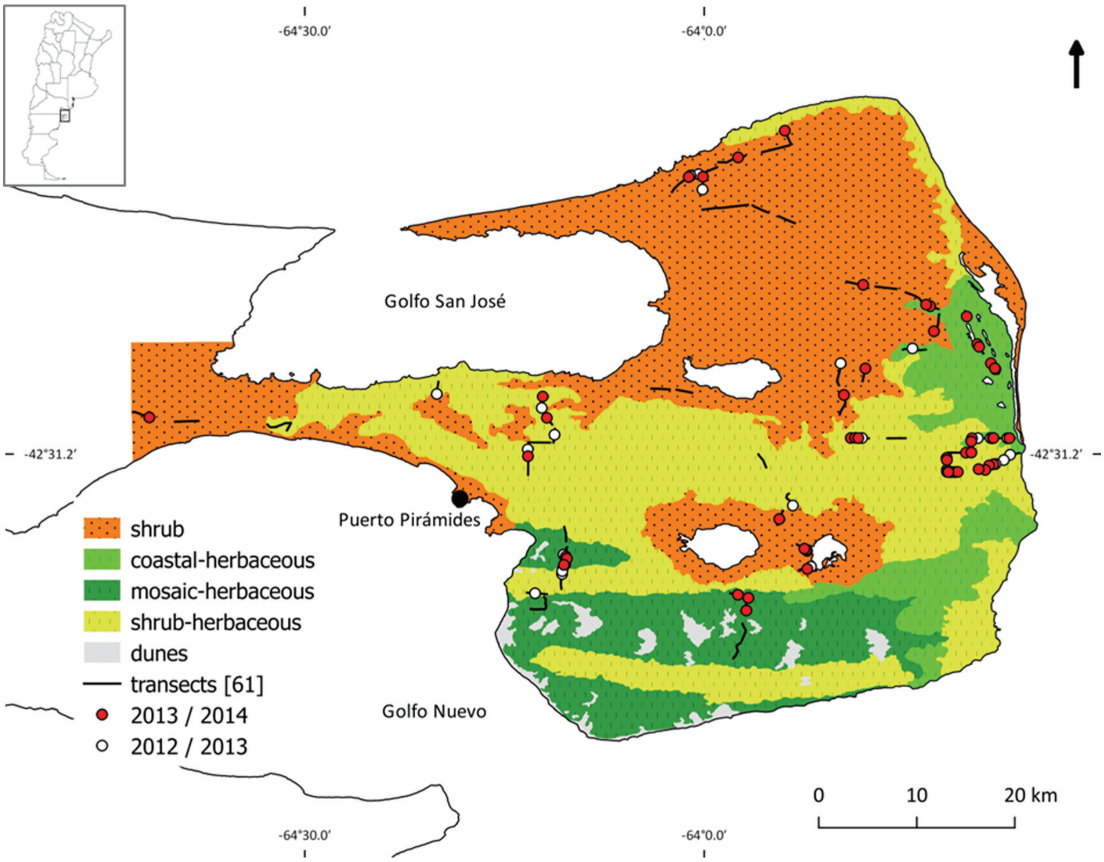

Figure 2. Map depicting vegetation types, sampled transects and groups of Lesser Rhea (*Rhea pennata pennata*) detected during 2012/2013 season (white dots) and 2013/2014 season (red dots) in Península Valdés Protected Area, Chubut, Patagonia, Argentina.

Table 1. Breeding, post-breeding and combined density estimations of Lesser Rhea (*Rhea pennata pennata)* in 2012/2013 and 2013/2014 seasons in Peninsula Valdés, Patagonia, Argentina. Standard deviations are in parentheses.

Years	Breeding	Post-breeding	Combined
2012/2013	0.57 ind/km^2 (0.35)	0.74 ind/km^2 (0.12)	0.65 ind/km^2 (0.30)
2013/2014	1.41 ind/km^2 (0.31)	1.06 ind/km^2 (0.30)	1.24 ind/km^2 (0.31)

contrasting patterns of seasonal variation within each year accounted for the significant term season (F = 9.85, df = 2, df = 362, $p < 0.05$) and year (F = 2.64, df = 1, df = 364, $p < 0.01$).

Group size – adults/subadults. Group size showed different patterns of variation between breeding and post breeding seasons in both study years (Figure 3A). During 2012/2013 group size increased from September through to post-breeding, while during 2013–2014 the pattern was reversed (Figure 3A, season x year interaction, χ^2 = 32.9, df = 2, df = 62, $p <$ 0.001). EVI showed comparable patterns of variation, increasing from breeding to post-breeding in 2012/2013 and decreasing in 2013/2014 (Figure 3B, interaction year x season, F = 69.2, df = 2, df = 62, $p <$ 0.001).

Group size – chicks. We recorded 11 groups of males tending chicks, 5 groups in the breeding season 2012/2013 (average size = 10 individuals, range = 7–18, SD = 4.5) and 6 in 2013/2104 (average size = 10.5 individuals, range = 6–14, SD = 3). Reproductive group size did not show significant differences between seasons (*Mann-Whitney* test, W = 11, p = 0.518).

DISCUSSION

Density estimates of the Lesser Rhea in Península Valdés were low in the first season when compared with

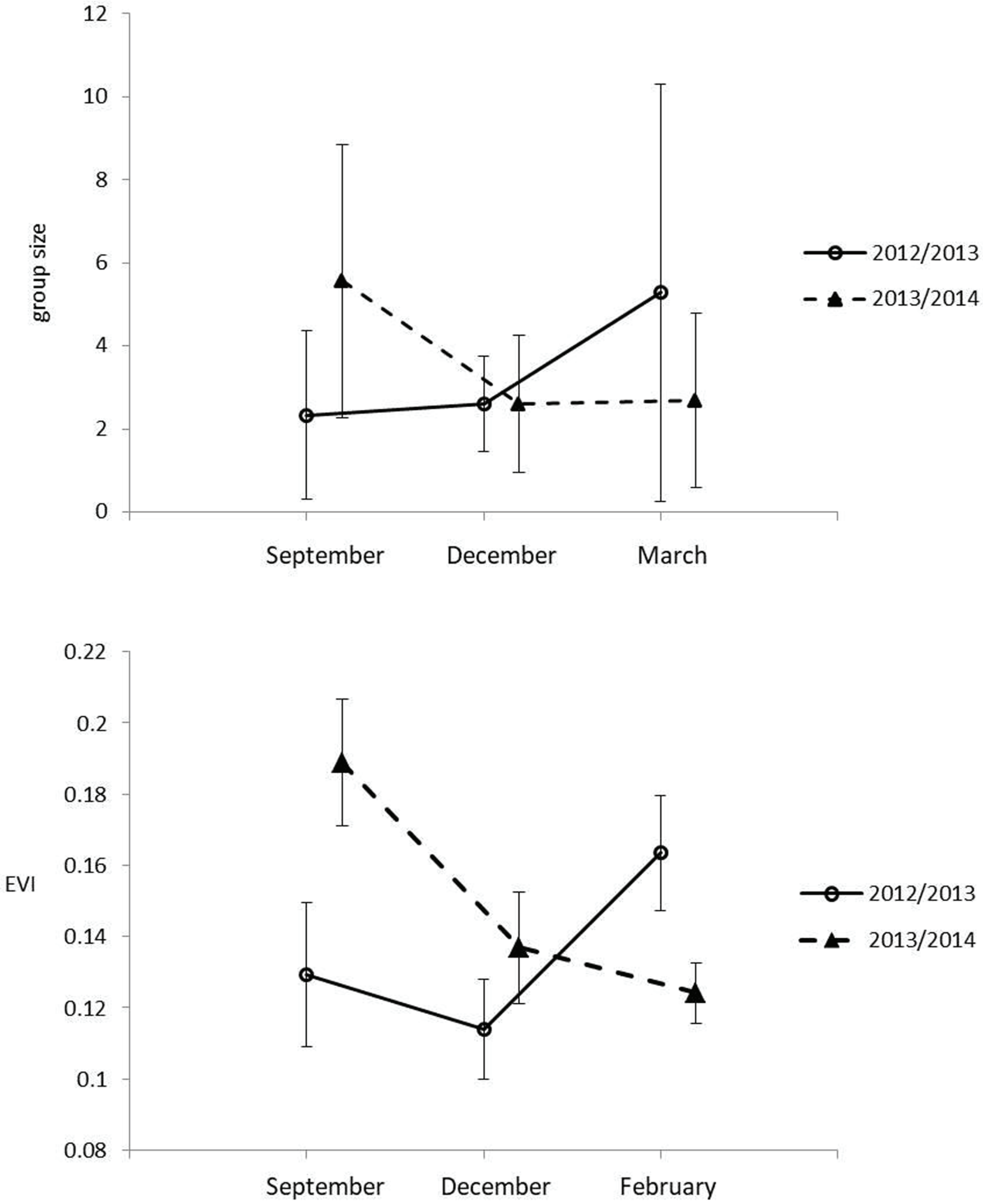

Figure 3. Average group size (A) of Lesser Rheas (*Rhea pennata pennata*) and EVI (Enhanced Vegetation Index, B) in transects sampled during the breeding (September, December) and post-breeding seasons in 2012/2013 and 2013/2014 in Península Valdés, Chubut, Argentina. Error bars depict SD.

estimations obtained by Barri et al. (2008) in a protected area and other studies conducted in other areas in Patagonia of Argentina and Chile (Table 2). The average group size of adults recorded in this study, was also lower than other estimates (Davies 2002, BirdLife International 2016), especially during droughts.

We found evidence of temporal fluctuations in Lesser Rhea densities in Península Valdés, and these seem to be correlated with variation in environmental conditions. Extreme and persistent droughts have occurred in northeastern Chubut since 2005, which decimated sheep population causing more than 60% mortality in the period of 2005–2012 (INTA 2011 and 2014). The drought happened together with the eruption of the volcanic complex Puyehue-Caulle causing both an environmental and socioeconomic disaster in 2011 (Wilson et al. 2013). This strongly reduced grass availability, affecting sheep and wildlife survival throughout northern Patagonia (Buteler et al.

Table 2. Densities of Lesser Rheas *Rhea pennata pennata* as estimated by different methods in several locations of Patagonia.

Location	Density	Method	Author
Pilcaniyeu, Río Negro, Argentina	1.65–1.59 ind/km^2	Distance	Barri et al. 2008a
Río Negro, Argentina	2.06 ind/km^2	Fixed width strip transect	Navarro et al. 1999
Neuquén, Argentina	1.94 ind/km^2	Distance	Navarro et al. 1999
Santa Cruz, Argentina	2.93 ind/km^2	Fixed width strip transect	Navarro et al. 1999
most of distribution, Neuquén, Argentina	0.44 ind/km^2	Interviews	Funes et al. 2000
National Park Torres del Paine, Última Esperanza, Chile	8 ind/km^2	Fixed width strip transect	SAG 2002
National Park Pali Aike, Magallanes, Chile	3.97 ind/km^2	Fixed width strip transect	SAG 2002
Coyhaique Alto, Coyhaique, Chile	1.22–2.29 ind/km^2	Spot density	CEA 2017

2011, Irisarri et al. 2012, Fernández-Arhex et al. 2013, Boretto et al. 2014, Flueck & Flueck 2013, 2014, Elissondo et al. 2016) including Lesser Rheas. Rhea densities were lowest estimation during the first breeding survey in 2012 (Table 1), but increased during the post-breeding surveys, together with our estimates of food availability (EVI, Figure 3B). Densities during the following year were higher, but showed the opposite seasonal pattern, declining from breeding to post-breeding, which again matched the seasonal pattern of EVI. This reduction could be due to low rainfall (< 10 mm in three months) which most likely affected food availability (CENPAT, Meteorology Laboratory). A hot and dry summer could reduce forb availability which could affect the survival of young rheas (Martella et al. 1996, Sbriller et al. 2003, Puig et al. 2013). Summer conditions and food offer could be important during post-breeding (autumn–winter), a time of the year when mortality of young birds may be high (Barri et al. 2009).

Adult group size seemed to correlate with food availability in a similar way (Figure 3B), and a similar pattern has been reported for the Greater Rhea (*Rhea americana*, de Azevedo et al. 2010). Food offer seems to be an important correlate of group size. When food availability is low, smaller groups may reduce intragroup competition for food. In a favorable foraging context, competition decreases and individuals could join in larger groups with the advantage of increased anti-predatory vigilance.

Reproductive group (male with chicks) sizes are similar to those found in other sites in Patagonia (De Lucca 1994) and the number of dependent chicks around breeding males did not seem to vary between years despite potential differences in food availability (Figure 3B). Reproductive groups are less flexible than groups composed by adults and subadults, because chicks are still dependent on the male for protection.

In conclusion, we found low densities of Lesser Rheas in our study areas (compared to other studies in Patagonia), and both density and adult group size seemed to correlate with seasonal variations in our estimate of food availability. Our data however stem from only two years of sampling and therefore causal relationships between food availability and rhea densities or group sizes should be interpreted with extreme care. We recommend conducting an extended and systematic monitoring of Lesser Rhea density, in order to understand temporal fluctuations in northeastern Patagonia.

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