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

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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 Peninsula Valdés, 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 Peninsula Valdés.

Resumen · Fluuctuaciones poblacionales del Choique (Rhea pennata pennata) en Península Valdés, Patagonia Argen-
tina
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 estadio 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 Peninsula 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
The climate is arid and semi-arid 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 Peninsula 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 km². During post-breeding densities were estimated as the sum of adults, sub-adults and just fledged juveniles per km². To increase precision of density estimates and to avoid the unrealistic assumption of constant detection (Rosenstock et al. 2002) and the under-estimation 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
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

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**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 Peninsula Valdés Protected Area, Chubut, Patagonia, Argentina.
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, $\chi^2 = 32.9$, 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 2013/2014 (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 Peninsula Valdés were low in the first season when compared with...
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.

<table>
<thead>
<tr>
<th>Location</th>
<th>Density (ind/km²)</th>
<th>Method</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilcuy, Rio Negro, Argentina</td>
<td>1.65–1.59</td>
<td>Distance</td>
<td>Barri et al. 2008a</td>
</tr>
<tr>
<td>Rio Negro, Argentina</td>
<td>2.06</td>
<td>Fixed width strip transect</td>
<td>Navarro et al. 1999</td>
</tr>
<tr>
<td>Neuquén, Argentina</td>
<td>1.94</td>
<td>Distance</td>
<td>Navarro et al. 1999</td>
</tr>
<tr>
<td>Santa Cruz, Argentina</td>
<td>2.93</td>
<td>Fixed width strip transect</td>
<td>Navarro et al. 1999</td>
</tr>
<tr>
<td>most of distribution, Neuquén, Argentina</td>
<td>0.44</td>
<td>Interviews</td>
<td>Funes et al. 2000</td>
</tr>
<tr>
<td>National Park Torres del Paine, Última Esperanza, Chile</td>
<td>8</td>
<td>Fixed width strip transect</td>
<td>SAG 2002</td>
</tr>
<tr>
<td>National Park Pali Aike, Magallanes, Chile</td>
<td>3.97</td>
<td>Fixed width strip transect</td>
<td>SAG 2002</td>
</tr>
<tr>
<td>Coyhaique Alto, Coyhaique, Chile</td>
<td>1.22–2.29</td>
<td>Spot density</td>
<td>CEA 2017</td>
</tr>
</tbody>
</table>

2011, Irisarri et al. 2012, Fernández-Arheٕ et al. 2013, Boretto et al. 2014, Flueck & Flueck 2013, 2014, Elissen 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 forage 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 (comparad 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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266


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