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Abundance and spatial distribution of Greater Rhea *Rhea americana* in two sites on the pampas grasslands with different land use

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Summary

In Argentina the original landscape structure of the pampas grasslands has changed rapidly due to intensified and specialized agricultural practices. The conversion of grasslands into croplands has been suggested as a threat to Greater Rhea *Rhea americana* populations. The main goals of this study were to estimate the abundance of Greater Rheas and to analyse the species' spatial distribution at two sites of the pampas region with different land use: agro-ecosystem and grassland. The former was mainly devoted to crop production whereas the latter was mostly used for livestock grazing. Data were collected through 14 aerial surveys from 1998 to 2001, and in 2004. Each survey consisted of six strip-transects per site, spaced at regular intervals. The total area surveyed represented 4% of each study site (113 km^2 in the grassland and 95 km^2 in the agro-ecosystem). Greater Rhea density ($\pm$SE) was significantly higher in the grassland (from 0.22 ± 0.11 to 0.86 ± 0.24 ind. km^{-2}) than in the agro-ecosystem (from 0.05 ± 0.05 to 0.12 ± 0.08 ind. km^{-2}). Greater Rheas occupied 51% of the study area in the grassland but less than 5% in the agro-ecosystem. They showed a wide and uniform spatial distribution in the former area, whereas in the latter individuals occurred in small and isolated clusters. These results raise concern about the future of the species because, over recent years, land has been increasingly used for crop production. Hence, if the current rate of change in land use continues, the conservation status of this species will be seriously affected.

Resumen

En Argentina, la estructura original de los pastizales pampeanos ha sufrido profundos cambios debido a la intensificación y especialización de las prácticas agrícolas. El reemplazo de pastizales por cultivos ha sido sugerido como una amenaza para las poblaciones silvestres de ñandú común *Rhea americana*. Los objetivos principales de este estudio fueron estimar la abundancia del ñandú común y analizar la distribución espacial de la especie en dos sitios de la región pampeana con diferente uso de la tierra: un agroecosistema y un pastizal. El primer sitio se caracteriza principalmente por la producción de cultivos mientras que la actividad predominante del segundo es la cría de ganado. Los datos fueron recolectados mediante 14 recuentos aéreos entre 1998 y 2001, y en 2004. Cada muestreo consistió en seis transectas de faja por sitio, colocadas a espacios regulares. El área muestreada representó el 4% del área total en cada sitio de estudio (113 km^2 en el pastizal y 95 km^2 en el agroecosistema). La densidad de los ñandúes ($\pm$ES) fue significativamente mayor en el pastizal (entre 0.22 ± 0.11 y 0.86 ± 0.24 ind. km^{-2}) que en el agroecosistema (entre 0.05 ± 0.05 y 0.12 ± 0.08 ind. km^{-2}). Los ñandúes ocuparon el 51% del área de estudio en el pastizal aunque menos del 5% en el agroecosistema. Los individuos presentaron una distribución espacial amplia y uniforme en el pastizal mientras que en el agroecosistema los ñandúes se encontraron en grupos pequeños y aislados entre sí. Estos resultados resultan preocupantes para el fururo de la especie porque durante los últimos años, la tierra ha sido utilizada de manera creciente para la producción de cultivos. En consecuencia, si la tasa actual de cambio en el uso de la tierra continúa, el estado de conservación de esta ratite se verá seriamente afectado.

Introduction

Grasslands are among the most human-modified and degraded habitats in the world (Guerschman and Paruelo 2004). Several bird populations are declining in North America (Vickery and Herkert 2001, Giuliano and Daves 2002) as well as in South America (Cardoso da Silva 1999, Cavalcanti 1999, Tubaro and Gabelli 1999), probably as a consequence of habitat conversion. However, knowledge about bird species status and distribution in South Amercia is still poor (Di Giacomo and Krapovickas 2005).

In Argentina, the original landscape structure of the pampas grasslands has been changing rapidly due to intensified and specialized agricultural practices (Díaz-Zorita *et al.* 2002, Brown *et al.* 2005a). This fact has been repeatedly mentioned as a threat to populations of Greater Rhea *Rhea americana*, which is an endemic bird species to South America and a typical inhabitant of the Argentine pampas grassland (Bucher and Nores 1988, Folch 1992, Codenotti and Alvarez 2000, Bazzano *et al.* 2002, Bellis *et al.* 2004, Herrera *et al.* 2004, Di Giacomo and Krapovickas 2005). Greater Rheas mostly persist in agro-ecosystems that include grasslands and pastures of both wild (e.g. *Plantago lanceolata*, *Conyza bonariensis*, *Cirsium vulgare*, *Phyla canescens*) and cultivated(e.g. alfalfa *Medicago sativa*) dicotyledonous species (Bellis *et al.* 2004), since both are preferred items in Greater Rhea's diet (Martella *et al.* 1996). However, nowadays several areas of the pampas grasslands as well as other similar habitats throughout the range of Greater Rhea in South America are exclusively devoted to grain production (Brown *et al.* 2005a).

As a consequence, there is an urgent need to gather information on how Greater Rheas could be affected by alternative land uses. Our goals in this work were to estimate the density of Greater Rhea populations and analyse the distribution of individuals at a large spatial scale, at two sites of central Argentina that exhibit different land use: agro-ecosystem and grassland.

Methods

Study areas

Data on population size and spatial distribution were collected at two sites of the Argentine pampas region, each located in the subregion known as Inland pampa. The study sites were selected on the basis of their conservation status: a semi-natural grassland area (central-southern San Luis province; 34°00′S, 66°11′W) and an agro-ecosystem (south-western Córdoba province; 33°30′S, 65°W) (León *et al.* 1984, Brown *et al.* 2005a) (Figure 1).

Although most of the pampas (94%) has been transformed into agro-ecosystems (Díaz-Zorita *et al.* 2002, Brown *et al.* 2005a), grasslands still persist in areas considered not suitable for agriculture. Previous studies (León and Anderson 1983, León *et al.* 1984) reported that changes in pristine vegetation have been less important in the semi-arid western extreme of the pampas than in other parts of that region. Hence, two study sites were selected: one located in the grassland, still resembling natural habitat of rheas, and the other in an agro-ecosystem close to the grassland site. The selected grassland is characterized by sandy soils and rolling hills with fixed and moving dunes (Anderson *et al.* 1970). Maximum summer temperatures can peak at 43°C, while winter temperatures can be as low as −15°C. Annual average rainfall is approximately 450 mm, concentrated between October and April. The main vegetation is composed of native grasses (*Sorghastrum pellitum*, *Elyomurus muticus*, *Bothriochloa springfieldii*, *Chloris retusa*, *Schizachyrium plumigerum*, *Eragrostis lugens*, *Sporobolus subinclusus*,

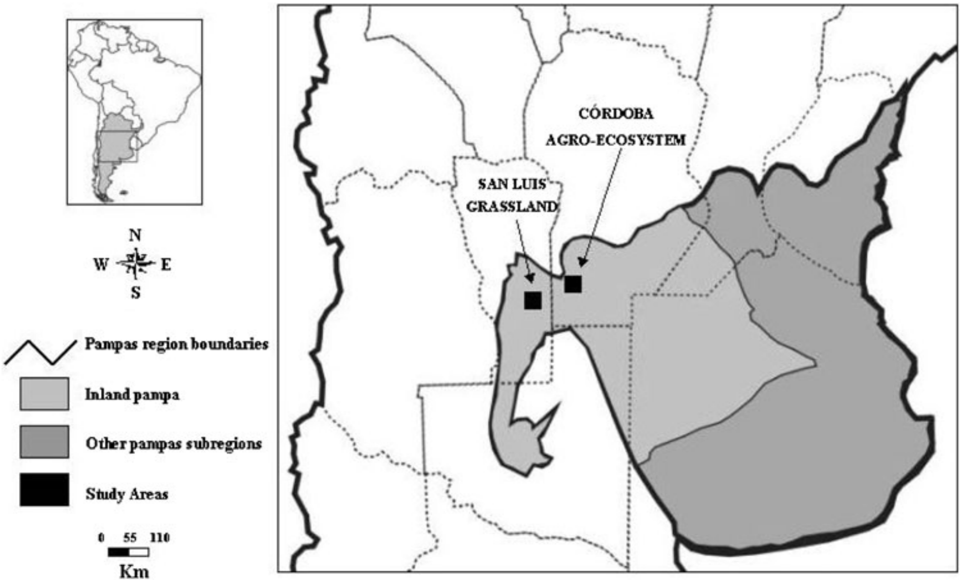

Figure 1. Location of the two study areas in the Inland pampa within the Argentine pampas region.

Aristida spegazzini, *Poa ligularis* and *Poa lanuginosa*), with small tree patches of *Geoffrea decorticans*, *Prosopis caldenia* and *Prosopis alpataco* (Anderson *et al.* 1970, Anderson 1973). Exotic grass species, such as *Eragrostis curvula* and *Digitaria eriantha*, were introduced to increase carrying capacity for livestock on ranches (Covas and Cairnie 1985). Land is mostly used for cattle-grazing and is only sporadically devoted to crop production because of the low annual rainfall (León *et al.* 1984), which in turn has contributed to maintaining its natural physiognomy. The study site in the grassland covered an area of 2,857 km^2 and included almost all the area where habitat conversion has been less extensive.

The other selected study site, the agro-ecosystem, was 2,153 km^2 in size; previous ground studies showed that Greater Rheas were present in this area (Sahade and Martella 1995, Martella *et al.* 1996). Unlike the neighbouring grassland study area, this agro-ecosystem has been severely transformed by agriculture and cattle-raising over the past 150 years (Díaz-Zorita *et al.* 2002, Brown *et al.* 2005a). Climate in the agro-ecosystem is temperate, with mean temperatures of 33°C in summer and 1.6°C in winter. The area is characterized by flat to gently rolling dunes. Rainfall is concentrated in the spring–autumn period (October–April) and the average annual rainfall is approximately 900 mm (Díaz-Zorita *et al.* 2002). The vegetation was originally composed of grasslands and forests, but is currently dominated by crops (*Zea mays*, *Triticum aestivum*, *Glycine max*, *Arachis hypogaea*; Díaz-Zorita *et al.* 2002) and pastures (*Medicago sativa*, *Eragrostis* sp., *Agropyron* sp., *Bromus* sp.; Ghersa and León 1999).

Aerial survey

We selected the aerial survey method for counting rheas because it is recommended for studies at large geographical scales, for open habitats, and for large and conspicuous individuals (Caughley 1974, Brown *et al.* 2005b, Sutherland 2005). A total of 14 aerial surveys, eight in the grassland and six in the agro-ecosystem, were conducted from 1998 to 2001 and in 2004. They were carried out in May (non-reproductive season) and December (post-reproductive season), because in both seasons rheas show aggregating behaviour and are more easily detected from the aircraft. Aerial counts were performed from a Cessna 182, flying at an average speed of 120 km h^{-1} and an average altitude of 100 m. The flight direction was west to east and vice versa across each site, to avoid glare. Each survey consisted of six parallel strip-transects per site: the first transect was set on the northernmost part of the predetermined study areas and the other five were systematically set at regular intervals of 10.4 km in the grassland and 9.3 km in the agro-ecosystem (Figure 2). Two observers, seated side by side in a high-winged aircraft, recorded the number of Greater Rheas and the coordinates of sightings with a GPS. Each observer scanned a 170 m-wide strip of ground on one side of the flight line (delineated by streamers on the aircraft's wing struts), leading to a total strip width of 340 m. Each transect had an average length of 55 km in the grassland and 46 km in the agro-ecosystem, covering areas of approximately 19 km^2 and 16 km^2, respectively. Therefore, the total area surveyed was 113 km^2 in the grassland and 95 km^2 in the agro-ecosystem, which represents 4% of the area of each study site.

Data analysis

We used the simple estimate method for equal-sized sampling units to estimate Greater Rhea densities and their respective 95% confidence limits (Sinclair *et al.* 2006) and we used the Mann–Whitney *U*-test (Zar 1984) to detect differences in Greater Rhea densities between study sites.

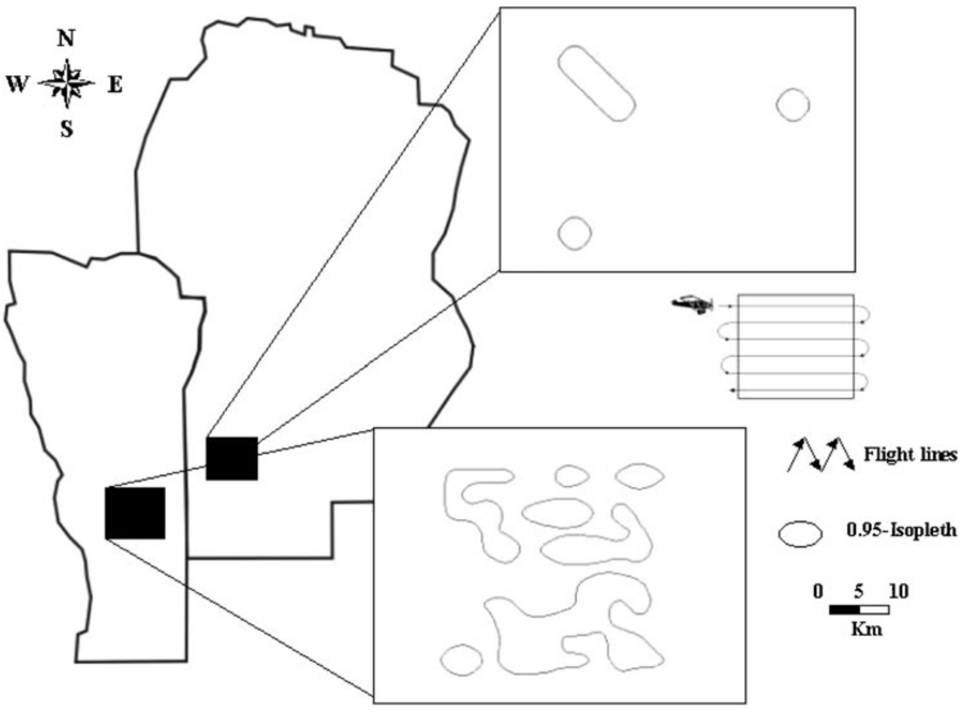

Figure 2. Spatial distribution of Greater Rheas, represented by 0.95-isopleths estimated from aerial surveys in a grassland and in an agro-ecoystem of central Argentina, during 1998 to 2004.

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To analyse the spatial distribution of Greater Rheas we created isopleths of population density, which are probability levels representing the proportion of observations that occur within them (Dixon and Chapman 1980, White and Garrot 1990, Reinert 1992). We estimated 0.95-isopleths (they include 95% of detections) based on data from all surveys pooled, using the non-parametric approach provided by the CAMRIS Geographic Information System (Ford 1998). With this method, the area over which rheas were surveyed was dissected by a grid and only those cells where one or more individuals were detected were considered.

Results

Abundance and density

Throughout the study, we recorded a total of 420 Greater Rheas, of which 404 (96%) were sighted in the grassland and 16 (4%) in the agro-ecosystem. Density of Greater Rheas (±SE) was significantly higher in the grassland (from 0.22 ± 0.11 ind. km^{-2} to 0.86 ± 0.24 ind. km^{-2}) than in the agro-ecosystem (from 0.05 ± 0.05 ind. km^{-2} to 0.12 ± 0.08 ind. km^{-2}) (Table 1) (Mann–Whitney U-test = 1041.5; $P < 0.0001$).

In the grassland, the group size of rheas ranged from one to 20 individuals during the non-breeding season, and from one to 11 in the post-reproductive season. Most groups observed at this site in both seasons consisted of two individuals. In the agro-ecosystem, group size was between one and seven individuals in the non-reproductive season, while not a single rhea was detected from the aircraft in the post-reproductive season. The groups most frequently observed consisted of four rheas.

Spatial distribution

The resulting isopleths visually identify those areas used by Greater Rheas at each site (Figure 2). In the grassland seven isopleths were defined, comprising a total area of 1,459 km^2. At this site, the spatial distribution of individuals showed a wide and uniform pattern. In the agro-ecosystem, only three isopleths were identified. Greater Rheas occurred in small clusters that

Table 1. Greater Rhea densities, their respective confidence limits (CL) and group sizes obtained from aerial surveys conducted from 1998 to 2004 in a grassland and an agro-ecosystem of central Argentina.

Area	Year	Density (individuals/km^2)		Modal group size	Group size range
		Estimate	±95% CL		
Grassland	1998[a]	0.86	0.62	1	1–20
	1998[b]	0.46	0.44	2	0–11
	1999[a]	0.45	0.49	2	1–14
	2000[a]	0.22	0.28	2	1–11
	2000[b]	0.23	0.25	1–2	0–5
	2001[a]	0.29	0.44	1–2	0–13
	2001[a]	0.55	0.41	1	1–12
	2004[a]	0.52	0.59	2	1–20
Agro-ecosystem	1998[a]	Not detected	–	–	–
	1999[a]	0.12	0.2	4	0–7
	2000[a]	0.05	0.13	4	0–4
	2000[b]	Not detected	–	–	–
	2001[a]	Not detected	–	–	–
	2004[a]	Not detected	–	–	–

[a]Non-breeding season and [b]post-reproductive season. We use the term 'Not detected' because not a single rhea was observed.

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comprised 110 km^2 in total and exhibited an uneven and restricted spatial distribution. These results show that Greater Rheas occupied 51% of the grassland but less than 5% of the agro-ecosystem.

Discussion

Our study stresses the differences in current status of Greater Rhea populations in two large areas of the Argentine pampas grasslands with alternative land uses. The dramatic contrast in abundance and spatial distribution pattern of the species between the grassland and the agro-ecosystem seems to be related to the type of land use practised in each area and, consequently, to spatial distribution and availability of resources.

In the grassland area, the low proportion of croplands (13%; P. F. G. unpubl. data) compared with that of grasslands and pasturelands is perhaps the main reason for the higher density and larger spatial distribution of Greater Rheas. In contrast, in the agro-ecosystem, most lands are currently devoted to grain production, subjecting Greater Rhea populations to disturbances driven by agricultural practices.

Only a few isolated wild populations of Greater Rheas persist in the agro-ecosystem. Those small clusters of individuals may be inhabiting ranches that have a mixture of grasses, pastures and crops. This hypothesis is supported by subsequent field ground studies (P. F. G. unpubl. data) conducted within some ranches that spatially coincide with the area defined by isopleths and where the above-mentioned habitat types were present. Therefore, this fact suggests that Greater Rheas are restricted to those private ranches where land-owners are in favour of conservation and that have become small protected areas currently ensuring the survival and reproduction of this bird species.

Since Greater Rheas' abundance and spatial distribution have not been estimated in central Argentina, this work provides novel and relevant information that can serve as the baseline for future monitoring studies. Our research also shows that habitat transformation, specifically the conversion of grasslands into croplands, has a strong and negative impact on Greater Rhea populations. As increasing grain production appears to be inevitable, and given that most of the grassland remnants in central Argentina are on privately owned land, the long-term persistence of Greater Rheas will partly depend on the development of education and outreach plans for stakeholders and adequate government policies encouraging conservation of grasslands and implantation of pastures throughout the geographical range of the species.

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