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The use of nutritional blocks as a tool for grazing management in extensive sheep husbandry

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Abstract. The improvement in grazing spatial distribution is an important goal for the efficient and sustainable management of rangelands. However, extensive livestock systems such as the Patagonian rangelands generally fails due to the large paddock size (up to 6000 ha). The purpose of this study was to evaluate the effectiveness of the strategic use of nutritional blocks as an attractive element in underused areas of the landscape, in a shrub steppe of low cover (less than 50%) under dry climate. The spatial distribution of sheep was evaluated in two extensive paddocks (1900 and 5500 ha) under two sequential treatments (With nutritional blocks and Traditional management without nutritional blocks) in two years. The study was carried out using wethers of the Corriedale breed, with an average stocking rate of 0.17±0.03 sheep/ha. The geotracking of wethers was obtained by means of collars equipped with global positioning system technology, configured with a measuring frequency of 5 minutes within an average period of 15 days. The use of nutritional blocks resulted in a 46.1-57.4% expansion in the daily home range with respect to the traditional management, suggesting a more spatial homogeneous use of the paddocks by sheep. These results would have important practical implications, considering that the use of nutritional blocks would allow the combination of supplementation strategies with the sustainable use of pastoral resources.

[Keywords: extensive management, home range, homogeneous grazing, landscape use, livestock movement, Patagonia, multi-nutritional supplement]

Resumen. El uso de bloques nutricionales como herramienta para el manejo del pastoreo en sistemas ovinos extensivos. Mejorar la distribución espacial del pastoreo es importante para lograr el objetivo de un uso eficiente y sustentable de los pastizales naturales. Sin embargo, los sistemas ganaderos extensivos como los que se utilizan en pastizales de la Patagonia generalmente fallan debido a la gran extensión de los cuadros de pastoreo (hasta 6000 ha). El objetivo del presente estudio fue evaluar la efectividad del uso estratégico de bloques nutricionales como elementos atractivos en áreas subutilizadas del paisaje; específicamente, en una estepa arbustiva de baja cobertura (menos de 50%), bajo un clima árido. La distribución espacial de ovinos fue evaluada en dos cuadros de pastoreo extensivo (1900 y 5500 ha) a través de dos tratamientos secuenciales (Con bloques nutricionales y Manejo tradicional sin bloques nutricionales), en dos años. Para el estudio se emplearon capones (carneros castrados) de la raza Corriedale, bajo una carga animal promedio de 0.17±0.03 ovinos/ha. La geolocalización de los capones se obtuvo mediante collares equipados con sistemas de posicionamiento global, configurados con una frecuencia de medición de 5 minutos en un período de 15 días. El uso de bloques nutricionales resultó en una expansión de 46.1-57.4% del área diaria de campeo con respecto al manejo tradicional, lo que sugiere que los ovinos hicieron un uso espacial más homogéneo de los cuadros. Estos resultados podrían tener importantes implicancias prácticas, considerando que utilizar bloques nutricionales permitiría combinar estrategias de suplementación con el uso sustentable de los recursos pastoriles.

[Palabras clave: manejo extensivo, área de campeo, pastoreo homogéneo, uso del paisaje, movimiento del ganado, Patagonia, suplemento multinutricional]

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Introduction

The uneven use of rangelands by domestic herbivores is one of the most common problems facing grazing management (Vallentine 2001; Holechek et al. 2010). Various techniques have been proposed to solve unequal distribution such as the correct placement and number of water sources per paddock, adequate fencing design, strategic locating of salt sources, periodic herding, burning or mowing, as well as bush control (Owens et al. 1991). Nevertheless, the search for management alternatives to achieve a more homogeneous spatial grazing entails an important challenge in extensive livestock systems. In these systems usually the climatic conditions, the size of the paddocks, as well as the topography complexity of the landscape constrain the frequent contact of the rancher with the animals. Moreover, in this context, management alternatives of proven effectiveness like the subdivision of paddocks, periodic herding, or the provisioning of new water sources are difficult to apply given the investment and maintenance costs that they entail (Tanaka et al. 2007).

In the analysis of grazing distribution patterns, it is important to consider that the animals possess innate skills which allow them to learn about their feeding environment in order to be able to function more efficiently in their habitat (Launchbaugh and Howery 2005). Learning by consequences allows animals to establish preferences or aversions for grazing sites based on positive or negative feeding consequences, respectively (Bailey et al. 1996), which, in turn, together with other stimuli, develops a general appraisal of the site visited. For example, if livestock learn to associate a palatable supplement with a particular place, it is predicted that they will return to that site if the supplement results in satiety or positive feedback (Launchbaugh and Howery 2005), especially if the forage in the surrounding area was not initially desirable.

In extensive livestock systems, the strategic placement of nutritional blocks in large paddocks represents a promising low-cost alternative to achieve a more homogeneous utilization of the rangeland and (indirectly) an improved nutritional condition of livestock (Bohnert and Stephenson 2016). The use of attractive elements to modify livestock distribution and rangeland utilization has been tested in several experiments with bovines, with successful achievements (Bailey and Welling 1999; Bailey et al. 2001; Bailey et al. 2008ab; George et al. 2008), partial achievements (Ganskopp 2001; Goulart et al. 2008) or more complex situations where the effectiveness depended on the type of attractive element (Bailey and Welling 2007; Bailey and Jensen 2008).

In the extensive Patagonian livestock systems, sheep production has historically been largely based on rangeland utilization (Cibils and Borrelli 2005). It is for this reason that the efficient use of the grazing resource is of critical importance, especially in the most fragile ecosystems of the Patagonian steppes (Borrelli et al. 1997). The large size of the paddocks (~1000 to 6000 ha) and their environmental heterogeneity naturally foster a more intense use by sheep of sites with that are more productive or offer higher forage quality (Cingolani et al. 2008). This pattern of utilization determines the existence of heterogeneous grazing over extensive paddocks, with important losses associated with the underutilization of the forage resource in some sectors and the overgrazing and environmental degradation in others (Golluscio et al. 1998). The forage resource deteriorates even more if the stocking rate is established based on the premise of a homogeneous use of the paddocks (Borrelli 2001).

In Patagonia, there are no published field studies on the use of nutritional blocks as an attractive element to improve sheep grazing distribution, and we are not aware of the application of this technology in commercial production systems (Ormaechea et al. 2019). Hence, the purpose of this study was to evaluate the effectiveness of the strategic placement of attractive nutritional blocks to modify the spatial distribution patterns of sheep in an extensive livestock system in Santa Cruz, Argentina. It was hypothesized that the strategic placement of nutritional blocks in large paddocks expands the grazing distribution of sheep, increasing the visits to sites rarely visited in the absence of nutritional blocks (henceforth 'blocks').

Materials and methods

Study site

The field study took place at Estancia El Milagro (47°20′ S - 70°57′ W), located in the

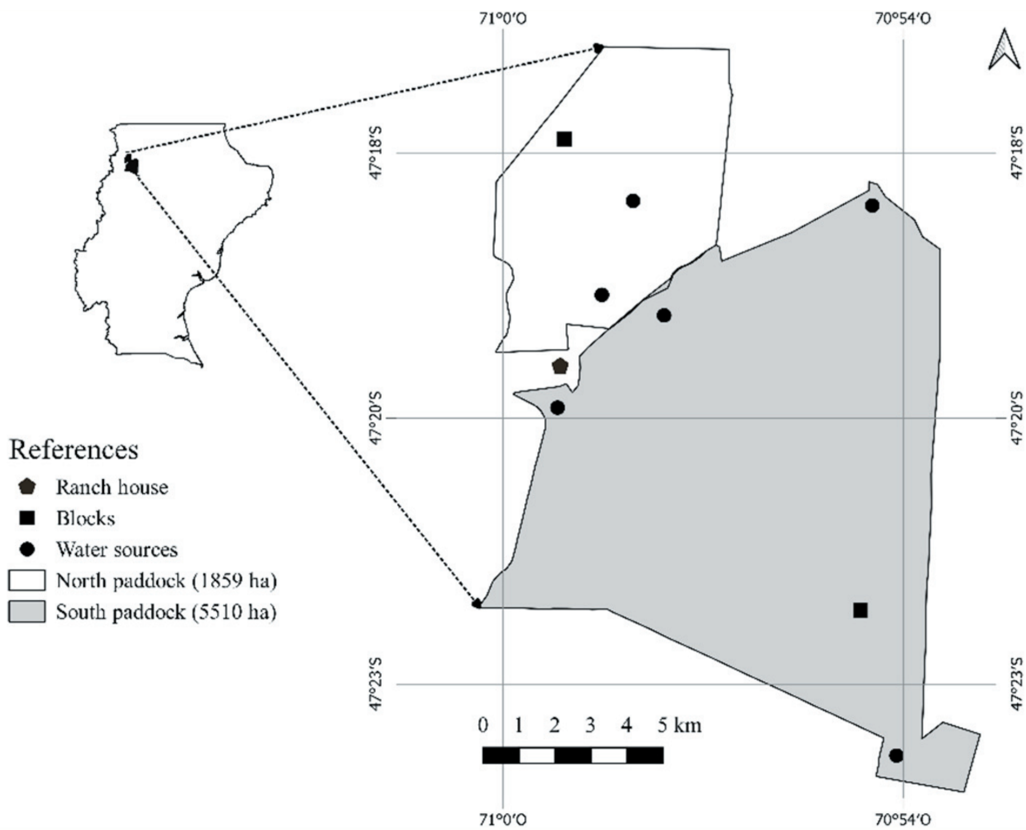

Figure 1. Localization of the paddocks of the field study, the positions of water sources, and the strategic placement of nutritional blocks. The El Milagro ranch, province of Santa Cruz, Argentina

Figura 1. Localización de los cuadros de pastoreo en el establecimiento bajo estudio, la posición de fuentes de agua, y la posición estratégica de los bloques nutricionales. Estancia El Milagro, provincia de Santa Cruz, Argentina.

northwest of the province of Santa Cruz, Argentina (Figure 1), within the Central Plateau (Meseta Central) ecological area (Figure A.1 in Supplementary Material). The ranch is part of the vegetation subunit called Erial, which was described by León et al. (1998) as a xeric shrub steppe with low vegetation cover (less than 50%), scarce grasses and cushion shrubs. The mean annual rainfall is 171 mm with relatively homogeneous distribution during the year, although slightly concentrated in the autumn. The average air temperature is 14.6 °C in January and 1.2 °C in July (Kreps et al. 2012). The dominant soils are classified as Haploxeralfic Natrargids, in undulated conglomeratic plains dissected by permanent and temporary water streams (del Valle et al. 2002).

The total area of the ranch is 17860 ha. Paddocks have been managed during the last 110 years under an extensive livestock system under year- round grazing. Each one has at least two water sources for the animals, supplied by rivers or windmill water pumps. The ranch is dedicated to raising Corriedale sheep crossed with MPM (Multi-Purpose Merino) for wool and meat production.

For the present study, two paddocks named North paddock (1859 ha) and South paddock (5510 ha), were used (Figure 1). In both paddocks, 3 plant communities can be distinguished: *Pappostipa speciosa* steppe, Grass-shrub steppe and Semidesert steppe. *Pappostipa speciosa* steppe is dominated by the tussock with the same name, while *Poa dusenii* and *Carex argentina* species represent the most important forage fraction in this community. Grass-shrub steppe has the same dominating species, but with a 5-10% of cover occupied by shrubs (*Fabiana Peckii*, *Schinus polygamus*, *Ephedra frustillata*). Finally, Semidesert steppe have similar dominating species, but with a higher cover (8-13%) of dwarf shrubs mainly represented by *Nassauvia glomerulosa.*

Field study

Two treatments were considered: 1) with blocks [henceforth, 'Block treatment'] and 2) without blocks [henceforth, 'Traditional treatment']. Each treatment was evaluated during a similar period (30 days) in two years (2015 and 2016), and over the two paddocks mentioned above. The treatments were applied at two consecutive intervals of thirty days in each paddock, beginning with the Traditional treatment (September) to control for habituation of the animals with sites associated with the presence of blocks. After 30 days, the animals from both paddocks were removed and fifty blocks (see composition and quality parameters in Tables A.1 and A.2, Supplementary Material) were weighed and placed to carry out the Block treatment (October) during the following 30 days. The blocks were placed at a target site in each paddock that met these characteristics: a) the site should be seldom frequented by the animals, according the experience of the rancher, b) must be accessible for the animals and for the transportation of the blocks, c) should be more than 2000 m away from any water source or wetland, and d) forage availability should be similar to the mean of the paddock. The blocks were placed within an area of 50x50 m, in groups of 10 (Figure A.1 in Supplementary Material) and arranged at a distance of 20 m from each other in order to facilitate access to the animals. At the end of trials each year, the blocks were removed and weighed. The daily consumption per animal was calculated based on the number of animals and the time with available blocks (30 days).

Stocking rate was 0.18±0.01 and 0.16±0.04 sheep/ha for the South and North paddocks, respectively. Forage availability (kg DM/ha) was estimated by the Santa Cruz method (Borrelli and Oliva 2001) prior the introduction of the animals in both paddocks each year. Three sampling stations were set up in each plant community, where three 0.2 m^2 cuts were performed. Then, forage availability in each paddock was determined considering the average forage availability of each plant community weighed by a rough estimate area occupied by each community within the paddock, since we did not map the spatial distribution of plant communities at paddock level.

For grazing distribution analysis, 5 wethers (two to six-year-old castrated males averaging 38.3 kg weight), familiar with the paddocks, but without prior experience with blocks were chosen at random for each paddock, treatment and year. At the beginning of the trials (September), each year, GPS collars were attached to five wethers (Figure A.1 in Supplementary Material), chosen at random from the flock assigned to each paddock (992 and 449 animals for the South and North paddock, respectively). The collars were configured to geotracking (GPS points with coordinates and timestamps were obtained) at intervals of five minutes, so autonomy reached 15 days in average. At the beginning of the consecutive treatment (October), the GPS collars were recharged and attached again on 5 other wethers chosen at random.

In the Block treatment, the animals were exposed enough time to the blocks at the target sites (~2 h) in order to recognize them as part of the management being tested. Sheep use spatial memory to locate feeding sites (blocks placement), and associations between cues (i.e., block aspect, structure) and rewards (intake of nutrients) to increase the chances of encountering preferred food (Bailey et al. 1996; Edwards et al. 1996).

The GPS collars comprise a microcontroller with 8-bit internal architecture and the coordinates are stored in a non-volatile memory EEPROM (Electrically Erasable Programmable Read Only Memory) of 64 KB. The GPS collars were powered by a battery pack of 6 AA rechargeable batteries, with an energy capacity of 4000 mAh and voltage of 3.6 V. The Institute of Rural Engineering of the National Agricultural Technology Institute of Argentina designed and built the GPS collars.

Data analysis

Visits to the target site. Based on GPS data, we calculated sheep visit frequency to the target site of each paddock, under both Traditional and Block treatments each year. In order to do so, we first defined a focal nearby area measuring up to 50 m from the center of the blocks or target site (George et al. 2008), and then considered that the animal had visited the blocks if there was at least one GPS point inside that area. It is worth pointing out that the above mentioned area is equivalent to 0.03±0.01% of the entire area of the paddocks under study. The time of each visit was also calculated. To do this, we have considered the number of consecutive GPS points and multiplied them by 5 (measurement frequency in minutes).

Use of the areas surrounding the target sites. Considering the extensive range characteristics of the system, we conducted an analysis to know if wider surrounding areas of the blocks (target sites) receive a greater use under the Block treatment. We separated out the GPS points that were inside a 500 m radius from the target sites as main locations. The same was done for the artificial water sources. We used 500 m because we consider it is an adequate max distance according to the use patterns in extensive systems and because it is also similar to the range or radii influenced by artificial water sources. Thus, we used the same criteria for blocks. To analyze these data under both treatments, we fit a generalized linear model for count variables (Negative Binomial distribution) with log(x) as link function considering single and interactive terms among treatment and paddock as fixed effects and year as block effect, for each response variable in separated way (counts from placement locations of blocks or artificial water locations). In addition, collared wethers were considered a random term, due we used different sheep across years and paddocks. We fitted this model using the R package lme4 (Bates et al. 2015) and we calculated a conditional pseudo-R^2 based on Xu (2003).

Space use pattern assessment. In order to determine if the use of nutritional blocks resulted in a more homogeneous grazing pattern across paddock, we used GPS data to estimate the daily home range (95% contour area) of all the animals monitored in each treatment. Then, we calculated the proportion of the paddock area used by all individuals. High proportions would indicate a more homogeneous grazing distribution pattern of sheep, while low proportions would indicate a more heterogeneous grazing distribution pattern of sheep. Daily home ranges were estimated using Minimum Convex Polygon technique (MCP; Southwood 1966) through the MCP function of the R adehabitatHR (Calenge 2006) package. The response variable was the daily proportion between daily home ranges and paddock area. In order to model the variability in the response variable between treatments, paddocks and years, we fitted a generalized hierarchical lineal mixed model using the R package glmmADMB (Fournier et al. 2012; Skaug et al. 2016), with Beta distribution and logit as link function (Bolker 2008). The main fixed predictors were treatment (i.e., Traditional *vs.* Blocks) and paddock (i.e., North *vs.* South), while year was considered as a block term. All the data processing and analysis were carried out using R software (R Core Team 2018).

Results

Visits to target site and consumption of blocks

In the absence of the blocks (Traditional treatment), 0 to 1 sheep with collars visited the focal area around target site (area up to 50 m from the center of the location of the blocks). The visits occurred 5±2% of the days evaluated, once every 22 days in average. During each visit, sheep remained in the target site for 8±4 minutes. In the block treatment, 3 to 5 sheep with collars visited the focal area around target site during the 15 days evaluated. The visits occurred 8±3% of the days evaluated, once

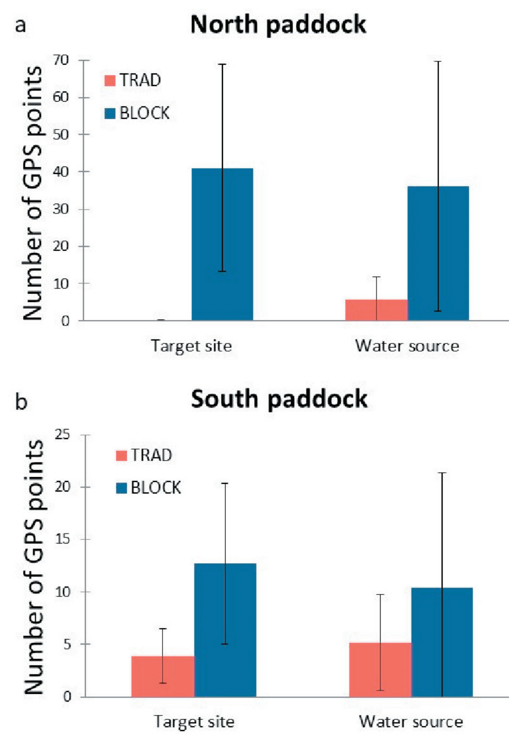

Figure 2. Predicted number of GPS points inside a 500 m radius from the target site (placement of nutritional blocks in the Block treatment) and artificial water sources for the Traditional and Block treatments in the North (a) and South (b) paddock during the 15 days of the treatments. Vertical lines represent standard error.

Figura 2. Número de puntos GPS predichos dentro de un radio de 500 m del sitio estratégico (lugar de colocación de los bloques nutricionales en el tratamiento con bloques) y fuentes de agua artificiales; para los tratamientos Tradicional y Con bloques en los cuadros de pastoreo Norte (a) y Sur (b) durante los 15 días de los tratamientos. Las líneas verticales representan el error estándar.

every 13 days in average. In each visit, sheep remained in the target site for 17±4 minutes. The observed variability in each treatment was due to differences between paddocks and years. Blocks consumption during the 30-day period of the Block treatment was variable between years and paddocks, averaging 1.11±1.15 kg/sheep. The daily consumption was 37±38 $g.sheep^{-1}.day^{-1}$. The mean availability of forage was 17.1±4.4 kg DM/ha, and varied among the sites from 0.1 kg DM/ha (sites with more than 80% of bare ground cover) to 35±16.3 kg DM/ha, with low variation between both years.

Use of the areas surrounding the target sites

The predicted number of GPS points in surrounding areas varied among treatments and paddocks, and according to each response variable (i.e., counts from nutritional blocks or water locations) (Table 1; Figure A.2a. in

Table 1. Estimated values for the fixed effects in log scale to model the counts of GPS sheep points recorded at two different surrounding areas (500 m) from target sites (a) and artificial water locations (b) according to the treatment (Block and Traditional) and paddock (North and South). The table shows the punctual estimates, standard errors, Z statistics and P values.

Tabla 1. Valores estimados para los efectos fijos en escala log, para el modelo de la cantidad de puntos GPS de ovinos registrados en las áreas circundantes (500 m) a los sitios de instalación de los bloques nutricionales (a) y en las aguadas artificiales (b) de acuerdo con los tratamientos (Con bloques y Tradicional) y los cuadros (Norte y Sur). La tabla muestra las estimaciones puntuales, errores estándar, estadísticos Z y valores P.

a)

Parameters	Estimated	Standard error	Z	P
Intercept[1]	4.01	0.912	4.39	<0.0001*
β1 (Year effect)	-0.96	0.818	-1.17	0.2425
β2 (Paddock effect)	-1.05	1.118	-0.94	0.3465
β3 (Treatment effect)	-5.11	1.411	-3.62	0.0003*
β2 × β3	3.89	1.717	2.27	0.0232*

[1] The reference level for intercept was set for the first year under Block treatment and North paddock.
* Indicates significance at P<0.05 level.

b)

Parameters	Estimated	Standard error	Z	P
Intercept[1]	3.98	1.223	3.25	0.0012*
β1 (Year effect)	-1.11	1.069	-1.04	0.2989
β2 (Paddock effect)	-1.11	1.541	-0.72	0.4731
β3 (Treatment effect)	-1.35	1.528	-0.89	0.3762
β2 × β3	0.54	2.095	0.26	0.7985

[1] The reference level for intercept was set for the first year under Block treatment and North paddock.
* Indicates significance at P<0.05 level.

Table 2. Estimated values for the fixed effects in logit scale to model the proportion of the total area of the paddocks used by sheep according to the treatment (Block and Traditional) and paddock (North and South). The table shows the punctual estimates, standard errors, Z statistics and P values.

Tabla 2. Valores estimados para los efectos fijos en escala logit, para el modelo de proporción del área total de los cuadros usada por los ovinos de acuerdo a los tratamientos (Con bloques y Tradicional) y los cuadros (Norte y Sur). La tabla muestra las estimaciones puntuales, errores estándar, estadísticos Z y valores P.

Parameters	Estimated	Standard error	Z	P
Intercept[1]	-1.09	0.176	-6.20	<0.0001*
β1 (Year effect)	-0.51	0.143	-3.59	0.0003*
β2 (Paddock effect)	0.25	0.217	1.14	0.2563
β3 (Treatment effect)	-0.46	0.218	-2.13	0.033*
β2 × β3	-0.105	0.289	-0.36	0.7164

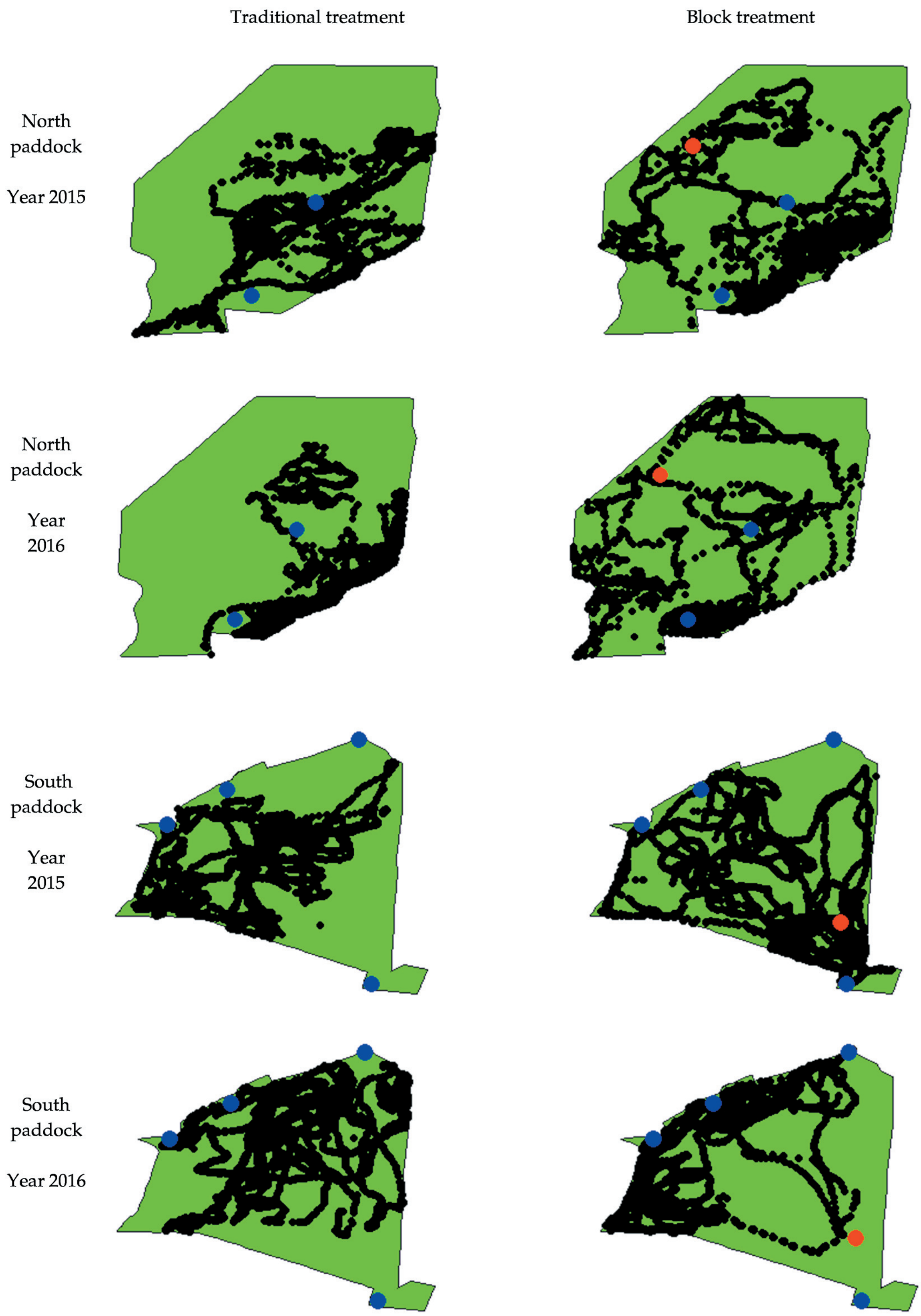

Figure 3. GPS points of 5 sheep during one week under the different treatments (Blocks *vs.* Traditional), paddocks (North *vs.* South) and years of study (2015 *vs.* 2016). The blue dots correspond to the watering locations, and the red dots are the placement sites of the nutritional blocks (target sites).

Figura 3. Puntos GPS correspondientes a 5 ovinos durante una semana bajo diferentes tratamientos (Con bloques *vs.* Tradicional), cuadros de pastoreo (Norte *vs.* Sur) y años de estudio (2015 *vs.* 2016). Los puntos azules corresponden a fuentes de agua, y los puntos rojos son los sitios de emplazamiento de los bloques nutricionales (sitios estratégicos).

Supplementary Material), with moderate pseudo-R^2 for the Block treatment (0.73). Particularly, the predicted number of GPS points in the area surrounding the target sites (i.e., placement of nutritional blocks in the Block treatment) was higher in the Block treatment than in the Traditional treatment (Table 1a), but with differences between paddocks due to a higher use in the North paddock (Table 1; Figure 2). In addition, the number of GPS points predicted by the fitted model in the area surrounding the sources of artificial water did not differ between treatments and/or paddocks (Table 1b; Figure 2).

Space use pattern assessment

The Block treatment caused a significant increase in the daily proportion of paddock area used by sheep, in comparison with the Traditional management (Table 2; Figure 3 and 4; Figure A.2b. in Supplementary Material). The fitted model reached a high pseudo-R^2 (0.87) and the proportion of the paddock area used by collared wethers was similar across paddocks, but different among treatments and across years (Table 2). The proportion of the total area used daily by the sheep was higher ($P<0.05$) in the Block treatment (20.6 and 25.5%, North and South paddock, respectively) than in the Traditional treatment (14.1 and 16.2%, respectively) (Figure 4).

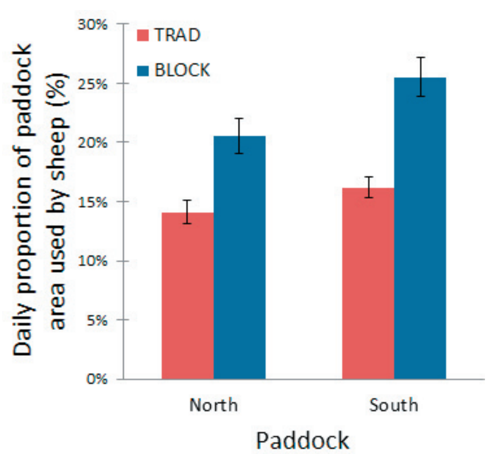

Figure 4. Predicted values of the daily proportion of the paddock area used by all collared wethers across different treatments (Block and Traditional) and paddocks (North and South) based on the fitted model presented in Table 1. The vertical lines represent the 95% confidence interval.

Figura 4. Valores predichos para la proporción diaria de área de cuadro utilizada por todos los capones equipados con GPS, para los diferentes tratamientos (Con bloques y Tradicional) y cuadros (Norte y Sur), basado en el modelo ajustado presentado en la Tabla 1. Las líneas verticales representan el 95% del intervalo de confianza.

DISCUSSION

The present study assessed an alternative to traditional grazing management in extensive livestock systems, and was based on the strategic use of nutritional blocks to improve herbivore grazing distribution patterns. The results supported the hypothesis that the strategic placement of blocks in large paddocks expands the grazing distribution of sheep, increasing the visits to sites rarely visited in the absence of blocks. However, the lack of information on the spatial distribution of plant communities represents a limitation of this study, since it can interact with the nutritional blocks to determine grazing distribution.

The more homogeneous spatial distribution of sheep was the result of an increase of the daily home range (46.1% more in the North Paddock, and 57.4% more in the South Paddock), in response to visits of target sites where the blocks were located (Figure 4). The initial herding of the sheep to the target sites to facilitate access and recognition of blocks, together with block attractiveness, produced the expected effect. This outcome agreed with previous works on the impact of food attractive elements in ruminant grazing distribution patterns, most of which has been done with cattle (Porath et al. 2002; Bailey et al. 2008ab; George et al. 2008; Bruegger et al. 2016; Stephenson et al. 2016). Several studies have analyzed the spatial distribution of the different breeds and subspecies of sheep (Hunter 1964; Grubb and Jewell 1974; Arnold et al. 1981; Clapp and Beck 2015), but few have addressed how food attractive elements can influence the spatial distribution of livestock (e.g., Lawrence and Wood-Gush 1988ab). In this regard, the present work contributes with important empirical evidence related the impact of blocks on the grazing distribution pattern of sheep in extensive production systems (with paddocks up to 6000 ha).

A more uniform use of space does not directly imply a more uniform use of forage resources. In this sense, an evaluation of forage consumption or changes in vegetation specific characteristics could have been useful to better understand the impact of the applied technology. However, several studies show how the strategic placement of nutritional supplements can increase forage utilization in the surrounding area (Golluscio et al. 1998; Frieder et al. 2003; Bailey et al. 2008a). In addition, a study carried in Patagonian steppe paddocks shows how controls over sheep spatial distribution patterns may be related to the impact over vegetation, eventually allowing minor degradation of preferred areas and promoting a more homogeneous moderate utilization (Oñatibia and Aguiar 2018).

On the other hand, it is important to highlight that the improvement in grazing distribution by strategic placement of nutritional blocks seeks to avoid overgrazing of most preferred sites, without overriding vegetation heterogeneity at landscape level. According to Cingolani et al. (2008), for natural grasslands that have contrasting environments or large areas, certain heterogeneity in vegetation is important for the conservation of biodiversity and the survival of forage species that are highly sensitive to livestock grazing. Moreover, considering the prevalent low rangeland condition observed in extensive Patagonian livestock production systems (Ormaechea et al. 2019), an excessive stocking rate could be much more detrimental in the maintenance of the heterogeneity of the vegetation and the survival of the desirable forage species (Fuhlendorf and Engle 2001).

The frequency and duration of the visits to the blocks by sheep showed relatively low values (frequency: once every 13 days; duration: 17±4 min/d), compared with previous observations in cattle (e.g., Bailey and Jensen 2008). These authors tested the use of a nutritive supplement as attractive element and found that cattle visited the supplement once every 2.5 days at an average visit duration of 57 min/d. However, regardless the relatively low frequency and duration of visits to blocks by sheep observed in the present study, the mean intake by the flock (37 g/d) was within the range of values reported for sheep by Bowman and Sowell (1997). These latter authors pointed out that in supplemented sheep it is common to observe a high percentage of animals that do not consume the supplementary feed, at least in part due to dominance among animals. However, by seeking out and consuming the supplement, these dominant animals may condition the spatial distribution of the rest of the flock, causing a more homogeneous spatial use of rangelands (Ducker et al. 1981; Lawrence and Wood-Gush 1988ab).

The availability and distribution of feeding resources influence the grazing area explored by mammalian herbivores (McNab 1963; Lindstedt et al. 1986; Jetz et al. 2004). As the availability of forage increases, the grazing area usually decreases (Schoener 1981; Ford 1983; Mace et al. 1983). Contrarily, in the present study, the grazing area explored by sheep increased when the flock had access to an additional source of nutrients provided by blocks. The high protein content of blocks (43.6%) might have stimulated forage consumption by sheep (Kawas 2008; Giraudo 2011), resulting in an incentive to explore in search of fibrous feed, even more so considering the scarce availability of forage in the paddocks under study (0.1-35 kg DM/ha). In this context, it could be argued that prior grazing of sheep under the Traditional treatment may have depleted forage availability up to a point to force sheep under the block treatment to expand the grazing area. However, this possibility would have been slightly probable since the grazing pressure was relatively low (~100 kg DM/sheep) and grasses are actively growing at the beginning of spring (Andrade et al. 2015).

The results of present study have key practical implications, since the use of nutritional blocks would allow a combination of supplementation strategies with the sustainable use of the pastoral resource. A more uniform use of the rangelands at moderate stocking rates would attenuate the degradation of the most preferred sites (Golluscio et al. 1998), would allow for an increase in productivity and plant species richness (Oñatibia and Aguiar 2016; Herrero-Jáuregui and Oesterheld 2018), and maintain or improve the health of the rangeland systems (Bailey and Brown 2011). Further research is needed to adjust the number of attraction locations according to paddock size and landscape characteristics, and the times of the year when the use of supplement to attract animals is more critical. Research is also needed to improve the attractiveness of supplemental food and to adjust the nutritional composition of the supplement to complement the nutritional profile of the available forage. Research should also evaluate the effect of nutritional blocks on vegetation recovering and animal performance. Further analysis could also be performed to consider the differences in the sites visited by the sheep during the days under treatment. Finally, it would be important to know whether the strategic placement of nutritional blocks enhances the effect of rotational grazing in improving the homogeneity of rangeland use in extensive livestock systems.

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References

Andrade, M., D. Suárez, P. L. Peri, P. Borrelli, S. Ormaechea, D. Ferrante, E. Rivera, and M. V. Sturzenbaum. 2015. Desarrollo de un modelo de asignación variable de carga animal en Patagonia Sur. Ediciones INTA, Buenos Aires, Argentina.

Arnold, G. W., S. R. Wallace, and W. A. Rea. 1981. Associations between individuals and homerange behaviour in natural flocks of three breeds of domestic sheep. Applied Animal Ethology 7:239-257. https://doi.org/10.1016/0304-3762(81)90081-X.

Bailey, D. W., and G. R. Welling. 1999. Modification of cattle grazing distribution with dehydrated molasses supplement. Journal of Range Management 52:575-582. https://doi.org/10.2307/4003626.

Bailey, D. W., and D. Jensen. 2008. Method of Supplementation May Affect Cattle Grazing Patterns. Rangeland Ecology and Management 61:131-135. https://doi.org/10.2111/06-167.1.

Bailey, D. W., and G. R. Welling. 2007. Evaluation of low moisture blocks and conventional dry mixes for supplementing minerals and modifying cattle grazing patterns. Rangeland Ecology and Management 60:54-64. https://doi.org/10.2111/05-138R1.1.

Bailey, D. W., and J. R. Brown. 2011. Rotational grazing systems and livestock grazing behavior in shrub-dominated semiarid and arid rangelands. Rangeland Ecology and Management 64:1-9. https://doi.org/10.2111/REM-D-09-00184.1.

Bailey, D. W., J. E. Gross, E. A. Laca, L. R. Rittenhouse, M. B. Coughenour, D. M. Swift, and P. L. Sims. 1996. Mechanisms that result in large herbivore grazing distribution patterns. Journal of Range Management 49:386-400. https://doi.org/10.2307/4002919.

Bailey, D. W., G. R. Welling, and E. T. Miller. 2001. Cattle use of foothills rangeland near dehydrated molasses supplement. Journal of Range Management 54:338-347. https://doi.org/10.2307/4003101.

Bailey, D. W., H. C. Van Wagoner, R. Weinmeister, and D. Jensen. 2008a. Evaluation of low-stress herding and supplement placement for managing cattle grazing in upland and riparian areas. Rangeland Ecology and Management 61:26-37. https://doi.org/10.2111/06-130.1.

Bailey, D. W., H. C. Van Wagoner, R. Weinmeister, and D. Jensen. 2008b. Comparison of low-moisture blocks and salt for manipulating grazing patterns of beef cows. Journal of Animal Science 86:1271-1277. https://doi.org/10.2527/jas.2007-0578.

Bates, D., M. Mächler, Bolker B, and S. Walker. 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software 67:1-48. https://doi.org/10.18637/jss.v067.i01.

Bohnert, D. W., and M. B. Stephenson. 2016. Supplementation and sustainable grazing systems. Journal of Animal Science 94:15-25. https://doi.org/10.2527/jas.2016-0520.

Bolker, B. M. 2008. Ecological models and data in R. Princeton University Press, Princeton, USA.

Borrelli, P. 2001. Producción animal sobre pastizales naturales. Pp. 129-160 *in* P. Borrelli and G. Oliva (eds.). Ganadería Ovina Extensiva Sustentable en la Patagonia Austral. EEA INTA Santa Cruz editions, Santa Cruz, Argentina.

Borrelli, P., and G. Oliva. 2001. Evaluación de pastizales. Pp. 163-184 *in* P. Borrelli and G. Oliva (eds.). Ganadería Ovina Extensiva Sustentable en la Patagonia Austral. EEA INTA Santa Cruz editions, Santa Cruz, Argentina.

Borrelli, P., G. Oliva, M. Williams, L. González, P. Rial, and L. Montes. 1997. Sistema regional de soporte de decisiones. Santa Cruz and Tierra del Fuego. PRODESER (INTA-GTZ), Buenos Aires, Argentina.

Bowman, J. G. P., and B. F. Sowell. 1997. Delivery method and supplement consumption by grazing ruminants: a review. Journal of Animal Science 75:543-550. https://doi.org/10.2527/1997.752543x.

Bruegger, R. A., L. A. Varelas, L. D. Howery, L. A. Torell, M. B. Stephenson, and D. W. Bailey. 2016. Targeted Grazing in Southern Arizona: Using Cattle to Reduce Fine Fuel Loads. Rangeland Ecology and Management 69:43-51. https://doi.org/10.1016/j.rama.2015.10.011.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516-519. https://doi.org/10.1016/j.ecolmodel.2006.03.017.

Cibils, A., and P. Borrelli. 2005. Grasslands of Patagonia. Pp. 121-170 *in* J. M. Suttie, S. G. Reynolds and C. Batello (eds.). Grasslands of the world. Food and Agriculture Organization.

Cingolani, A. M., I. Noy-Meir, D. D. Renison, and M. Cabido. 2008. La ganadería extensiva, ¿es compatible con la conservación de la biodiversidad y de los suelos? Ecología Austral 18:253-271.

Clapp, J. G., and J. L. Beck. 2015. Evaluating distributional shifts in home range estimates. Ecology and evolution 5: 3869-3878. https://doi.org/10.1002/ece3.1655.

del Valle, H. F., P. J. Bouza, P. E. Rial, and L. González. 2002. Suelos. Pp. 815-828 *in* M. J. Haller (ed.). Geología y Recursos Naturales de Santa Cruz. XV Argentine Geological Congress. El Calafate, Argentina.

Ducker, M. J., P. T. Kendall, R. G. Hemingway, and T. McClelland. 1981. An evaluation of feedblocks as a means of providing supplementary nutrients to ewes grazing up-land/hill pastures. Animal Science 33:51-57. https://doi.org/10.1017/S0003356100025198.

Edwards, G. R., Newman J. A., Parsons A. J., and J. R. Krebs. 1996. The use of spatial memory by grazing animals to locate food patches in spatial heterogeneous environments: an example with sheep. Applied Animal Behaviour Science 50:147-160. https://doi.org/10.1016/0168-1591(96)01077-5.

Friedel, M. H., Sparrow A. D., Kinloch J. E., and D. J. Tongway. 2003. Degradation, recovery processes in arid grazing lands of central Austalia 2: Vegetation. Journal of Arid Environment 55:327-348. https://doi.org/10.1016/S0140-1963(03)00026-0.

Ford, R. G. 1983. Home range in a patchy environment: optimal foraging predictions. American Zoologist 23:315-326. https://doi.org/10.1093/icb/23.2.315.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software 27:233-249. https://doi.org/10.1080/10556788.2011.597854.

Fuhlendorf, S. D., and D. M. Engle. 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns: we propose a paradigm that enhances heterogeneity instead of homogeneity to promote biological diversity and wildlife habitat on rangelands grazed by livestock. BioScience 51:625-632. https://doi.org/10.1641/0006-3568(2001)051[0625:RHOREM]2.0.CO;2.

Golluscio, R. A., V. A. Deregibus, and J. M. Paruelo. 1998. Sustainability and range management in the Patagonian steppes. Ecología Austral 8:265-284.

Golluscio, R. A., J. M. Paruelo, J. L. Mercau, and V. A. Deregibus. 1998. Urea supplementation effects on the utilization of low-quality forage and lamb production in patagonian rangelands. Grass and Forage Science 53:47-56. https://doi.org/10.1046/j.1365-2494.1998.00103.x.

Ganskopp, D. 2001. Manipulating cattle distribution with salt and water in large arid land pastures: GPS/GIS assessment. Applied Animal Behaviour Science 73:251-262. https://doi.org/10.1016/S0168-1591(01)00148-4.

George, M. R., N. K. McDougald, W. A. Jensen, R. E. Larsen, D. C. Cao, and N. R. Harris. 2008. Effectiveness of nutrient supplement placement for changing beef cow distribution. Journal of Soil and Water Conservation Vol 63, N°1. https://doi.org/10.2489/jswc.63.1.11.

Giraudo, C. G. 2011. Suplementación de ovinos y caprinos. Technical note. INTA EEA Bariloche, Argentina.

Goulart, R. C. D., M. Corsi, D. W. Bailey, and S. S. Zocchi. 2008. Cattle Grazing Distribution and Efficacy of Strategic Mineral Mix Placement in Tropical Brazilian Pastures. Rangeland Ecology and Management 61:656-660. https://doi.org/10.2111/08-137.1.

Grubb, P., and P. A. Jewell. 1974. Movement, daily activity and home range of Soay sheep. Pp. 160-194 *in* P. A. Jewell, C. Milner and J. Morton Boyd (eds.). Island Survivors; the ecology of the Soay Sheep of St. Kilda. Athlone Press, London, UK.

Herrero-Jáuregui, C., and M. Oesterheld. 2018. Effects of grazing intensity on plant richness and diversity: a meta-analysis. Oikos 127:757-766. https://doi.org/10.1111/oik.04893.

Holechek, J. L., R. D. Pieper, and C. H. Herbel. 2010. Range management: principles and practices. 6th ed. Pearson, Nueva Jersey, USA.

Hunter, R. F. 1964. Home range behaviour in hill sheep. Pp. 155-171 *in* D. F. Crisp (ed.). Grazing in terrestrial and marine environments. Blackwell, Oxford, USA.

Jetz, W., C. Carbone, J. Fulford, and J. H. Brown. 2004. The scaling of animal space use. Science 306:266-268. https://doi.org/10.1126/science.1102138.

Kawas, R. J. 2008. Producción y utilización de bloques multinutrientes como complemento de forrajes de baja calidad para caprinos y ovinos: la experiencia en regiones semiáridas. Tecnologia y Ciência Agropecuária 2:63-69.

Kreps, G., G. Martínez Pastur, and P. Peri. 2012. Cambio climático en Patagonia Sur. INTA eds. EEA INTA Santa Cruz-CONICET, Buenos Aires, Argentina.

Launchbaugh, K. L., and L. D. Howery. 2005. Invited Synthesis Paper: Understanding Landscape Use Patterns of Livestock as a Consequence of Foraging Behavior. Rangeland Ecology and Management 58:99-108. https://doi.org/10.2111/03-146.1.

Lawrence, A., and D. Wood-Gush. 1988a. Influence of social behaviour on utilization of supplemental feed blocks by Scottish hill sheep. Animal Science 46(2):203-212. https://doi.org/10.1017/S0003356100042252.

Lawrence, A., and D. Wood-Gush. 1988b. Homerange behaviour and social organization of Scottish blackface sheep. Journal of Applied Ecology 25-40. https://doi.org/10.2307/2403607.

León, R. J., D. Bran, M. Collantes, J. M. Paruelo, and A. Soriano. 1998. Grandes unidades de vegetación de la Patagonia extra andina. Ecología Austral 8:125-144.

Lindstedt, S. L., B. J. Miller, and S. W. Buskirk. 1986. Home range, time, and body size in mammals. Ecology 67:413-418. https://doi.org/10.2307/1938584.

Mace, M., P. H. Harvey, and T. H. Clutton-Brock. 1983. Vertebrate homerange size and energetic requirements. Pp. 32-53 *in* I. R. Swingland and P. J. Greenwood (eds.). The Ecology of Animal Movements. Clarendon Press, Oxford, UK.

McNab, B. K. 1963. Bioenergetics and the determination of home range size. The American Naturalist 97:133-140. https://doi.org/10.1086/282264.

Oñatibia, G. R., and M. R. Aguiar. 2016. Continuous moderate grazing management promotes biomass production in Patagonian arid rangelands. Journal of Arid Environments 125:73-79. https://doi.org/10.1016/j.jaridenv.2015.10.005.

Oñatibia, G. R., and M. R. Aguiar. 2018. Paddock size mediates the heterogeneity of grazing impacts on vegetation. Rangeland Ecology and Management 71:470-480. https://doi.org/10.1016/j.rama.2018.03.002.

Ormaechea, S. G., P. L. Peri, P. A. Cipriotti, and R. Distel. 2019. El cuadro de pastoreo en los sistemas extensivos de Patagonia Sur. Percepción y manejo de la heterogeneidad. Ecología Austral 29:174-184. https://doi.org/10.25260/EA.19.29.2.0.829.

Owens, K. M., K. L. Launchbaugh, and J. W. Holloway. 1991. Pasture Characteristics Affecting Spatial Distribution of Utilization by Cattle in Mixed Brush Communities. Journal of Range Management 44:118-123. https://doi.org/10.2307/4002308.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: R-project.org.

Porath, M. L., P. A. Momont, T. DelCurto, N. R. Rimbey, J. A. Tanaka, and M. McInnis. 2002. Offstream water and trace mineral salt as management strategies for improved cattle distribution. Journal of Animal Science 80:346-356. https://doi.org/10.2527/2002.802346x.

Schoener, T. W. 1981. An empirically based estimate of home range. Theoretical Population Biology 20:281-325. https://doi.org/10.1016/0040-5809(81)90049-6.

Skaug, H., D. Fournier, A. Nielsen, A. Magnusson, and B. Bolker. 2016. Generalized Linear Mixed Models using 'AD Model Builder'. R package version 0.8.3.3.

Southwood, T. R. E. 1966. Ecological methods. Methuen, London, UK.

Stephenson, M. B., D. W. Bailey, L. D. Howery, and L. Henderson. 2016. Efficacy of low-stress herding and low-moisture block to target cattle grazing locations on New Mexico rangelands. Journal of Arid Environments 130:84-93. https://doi.org/10.1016/j.jaridenv.2016.03.012.

Tanaka, J. A., N. R. Rimbey, L. A. Torell, D. Bailey, T. DelCurto, K. Walburger, and B. Welling. 2007. Grazing distribution: the quest for the silver bullet. Rangelands 29:38-46. https://doi.org/10.2111/1551-501X(2007)29[38:GDTQFT]2.0.CO;2.

Vallentine, J. F. 2001. Grazing management. Second Edition. Academic Press, San Diego, USA.

Xu, R. (2003). Measuring explained variation in linear mixed effects models. Statistics in Medicine 22:3527-3541. https://doi.org/10.1002/sim.1572.