



Forage offer from a saline wetland of Central Argentina (San Luis Province)

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Abstract Saline wetlands usually suffer degradation processes, so their exploitation requires planning to achieve the conservation of their resources. Our objective was to determine the forage capacity of a degraded saline wetland in the east central province of San Luis, Argentina, called “Bajo Las Saladas”. Five different vegetation physiognomic types were recognized across three landscape units and their vegetation characteristics and aerial biomass were determined. In those areas, species with forage value were: *Atriplex lampa* and *Atriplex undulata* (Amaranthaceae), *Sporobolus phleoides*, *Pappophorum caespitosum* and *Distichlis spicata* (Poaceae). Other Amaranthaceae, *Sarcocornia neei*, was a forage of low value. Considering the total forage production, its use factor, and the foraging habits of a breeding cow,

we estimated a forage offer able to sustain 11.5 breeding cows 100 ha⁻¹. The grazing of this saline wetland, carrying out forage management taking into account the limitations of the area, could be an attractive economic alternative minimizing the present wetland deterioration.

Keywords Salt marshes · Plant communities · Saline soils · Marshland grazing · Conservation management

Introduction

Wetlands and salt marshes play a variety of environmental functions and are considered a priority for the preservation of biodiversity. However, most of them are influenced by human activity, including conversion to farmland and even to urban land (Morris and Reich 2013). One of the most common anthropic activities carried out in these environments is direct grazing by domestic species (Gedan et al. 2009). The effect of grazing on salt marsh vegetation has been studied in the northern hemisphere, but information is scarce regarding South American saline wetlands (Doody 2008; Taylor et al. 2021).

Grazing has detrimental effects on salt marsh vegetation due to intense, sometimes selective, defoliation and trampling. This reduces the proportion of rare plant species and affects the regeneration or reestablishment of the vegetation cover. However, domestic

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herbivores may be beneficial in some wetlands by improving floristic diversity (Taylor et al. 2021). One key issue is the intensity of grazing which, depending on factors such as grazing history, climate, and productivity, differently affects the spatial structure of wetland vegetation and species composition (Morris and Reich 2013). In addition, grazing leads to soil compaction and the occurrence of bare soil patches, which frequently enables the upward capillary movement of saline water and promotes surface salts accumulation (Cisneros et al. 1999; Di Bella et al. 2020). This is why the exploitation of wetlands requires site-specific planning in order to achieve the maximum benefit within the framework of environmental conservation (Cronk and Fennessy 2001).

One of the main tools for this purpose is grazing management, and therefore it is important to estimate the maximum number of animals sustained by a specific environment, the load capacity of the grazing system without being deteriorated (Vallentine 1990). In this context, there are grazing technologies that have been adequate for sustainable management of wetland ecosystems. For example, patch burns across the year followed by cattle exclusion and rotational stocking most of the time (Di Bella et al. 2020) or changing grazing duration and pressure, providing supplementary food, etc. (Taylor et al. 2021). The receptivity of those systems could be improved by applying those sustainable management strategies, which change vegetation cover, floristic composition and forage availability. In many cases, a change in soil salinity and pH and an increase in water infiltration rates could be expected (Di Bella et al. 2020).

Numerous species thrive in saline wetlands worldwide, but among dicots Asteraceae, Fabaceae, Solanaceae, Verbenaceae and Amaranthaceae stand out. The latter is one of the most conspicuous families, including the Chenopodiaceae subfamily (Kadereit et al. 2006). Species of the genus *Atriplex* or *Sarcocornia*, for example, are outstanding forage in those environments. Among the monocots growing in wetlands, the Poaceae family stand out. The different plant species and their characteristics affect the amount of nutrients absorbed by the cattle, which is also known as forage digestibility. There are relations between digestibility and succulence (Lyons and Machen 2000). Changes in leaf succulence are related to tissue salt accumulation (Norman et al. 2013). Most halophytes are succulents; compared with

non-succulent plants, these have a high-water content per unit area of leaves, large cells, thick leaves or stems, and a small number of leaves per plant (Cronk and Fennessy 2001). The succulence dilutes the internal saline concentration (mainly sodium salts) and, consequently, decreases the negative effects of salts in plants (Zeng et al. 2018). Norman et al. (2013) indicated that succulence in itself is not of importance to ruminants but salt intake is the critical factor and the water content of the forage has little consequence. Conversely, Krausman (1978) found that carbohydrates of succulents are important in livestock feeding and water provided by succulents is important in xeric areas.

Succulents as well as other species are found in the saline wetlands that interrupt the flat landscape of the Chaco-Pampas sedimentary plain (Rubio et al. 2018). This is a vast arid/semiarid area in South America, occupying more than half a million square kilometers, including a large part of Argentina and other neighboring countries. A conspicuous vegetation type in the area is deciduous xerophytic forests, in which the predominant soils are Entisols and Mollisols (Rubio et al. 2018). Across this flat landscape are depressions: intrazonal environments that in many cases are saline wetlands (Rubio et al. 2018). The area is marginal from the agricultural point of view, with large ranches subjected to extensive cattle grazing and, to a lesser extent, sheep and goats. The whole area suffers from varying degrees of deterioration, although, due to their characteristics, the saline wetlands are the most fragile. Our objective was to estimate forage offer of plant species growing in one depression, located in the province of San Luis, Argentina, as a first step aiming towards the sustainable use of the forage resources of these saline wetlands.

Materials and methods

General characterization of the Caldén forest

The Caldén forest expands into the border between the semiarid and arid zones of the Chaco-Pampas sedimentary plain. This forest surrounds the studied depression. A negative annual water balance characterizes the climate: the annual average rainfall is 697 mm and the mean annual evapotranspiration rate is 781 mm. A dry and cold autumn–winter semester

(averaging 10.8 °C) contrasts sharply with a warm semester (averaging 20.5 °C) concentrating almost all the annual rainfall. The typical vegetation physiognomies of the territory consist of an open deciduous forest with trees up to 12 m high, dominated by *Prosopis caldenia* (caldén), accompanied by other trees (i.e., *Geoffroea decorticans*), bushes, grasses, other plants and cacti specimens. In many areas, the forest has disappeared due to logging for timber and cattle grazing. Pastures were sowed in some places, the main species being *Eragrostis curvula* (weeping love grass) and *Thinopyrum ponticum* (tall wheatgrass), which behaves as an aggressive invader. The forest is subjected to continuous grazing all year round (Barbosa 2020).

Characteristics of the studied zone

The study area, the depression called “Bajo Las Saladas” is located between latitudes 33° 36′ and 33° 37′ South and longitudes 65° 25′ and 65° 26′ West, to the North-Northeast of the city of Villa Mercedes (San Luis province, Argentina). The study was carried out in two representative areas of the depression, comprising a total area of 84.2 ha. The altitude ranges from 528.4 to 536.8 m above sea level.

The depth to the water table in the depression was determined monthly for a year and a half (Barbosa et al. (2022)). There was no relationship between rainfall and the water table, which varied in depth from −1.41 m to +0.07 m. The variation of the water table was significant over time, and it changed unevenly in the different physiognomic types. The lower parts of the relief are flooded, or with water very close to the surface, for several months a year, while in the rest of the area these phenomena are shorter (Barbosa et al. (2022)). The combination of the phreatic rise and the occurrence of a superficial water level, which maintains very high soil humidity, determined the appearance of gleyzation processes in most soils. The soil oxide-reduction potential in the A horizons varied from 103 to 449 mV (Barbosa et al 2022).

Barbosa et al. (2022) described the dominant soils, and their main characteristics, which are associated with the vegetation physiognomic types located in the studied depression. The soils of the area are sandy loam with variable organic carbon content (4.7 to 13.7 g kg^{−1}), salinity (5.6 to 30.3 dSm^{−1}) and alkalinity—pH 1:2.50 (8.1–9.8) but sharing a

similar sequence of horizons (A/AC/C). The soils in the periphery and outside the depression were classified as Typic Ustortents, and in the center were Typic Epiaquents.

At present, there are no specific regulations for the use of this saline wetland and the area is subjected to indiscriminate grazing by cattle (also horses and donkeys) some months of the year. The current load is around 5 livestock unit (LSU) 100 ha^{−1} (E.O. Coser, personal communication).

Determinations

Photointerpretation was carried out using contact aerial photos at a scale of 1:20,000 and a Google Earth image, taken on February 28, 2009, summer in the southern hemisphere. Likewise, a topographic survey of the land was carried out. From the detection and delineation of relief, natural vegetation, crops, soil surface characteristics, drainage pattern, land use, etc., landscapes and physiognomic types were identified (Barbosa 2020).

In each physiognomic type, the dominant species were determined through floristic surveys carried out from November to March, and plant species were identified using current keys (Instituto de Botánica Darwinion 2019). The collected specimens are deposited in the Herbarium of the Department of Agricultural Sciences, Faculty of Engineering and Agricultural Sciences, National University of San Luis. Three sampling plots were set up in the area occupied by each one of the five physiognomic types studied and biomass samples were taken in at the end of the cycle of these species (March). We assumed that samples taken at the end of the growing season are representative of annual production. The plant aerial biomass was determined by cutting a round area of 1.5 m², selected at random within each one of the plots. The plant material was dried at 60 °C until constant weight, and weighed. In three most conspicuous species, *Atriplex undulata*, *Sarcocornia neei* and *Distichlis spicata*, succulence was measured from the plant green/dry ratio. The same samples were subjected to a digestion in HClO₄ and HNO₃ and the concentration of sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺) and magnesium (Mg²⁺) were determined by atomic absorption spectrophotometer (Kalra 2019). An ANOVA test to distinguish the significant differences among cation concentration was applied. Means were compared using the Least Significant Differences test (LSD; P < 0.05).

Calculation of cattle load

The cattle load capacity of the saline depression was estimated from the data of biomass production of the different physiognomic types and the area they occupy. For the local extensive production systems of Argentina, it was proposed that in annual average, a breeding cow has a daily forage consumption (dry matter—DM) in the order of 2% of its body weight (8 kg DM per day), when it consumes foraging herbs with an approximate digestibility of 55% (Barbosa 2020; Cahuepé and Gutheim 2020). A use factor of 40% for the consumption of global forage production was established. The use factor depends on the component species of each ecosystem and their conditions. For example, in the Caldén forest or local pastures, a factor between 50 to 60% is estimated. However, in this saline and extremely fragile environment, a factor of 40% was considered for the conservation of the resource of this saline wetland (Barbosa 2020; Cahuepé and Gutheim 2020). The following series of steps was used to calculate the load capacity of the wetlands:

Annual biomass of each physiognomic type

× Area = Forage availability

Forage availability × Use factor = Final forage availability

Final forage availability/

Annual forage consumption of 400kg breeding cow

= Total load

Σ Total load for each physiognomic type

= Total load for Bajo Las Saladas

Results

Five different vegetation physiognomic types with homogeneous characteristics were recognized across the three landscape units (Halophilic bush, Creeping halophilic bush, Dense halophilic meadow, Open halophilic meadow and Saline playa). Figure 1 shows the structure of the vegetation in the different physiognomic types within the study area, as well as their main plant species. For comparative purposes, this figure includes the Halophilic forest, a transitional physiognomic type between the Caldén forest and the vegetation of the depression.

The Halophilic bush located in the topographically highest sector of the saline depression includes *Atriplex undulata*, *Atriplex lampa*, and other species (Table 1). In the sectors where the bush was open,

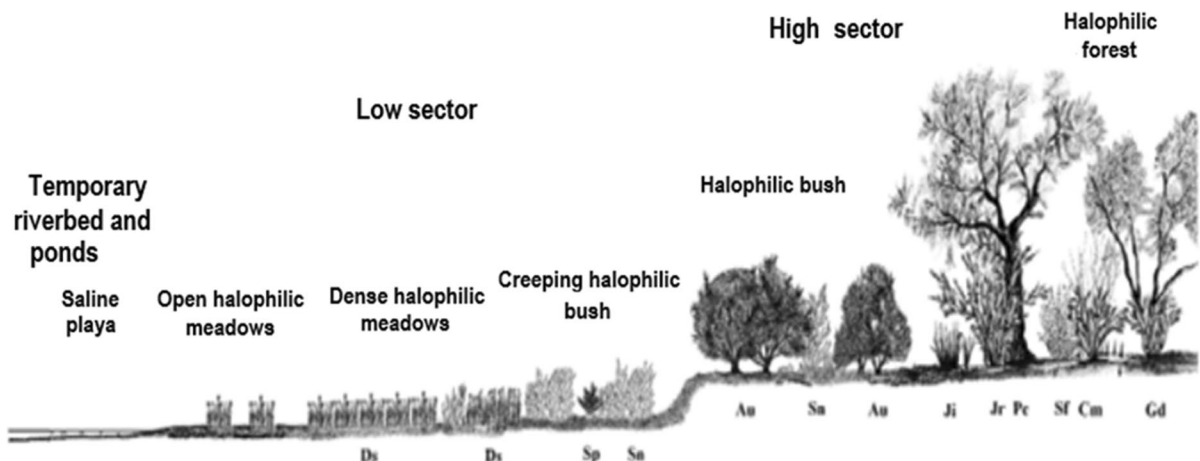


Fig. 1 Schematic cross-section of vegetation distribution in the study area showing the five physiognomic types of vegetation identified. Some Halophilic forest species are shown at the right of the figure (Gd: *Geoffroea decorticans*; Cm: *Condalia microphylla*; Sf: *Schinus johnstonii*; Pc: *Prosopis caldenia*; Jr:

Jodina rhombifolia; Ji: *Jarava ichu*) The studied physiognomic types are shown on the left of the figure: Au: *Atriplex* sp.; Sp: *Sesuvium portulacastrum*; Sn: *Sarcocornia neei*; Ds: *Distichlis spicata*

Table 1 Physiognomic types and its occupied area, dominant species and other forage species

Sub-landscapes	Physiognomic types and its occupied area	Dominant species	Main companion forage species
High sector	Halophilic bush (31.9 ha)	<i>Atriplex undulata</i> , and <i>Atriplex lampa</i>	<i>Sarcocornia neei</i> , <i>Sporobolus phleoides</i> , <i>Pappophorum caespitosum</i>
Low sector	Creeping halophilic bush (4.2 ha)	<i>Sarcocornia neei</i>	–
	Open halophilic meadow (22.3 ha)	<i>Distichlis spicata</i>	–
	Dense halophilic meadow (12.7 ha)		<i>Sarcocornia neei</i>
Temporary riverbed and ponds	Saline playa (13.1 ha)	Bare soil predominates	–

a loose salty layer could be found on soil surface. Three physiognomic types occupied the topographically lower sector.

(i) Creeping halophilic bush, with the absolute dominance of *Sarcocornia neei*. The bushes were distributed in dispersed round patches covering 39% of the area and leaving a great surface of bare soil among them; (ii) the Open and (iii) the Dense halophilic meadows, with *Distichlis spicata* as the dominant species. In bare areas of the *D. spicata* Open meadow, which suffer waterlogging usually, the presence of Cyanophyta-Cyanobacteria algae was common. The topographically most depressed sector was a bare saline playa that presented small ephemeral rills and temporary ponds, flooded during rainy periods due to surface runoff flowing from the topographically upper zones. When the water evaporates these places showed a characteristic surface salt cover and only few and scattered plants of *Sarcocornia neei* and *Distichlis spicata* survived.

The five species used as forage by cattle in the Halophilic bush plots were *Atriplex lampa* and *Atriplex undulata* (the dominant species, indicated as *Atriplex spp.*), *Sporobolus phleoides* *Pappophorum caespitosum* and *Sarcocornia neei* (Table 2). In the Creeping halophilic bush plots, the dominant species, *Sarcocornia neei*, produced the highest dry biomass recorded in this study (Table 2). In the Open halophyte meadow *Distichlis spicata* produced 62% of the total dry biomass. In the Dense halophyte meadow, not only the production was higher but *Distichlis spicata* produced 87% of the total harvested dry biomass. Considering only the forage resource, the production of the Dense halophyte meadow was 370% higher compared to the Open halophyte meadow. The identification of forage species was based on observations of cattle grazing and previous local and global

literature, indicated in the Discussion. Also, Table 2 records the biomass of *Cressa truxillensis* and other species but they were not considered from the grazing point of view.

Table 3 shows the green biomass/dry biomass ratio and the succulence of the leaves and stems of *Atriplex undulata*, and the leaves of *Sarcocornia neei* and *Distichlis spicata*. *Sarcocornia neei* showed the highest succulence percentage followed by the leaves of *Atriplex undulata* while *Atriplex undulata* stems and *Distichlis spicata* showed the lowest succulence. Plant species showed some differences in the ionic accumulation patterns of the different ions but Na^+ was the main cation accumulated by the three species analyzed, followed by K^+ and, in much lower concentration, Ca^{2+} and Mg^{2+} (Table 4). The leaves of *Atriplex undulata* accumulated more cations than the other two species. The relationship between succulence and total cationic concentration (Tables 3 and 4) considering the leaves of the three studied species was positive, $r = 0.654$ ($n: 9$, $P < 0.05$).

Table 5 synthesizes the recorded data (Tables 1 and 2) and applying the series of steps to the calculation of cattle load above, the estimation of the forage capacity of each physiognomic type is shown. The sum of biomass produced was around 4.5 t $\text{ha}^{-1} \text{ year}^{-1}$.

Discussion

We found different vegetation physiognomic types in the Bajo Las Saladas and determined their extension, their forage biomass production as well as some characteristics, and the forage capacity of each vegetation unit. In this section we compare our results with data from similar wetlands and offer

Table 2 Average total aerial biomass production (DM) ($\text{kg ha}^{-1} \text{ year}^{-1}$) in Halophilic bush, Creeping halophilic bush and Dense and Open halophilic meadow plots, standard deviation, maximum and minimum values in brackets and % of the total production of the species found (N = 3)

Physiognomic types/Species	Biomass production (DM)	% of the total
Halophilic bush		
<i>Atriplex</i> spp. (leaves)	503.1 ± 32.4 (474.0–538.2)	21.8
<i>Atriplex</i> spp. (stems) **	847.0 ± 228.0 (704.2–1110.0)	36.8
<i>Baccharis tenella</i> **	36.7 ± 34.9 (4.0–73.4)	1.6
<i>Prosopis strombulifera</i> **	63.4 ± 10.9 (55.6–75.8)	2.8
<i>Sporobolus phleoides</i>	157.9 ± 8.6 (148.0–164.0)	6.8
<i>Sarcocornia neei</i>	558.3 ± 265.1 (306.2–834.8)	24.2
<i>Pappophorum caespitosum</i>	137.7 * (0.11–178.2)	6.0
Creeping halophilic bush		
<i>Sarcocornia neei</i>	1799.0 ± 409.5 (1536.0–2270.8)	99.4
<i>Cressa truxillensis</i> **	10.0 *	0.6
Open halophilic meadows		
<i>Distichlis spicata</i>	286.5 ± 146.5 (186.6–454.6)	61.5
<i>Cressa truxillensis</i> **	178.1 ± 57.9 (112.0–219.6)	38.3
<i>Sarcocornia neei</i>	1.0 *	0.2
Dense halophilic meadows		
<i>Distichlis spicata</i>	1059.3 ± 181.2 (889.2–1214.9)	87.5
<i>Cressa truxillensis</i> **	152.1 ± 2.8 (149.6–155.0)	12.5

*Species that did not appear in all plots

**Not accounted as forage resource

Table 3 Green biomass/dry biomass ratio and the succulence percentage ± standard deviation of the analyzed species (n = 3)

Species	Green/dry ratio	Succulence (%)
<i>Distichlis spicata</i> —Open halophilic meadow (leaves)	1.42 ± 0.06	29.65 ± 2.97
<i>Distichlis spicata</i> —Dense halophilic meadow (leaves)	1.63 ± 0.03	38.52 ± 1.03
<i>Sarcocornia neei</i> (leaves)	4.19 ± 0.10	76.07 ± 1.29
<i>Atriplex undulata</i> (leaves)	3.01 ± 0.00	66.67 ± 1.89
<i>Atriplex undulata</i> (stems)	1.45 ± 0.05	31.19 ± 2.38

some recommendations for management, in order to improve present use of this kind of ecosystems.

The leaf biomass production of both *Atriplex* species located in the Halophilic bush was clearly lower when compared with a community of *Atriplex* spp. located in a nearby non-saline arid zone, in which the forage production was in the order of 1.2 t DM $\text{ha}^{-1} \text{ year}^{-1}$ (Blanco et al. 2001). The nutritional value of the species of this genus generally presents great homogeneity. *A. lampa* has 14–20% crude protein with 65% in vitro digestibility (DM) (Barbosa 2020), while *Atriplex undulata* has 15–18% crude protein and 55–67% digestibility in vitro (DM) (Norman

Table 4 Average ion concentrations (mg kg⁻¹ of dry matter) ± standard deviation measured in the analyzed species (n = 3)

Species	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
<i>D. spicata</i> in Dense halophilic meadow (leaves)	27201 ± 3261a	4038 ± 489a	172 ± 11a	181 ± 28a
<i>D. spicata</i> in Open halophilic meadow (leaves)	17190 ± 2824b	4082 ± 545a	330 ± 54b	244 ± 30b
<i>Sarcocornia neei</i> in Creeping halophilic bush (leaves)	47438 ± 5343c	2883 ± 674b	431 ± 85b	348 ± 60c
<i>Atriplex undulata</i> in Halophilic bush (leaves)	67659 ± 6351d	8341 ± 997c	725 ± 96c	573 ± 53d
<i>Atriplex undulata</i> in Halophilic bush (stems)	9537 ± 1377e	4778 ± 303a	391 ± 41b	253 ± 36b

For each ion, the letters indicate significant differences between the different species or organs (Tukey, $p \leq 0.05$)

Table 5 Synthesis of the forage offer (DM) and estimated livestock units (LSU) by the area of each physiognomic type

Physiognomic type	Annual total biomass (kg ha year ⁻¹)	Area occupied (ha)	Forage availability (kg year ⁻¹)	Final forage availabil- ity (kg year ⁻¹)	Total load (LSU)
Halophilic bush	1357	31.9	43,288	17,315	5.9
Creeping halophilic bush	1799	4.2	7556	3022	1.0
Open halophilic meadow	287	22.3	6400	2560	0.9
Dense halophilic meadow	1059	12.7	13,449	5380	1.8
Saline playa	0	13.1	0	0	0

et al. 2013). On the other hand, Na⁺ concentration in our *Atriplex undulata*, the highest among the studied species (Table 3), was similar to the concentrations in *Atriplex canescens* and *Atriplex leucoclada* (Mantinzadeh et al. 2019). However, other species of this genus can accumulate higher concentrations of Na⁺ and other ions in their tissues, and have been proposed for the phytoremediation of saline soils, such as *Atriplex nummularia* (Freire et al. 2020) or *Atriplex halimus* and *A. hortensis* (Suairé et al. 2016).

The other prominent component of the Halophyte bush, *Pappophorum caespitosum*, is one of the few grasses of fodder value growing in saline soils located in Northwest Chaco-Pampas plain (Pensiero et al. 2020). Concentrations of 9–10% crude protein have been recorded for this species (Attia-Ismail 2015). *Sporobolus phleoides* is the other grazed grass in the present study, although its forage quality is unknown. *Sporobolus rigens* presented 3–5% protein, 41–43% acid detergent fiber and 72% neutral detergent fiber, 15–16% lignin and 7–8% ash, *Sporobolus indicus*, 6% crude protein, 45% acid detergent fiber and 10% ash, and *Sporobolus airoides* shows 6–9% crude protein (several local authors cited by Barbosa 2020).

The species of *Sarcocornia* are considered a forage of low quality (Cantero et al. 1998; Rodríguez

et al. 2016). *Sarcocornia neei*, for example, depicted high content of phenolic compounds (Riquelme et al. 2016) which reduce plant palatability to herbivores (Norman et al. 2013). This fact can explain the preference of grazing animals for other more digestible food resources (Attia-Ismail 2015). In accordance, several local studies (summarized by Barbosa 2020) and authors' visual observation in the Creeping halophilic bush found that native *Sarcocornia* species are usually little consumed by livestock. *Sarcocornia neei* contains up to 6.5% protein according to Barbosa (2020) while Riquelme et al. (2016) indicated protein contents from 7 to 13%. Compared to other *Sarcocornia* species, the succulent *Sarcocornia neei* accumulates high concentration of Na⁺ salts (Riquelme et al. 2016). Norman et al. (2013) stated that succulence is important to rank forage plants. In this study *Sarcocornia neei*, showed more succulence than *Atriplex spp.* but was less consumed, as indicated above, showing that succulence is not always a good indication for grazing.

The genus *Distichlis* is considered of very low forage value in environments with good to very good productivity, but in saline areas it constitutes an important forage resource (Bustan et al. 2005; Yensen et al. 1985) and provides the benefit of reducing soil

erosion (Pensiero et al. 2020). The participation of *Distichlis* spp. in the diet of different herbivores was shown by micro-histological analysis and its identification in the feces (Holech and Gross 1982). *Distichlis* spp. constitutes an important part of the bovine diet in saline and alkaline soils of the Flooding Pampas and was identified in the diet of cattle, horses and goats as well as in American camelids, both in the Patagonia and the Andean Puna (several local authors cited by Barbosa 2020). The biomass production of *Distichlis spicata* in the “Bajo Las Saladas” is clearly lower than in other situations: a *Distichlis humilis* field showed a forage production around 2.1 t DM ha⁻¹ year⁻¹ (Biurrun et al. 2010) and in a humid area with alkaline soils, a community of salt grass production was close to 2.5 t forage DM ha⁻¹ year⁻¹ (Cahuepé and Gutheim 2020). *Distichlis* species grow throughout the whole year, although summer is the main productive season. Thus, cattle always have the possibility of finding plants with green leaves to eat during the year. Values of 5–12% crude protein and 18–53% in vitro digestibility were found in *Distichlis spicata* (Cahuepé and Gutheim 2020). *Distichlis spicata* showed the lowest percentage of succulence in the present study, since it does not accumulate a large amount of water in its tissues and showed the lowest ionic concentration in leaves of the studied species. However, *Distichlis spicata* grown in the Dense meadow showed the higher percentage of water, perhaps related to its lower level of transpiration, presenting a higher succulence than plants grown in Open meadow (Table 3). Probably for the same reason, mean Na⁺ concentrations found in the Dense meadow plants were higher than when the species grew up in the Open meadow (Table 4).

The total biomass production in the studied area was in the same order of magnitude than other wetlands. For example, a Canadian saline wetland yielded 5.02 t ha⁻¹ (Trites and Bayley 2009). The results shown in Table 5 indicated that the annual forage consumption supports 9.6 LSU 84.2 ha⁻¹, or 11.5 LSU 100 ha⁻¹. This estimation is lower than the cattle load capacity of Caldén forest, the zonal deciduous forest, which is around 16.6 LSU 100 ha⁻¹ (Barbosa 2020) but clearly surpassed the present load of the depression, estimated as around 5 LSU 100 ha⁻¹ (E.O. Coser, personal communication). In both cases, the grazing is uncontrolled.

Morris and Reich (2013) stated that continued grazing reduced vegetation biomass and had mixed effects on the dominant plant species. In this context, the plant recovery from grazing due to carbohydrate reserves stored in underground tissues is a factor to take into account (Morris and Reich 2013). In this case, forage management has to consider not only the surfaces of each physiognomic type and the biomass production, but that all the studied species have spring–summer–autumn growth (Pensiero et al. 2020). It is known that the effect of grazing on wetland vegetation varies across time and that the effects of trampling usually varies seasonally (Taylor et al. 2021). Concentrating the grazing when natural vegetation grows the best could allow not only restoration of present disturbance but can also increase the economic utilization of the wetland.

Concluding remarks

The information collected in the present study shows that the forage offer of a saline wetland such as the “Bajo Las Saladas” could be an attractive option for productive animal production, since their biomass production is significant. The estimated LSU of 11.5 breeding cows per 100 ha indicates that this saline wetland could sustain a biomass production that clearly surpassed the present load of the depression, subjected to uncontrolled grazing. The partial forage production capacity of each physiognomic type must be spatially managed on technical bases to limit the present degradation of the vegetation and soils; that is, vegetation and livestock need to be managed in small areas, in order to minimize the present wetland deterioration. This management scheme contradicts the traditional local way of grazing all year round in the large plots, as is customary in the surrounding forest and in the wetland today.

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Author contributions All authors contributed to the study conception and design. OAB performed material preparation, data collection and RSL wrote analysis; the idea and the first draft of the manuscript. JAR did the review & editing. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability Data are available on request from Osvaldo A. Barbosa.

Declarations

Competing interests The authors of this article declare that we have no conflict of interest, and that the information has been entirely generated by the authors.

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