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Effects of livestock exclusion on density, survival and biomass of the perennial sagebrush grass *Hymenachne pernambucense* (Poaceae) from a temperate fluvial wetland

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ABSTRACT

In Argentina, the intensification of soybean production has displaced a substantial proportion of cattle ranching to fluvial wetlands such as those in the Delta of the Paraná River. Cattle grazing affects structure and dynamics of native forage plants but there is little information on this impact in populations from fluvial wetlands. This study addresses the effect of cattle ranching on density, survival, mean life-span and aerial biomass of *Hymenachne pernambucense* (Poaceae), an important forage species in the region. The study was carried out monthly for one year in permanents plots subject to continuous grazing and plots excluded from grazing in the Middle Delta of the Paraná River. In plots excluded from grazing, tillers showed significantly higher population density and survival, and a two-fold increase in mean life-span, while continuous grazing decreased survival of cohorts. The largest contribution to tiller density in ungrazed and grazed populations was made by spring and summer cohorts, respectively. Total and green biomass were significantly higher in the ungrazed population, with highest differences in late spring-early summer. Cattle grazing affected the relationship between tiller density and green biomass suggesting that cattle prefer sprouts because they are more palatable and nutritious than older tissue.

1. Introduction

The knowledge of demographic parameters such as survival, life expectancy and mean life span is of relevance for understanding population dynamics (Harper, 1977; Silvertown and Charlesworth, 2009). There are few studies analysing these parameters for plant species (Lauenroth and Adler, 2008; Roach, 2003; Van Der Maarel, 1996; Wright and Van Dyne, 1976). According to Lauenroth and Adler (2008), this is mainly due to the difficulty of data collection and analysis. The prediction of plant population dynamics is hindered by the lack of demographic data (Silvertown et al., 2001), particularly when vegetation is subject to anthropogenic disturbances (e.g. resulting from its interaction with livestock). Effects of mammal herbivory can lead to decreasing density, production and survival rate of tillers (Bullock et al., 1994; Crawley, 1983; Fetcher and Shaver, 1983; Leiva and Alés, 2000; O'connor, 1994) and changes the biomass-size relationship (Guevara et al., 2002; Nafus et al., 2009). However, there is a lack of information about these topics in fluvial wetlands and there is available data only at community level (e.g., Crosslé and Brock, 2002; Champion et al., 2001; Jutila, 1999; Keddy, 2010; Reeves and Champion, 2004; Tanner, 1992).

A few decades ago, South American wetlands were relatively free of anthropogenic impacts, maintaining their original extension, structure and function. In Argentina, the expansion of the agricultural frontier due to the intensification of soybean production (Paruelo et al., 2006) has displaced a substantial proportion of cattle ranching activity to fluvial wetlands (such as those in the Paraná River Delta region) because of their high natural productivity (Quintana et al., 2014) and a large number of important forage species (González et al., 2008; Rossi et al., 2014).

Hymenachne pernambucense (Spreng.) Zuloaga (Poaceae) is a perennial and mat forming clonal grass, with broad leaves and erect stems of a maximum height of 2.5 m, and is distributed from southern Brazil

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and Paraguay to central-eastern Argentina and central Uruguay (Cabrera and Zardini, 1993). The southernmost limit of its distribution is in the Delta of the Paraná River and along the banks of the De La Plata River, in Argentina (Cabrera and Zardini, 1993). *H. pernambucense* is usually present in highly disturbed areas where it can establish as a pioneer species (Kandus and Malvárez, 2004; Morandeira, 2014). This trait is shared with the South American species *Hymenachne amplexicaulis*, which has been reported as an invader in wetlands of southern USA and Australia (Diaz et al., 2009; Grice et al., 2011).

The aim of this study was to analyse the changes in population dynamics and in the aerial biomass of *H. pernambucense* when this species is excluded to grazing. This grass species was selected because: (i) It is both one of the dominant and most important forage species in the Delta of the Paraná River, (ii) Under grazing situation, its abundance undergoes a significant decrease, and (iii) there is a lack of information about its population dynamics not only in Argentina but also in the remaining of its geographical range. Considering that livestock exhibits forage selection on palatable species including, in the Delta region, species of Genus *Hymenachne* (Quintana et al., 1998), we hypothesized that cattle grazing decreases tiller survival, density and mean life-span as well as aerial biomass of *H. pernambucense*. Thus, we conducted a 1-year study of a freshwater marsh dominated by this species and subject to two different conditions: under continuous grazing and ungrazed. Measurements were made in permanent sample plots on a private ranch located in the Middle Delta of the Paraná River, Argentina.

2. Materials and methods

2.1. Study area

In Argentina, the Paraná Delta Region (with a surface area of about 17,500 km^2) is a complex floodplain located in a strategic position at the lower end of the Paraná River Basin and the mouth of the De La Plata River Estuary, with unique ecological features (Malvárez, 1999). In South America, it is ranked third in importance after the Deltas of the Amazonas and Orinoco Rivers, and is the only of the great deltas that discharges into a freshwater estuary (the De La Plata Estuary) rather than into the sea. This region has been defined by Malvárez (1999) as a vast macro-mosaic of wetlands because it shows distinct climate features, a remarkable landscape diversity resulting from geomorphological processes occurring both in the present and recent past, and a particular hydrological regime. As a result, the biodiversity of the Paraná Delta is higher than that expected at these latitudes (Brinson and Malvárez, 2002). This region is included in a 3400 km wetland corridor along the Paraná and Paraguay Rivers shared by four South American countries. The corridor, which is of primary ecological importance, is inhabited by 20 million people who benefit from wetland goods and services (Benzaquén, 2013). The Paraná Delta is close to the major urban, industrial and agricultural areas of Argentina.

The field study was conducted in a cattle ranch placed on the Lechiguanas Islands (Fig. 1), Entre Ríos province, Argentina (33°27′S, 59°55′W), with a stocking density of about 0.7 livestock units/ha. The ranch is located within a landscape unit that originated from current sedimentation and erosion processes on the alluvial plain of the Paraná River and its main tributaries (Malvárez, 1999). The landscape pattern includes levees, mid-slopes and lowlands along a micro-topographic gradient with different level of flooding. Levees and mid-slopes are characterized by open forest of willows (*Salix humboldtiana*) and grassland dominated by *H. pernambucense*, respectively. Freshwater marshes of *Ludwigia* spp., *Echinochloa polystachya* and *Alternanthera philoxeroides* dominate the lowlands (Malvárez, 1999). The climate is temperate-humid and, for the period 2006–2016, the mean annual temperature was 17.4 °C (mean minimum and maximum temperatures of 10.4 °C and 24.4 °C for July and January, respectively). Mean annual rainfall from last decade was 1093.6 mm, ranging between 28.3 and 170.3 mm in June and February, respectively (INTA, 2017). The water level rises in October, reaches a peak in February–March, upturns in July–August and decreases in the remaining months. This hydrological regime shows remarkable interannual and interdecadal variability leading to severe droughts and to extreme floods (Coronel and Menéndez, 2006).

2.2. Experimental design and data collection

To evaluate the effect of livestock on population parameters of *H. pernambucense*, the study was performed in two contiguous areas, continuously grazed and ungrazed. Both areas, located in the mid-slope of the gradient, placed in a landscape subunit of 1455 ha, with a homogeneous plant community as well as water regime and geomorphology (Borro et al., 2014; Ramonell et al., 2012). Thus, the grazing treatment was considered as the major cause for the eventual differences between areas (Altesor et al., 2005). The experimental plots were settled in the mid-slope because, as was mentioned before, *H. pernambucense* growths only in that part of the topographic gradient.

The selection of *H. pernambucense* for this study was due to the fact that the field observations and the previous nutritional studies (Table 1; Magnano, 2017) show that this grass is an important native forage species both for quality and for the volume of fodder biomass that it produces.

For demographic analysis five and seven mats were randomly chosen from ungrazed (ungrazed population) and continuously grazed area (continuously grazed population), respectively. In each mats a permanent plot of 25 × 25 cm was settled. For the demographic analysis, tillers of *H. pernambucense* were counted within sample plots.

All tillers were tagged at their bases with self-adhesive tape at the beginning of the study period. Newly emergent tillers were tagged on each subsequent sampling date; they were considered a cohort and used to construct survival curves. Tillers present at the beginning of the study period constituted a depletion curve (sensu Harper, 1977), and those that were not recorded on three consecutive dates were considered as dead. Counts were done every 30–45 days for one year, between July 2012 and July 2013. After this date, surveys were suspended due to a flood event occurring at the end of July and beginning of September. Although the field work was performed during a single year, the climatic values for this period (mean annual rainfall of 1100.1 mm and mean annual temperature of 17.5 °C) were similar to the values registered during the last decade (Fig. S1).

Tiller density was expressed as the number of tillers/m^2 and the subsequent multiplication by the average coverage of *H. pernambucense* in both areas. The latter was determined seasonally by measuring the average basal area of all mats (Hayes et al., 1981) present in 10 randomly distributed 5 × 5 m square quadrats, half of which were placed within ungrazed area and the rest outside of it.

The cohort survival curves were based on sampling in different plots and at irregular time intervals. To reduce variation between samples and sampling periods, the number of tillers from each cohort was adjusted by using a regression equation, yielding a monotonically decreasing series of the number of individuals within each age class. We followed one cohort per season, selecting those with a higher number of records. As a result, we only considered the cohorts of winter, spring and summer.

To estimate biomass, an allometric method based on the relationship between tiller total height and biomass (Trilla et al., 2009; Vicari et al., 2002) was used. All tillers present in permanent plots were measured from the base to the tip of the longest upper leaf. To examine the possible influence of seasons on the allometric equations, some tillers were randomly chosen from inside the ungrazed area in each season. They were harvested, submitted to the laboratory and measured as explained above. The green material was then separated from the dry material, oven-dried at 60 °C for 72 h and weighed separately. Weight and height were incorporated into a regression model to establish the

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