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Habitat use by vicuñas *Vicugna vicugna* in the Laguna Blanca Reserve (Catamarca, Argentina)

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We studied the use of vegetation types by vicuñas in the Laguna Blanca Reserve (Argentina) at the end of the dry season. For a coarse scale analysis, 521 vicuñas were counted along 150 km of road crossing four different vegetation types. Vicuñas avoided the open rocky areas, which were almost without vegetation, and the areas dominated by isolated shrubs of *Acantholippia hastulata*. They preferred the sparse vegetation dominated by *Fabiana densa*, *Baccharis bolivianensis*, and *Adesmia horridiuscula*, and they used the areas dominated by grasses (mainly *Stipa* sp.), and chamaephytes in proportion to availability. For a fine-scale analysis, we observed from a fixed point the vicuñas using the area surrounding the 'Laguna Blanca' lagoon. Vicuñas preferred the swamp areas with dense, green vegetation that surround the lagoon. We concluded that, even when this type of vegetation (called 'vegas' in Latin America) occupied a small proportion of the total area, it is an important habitat for the vicuñas.

Keywords: habitat use; *Vicugna vicugna*; management; Laguna Blanca Reserve; Catamarca; Argentina

Introduction

Study of the use of habitat mosaics by terrestrial vertebrates has important implications for their conservation and management (Law & Dickman, 1998) as these studies provide information on habitat availability and management (McIntyre & Barret, 1992). Most wildlife species in arid environments live in extreme conditions. Food, shelter and water are scarce and heterogeneously distributed. Animals respond to these environmental gradients by avoiding habitat types that do not offer the minimum resources required for survival. Therefore, the biological requirements of species should be incorporated into the design of wildlife and livestock management plans (Ellis & Swift, 1988; Behnke & Scoones, 1992).

Habitat use takes place on a variety of spatial and temporal scales, from a daily requirement for adjacent habitats to seasonal use of geographically separated environments (Law & Dickman, 1998). Mosaics of the appropriate temporal and spatial scale will not always be obvious, so a detailed knowledge of faunal movement patterns is a key factor in understanding the vulnerability of species to landscape change, and in increasing the effectiveness of management (Law & Dickman, 1998).

The vicuña is a wild South American Camelid that inhabits the Puna region (between 3000 and 4700 m.a.s.l.) of Perú, Bolivia, Chile and Argentina (Koford, 1957). Their social organization includes family groups, bachelor groups and solitary animals (Koford, 1957; Franklin, 1974). They need to drink water almost every day (Franklin, 1983) and their daily pattern of activities is determined by their distance from water (Vila & Cassini, 1994; Renaudeau d'Arc, 1997). It is the only ungulate with open-rooted, continuously growing incisors (Miller, 1924) which are adapted to graze small forbs and perennial grasses close to the ground (Franklin, 1983). Like many ungulates, vicuñas spend most of their time foraging (Franklin, 1974; 1983; Ménard 1982; Vilá & Cassini, 1993).

The excessive commercial hunting of vicuñas for their valuable fleece caused a severe decline in their population in the middle of the 20th century which caused them to almost become extinct. Effective protection laws resulted in a recovery of some populations (Torres, 1992). Vicuñas were classified as 'lower risk: conservation dependent' in the 1996 Red List of Threatened Animals (IUCN, 1996).

In Argentina, there are approximately 30,000 animals (Puig, 1997) distributed in the north-western provinces of Jujuy, Salta, Catamarca, la Rioja and San Juan. The species is still under strict protection, except in the Jujuy province where vicuñas are now classified under Appendix II of the Convention International for Trade on Endangered Species (CITES). Plans to exploit vicuñas are in preparation (Renaudeau d'Arc & Vilá, 1998).

Previous studies carried out in large reserves (e.g. Pampa Galeras Reserve in Perù; Franklin, 1983) showed that the vicuña utilized only a small proportion of the area. In this study, carried out in the large Laguna Blanca Reserve, similar trends in vicuña habitat use are predicted. The aim of this study is to obtain a preliminary estimation of habitat types used by the vicuñas.

The present paper forms part of a programme called 'Holistic approach to the conservation and sustainable use of vicuñas *Vicugna vicugna* in Argentina' that includes ecological studies on vicuñas, environmental education for teachers and children in the Puna region, and the future substitution of exotic livestock (sheep, cattle and goats) by llamas *Lama glama*.

Materials and methods

Study area

The study was conducted from 22 to 30 November 1997 in the Laguna Blanca Reserve (973,000 ha, elevation from 3200 to 5500 m.a.s.l.) located in the high, northern-most part of Catamarca province, Argentina (26°30′ S and 66° 40′ W) (Diaz & Paredes, 1981).

The climate is severe, with great daily variation in temperature, and frequent frosts. Rainfall is seasonal (December to March) and scarce (100–250 mm year^{-1} (Knoche & Borzakov, 1947), and strong and dry winds are frequent. Soils are stony, sandy or saline. Phytogeographically, the reserve includes the 'Puna' and 'Altoandine' Provinces (Cabrera, 1976). The vegetation is mainly a xerophilus steppe with a heterogeneous horizontal pattern of vegetation patches alternating with areas of bare soil.

The reserve was created during 1979 in order to protect the vicuña population. In 1982, the reserve was declared part of the International Network of Biosphere Reserves established by the UNESCO Man and the Biosphere Programme. Vicuñas share the area with local people and their pastoral activities. A pattern of mixed herding exists where domestic camelids (llamas) and exotic livestock (mainly sheep) grazing together is common (Vila & Roig, 1992).

During this study, local authorities were planning the exploitation of vicuñas in the reserve. A funnel-shaped net with a corral at its end (called a 'manga'), was built on the west side of the Laguna Blanca lagoon, the largest water feature in the area. The manga was located in a marshy area called 'vega'. During the study, the manga was not used for capturing vicuñas. In view of this and taking account of future management plans in the area, we also evaluated the behavioural responses of vicuñas to the presence of the manga.

The study area was classified into five discrete vegetation categories distinguished by a recurrent pattern of relief, soil and vegetation, on the basis of 1: 250,000 national topographic maps: (1) 'Peladar': wide open areas of rocky bare soil where isolated shrubs of *Acantholippia hastulata* can occur; (2) 'Rica-rical': areas dominated by shrubs of *A. hastulata* (called 'rica-rica' in local name) 50 cm–1m tall, sparsely distributed within a matrix of bared soil; (3) 'Tolar': areas with sparse vegetation dominated by *Fabiana densa* (called 'tolillar' in local name) 1-m tall, often associated with other shrub species like *Baccharis boliviensis* (called 'chijua' in local name) and *Adesmia horridiuscula* (called 'añagua' in local name), all sparsely distributed within a matrix of bare soil; (4) 'Pastizal': high-altitude grasslands characterized by sparse grass cover of about 20% dominated by *Stipa* sp. and chamaephytes; (5) 'Vega': swamp areas, associated with ground-water, lagoons or streams that create locally moist edaphic conditions, where hardy grass and green herb, represented by *Oxychloe* sp. and rizomateus species, cover almost 100% of the soil.

Field design

The vegetation-type use by vicuñas was studied at two geographical scales, coarse and fine. We assumed that the availability of vegetation patches was constant during the study, and that each observation of an animal represented an independent choice taken from the pool of available vegetation types.

Sampling at the coarse scale was conducted by driving slowly along a 150 km stretch of Route 53, during the morning when visibility was good. Four vegetation patches were identifiable: peladar, rica-rical, tolar, and pastizal. Vegas were too small (less than 1 ha) to be considered at this scale. The availability of the vegetation types was estimated by the transect length (kilometers of road driven per vegetation type) and we counted observable vicuñas on both sides of the road. The number of vicuñas were recorded from the transect road where the maximum distance of visibility was approximately 2 km on each side, with no difference in visibility between vegetation types.

Sampling at the fine scale was conducted from a fixed, high point from where the vicuñas were scanned with the aid of a 20 × 40 telescope, from 07 30 h to 19 30 h, every 30 min using standard behavioural sampling methods (Altmann, 1974). The following information was recorded on a map: number of vicuñas in group, group composition and group location (vegetation type). The behaviour of individuals was classified according to the following activities (Vilá, 1990): (1) grazing, when the animal was standing or walking very slowly with its head close to the ground; (2) walking, or slow movement with head up; (3) running; (4) lying, when resting on the ground; (5) standing, with its head up, and (6) alert, when standing with the head high and ears erect.

The name of the reserve (Laguna Blanca) is derived from the largest water feature in the area (3450 ha). Vicuñas use the lagoon edge to drink from the shallow water and lick salt deposits. The area was divided into three sectors: lagoon edge (1 km), 'vega' 0·67 ha) and 'tolar' (13·3 ha), the boundaries of which were recognized by the change in vegetation physiognomy, visible from the observation point. This vegetation type classification was validated at the end of the study using the following method: three transects of 150 to 200 m, placed perpendicular to the lagoon, were randomly selected.

Every 10 m along the transects the dominant plant species, the percentage of bare soil and the slope was recorded.

Statistical analysis

Habitat use at the coarse scale was studied using the method described by Manly *et al.* (1993). The observed values for use and availability of each vegetation type were statistically compared using a log-likelihood Chi square test. A resource selection index was calculated as $\alpha = r_i/n_i\ (1/\Sigma\,(r_j/n_j))$, where r_i and r_j are proportions of vegetation type i or j that were used by the vicuñas, and n_i and n_j are proportions of vegetation types in the environment. The value of α is normalized so that the sum of all values equals 1. When a vegetation types is not selected or rejected, α is equal to the inverse of the total number of vegetation types.

For the fine-scale analysis, two-way ANOVA were used. The numbers of vicuñas observed in each of the three identified vegetation types, tolar, vega, and lagoon, were the dependent variable. The time of day, divided into five categories (07 30–09 30 h, 10 00–12 00 h, 12 30–14 30 h, 15 00–17 00 h, 17 30–19 30 h), was the independent variable. These two variables were entered into the analysis with three replications (corresponding to the three sampling days). The same type of ANOVA was applied to the data on activity. In this case, the dependent variable was the number of vicuñas grazing in proportion to the number of vicuñas grazing and walking (these data were transformed using the arcsine of the square root).

Results

A total of 521 vicuñas forming 113 groups were counted along the 150 km of road crossing four different vegetation types: peladar (75 km of road), rica-rical (25 km), tolar (30 km) and pastizal (20 km). Vicuñas were distributed differently amongst these vegetation types (Fig. 1). No vicuñas were observed in the peladar. Significant differences in use *vs.* availability for individuals ($\chi^2 = 10{\cdot}56$ $n = 3$, $p < 0{\cdot}01$) and for groups ($\chi^2 = 12{\cdot}97$ $n = 3$, $p < 0{\cdot}01$) were observed for the other three vegetation types. The rica-rical was used by vicuñas significantly less in proportion to its availability (indexes of Manly for individual and group analyses were $\alpha = 0{\cdot}23$ and $0{\cdot}14$, respectively, $p < 0{\cdot}05$), the tolar was used significantly more in proportion to its availability ($\alpha = 0{\cdot}53$ and $0{\cdot}55$, $p < 0{\cdot}05$), and the pastizal was used in proportion to its availability ($\alpha = 0{\cdot}24$ and $0{\cdot}32$, $p > 0{\cdot}05$) (Fig. 1).

The numbers of vicuñas observed from the fixed point showed highly significant differences between vegetation types ($F_{2,6} = 30{\cdot}24$, $p = 0{\cdot}0007$), between hours ($F_{4,24} = 8{\cdot}91$, $p < 0{\cdot}0001$) and for the interaction of the two factors ($F_{8,24} = 12.58$, $p < 0{\cdot}0001$). The significance of the interaction term indicates that the use of vegetation types varied with the time of day (Fig. 2). Early in the morning, most vicuñas were found in the tolar, but they rapidly moved to the vega, where they spent most of the day. Drinking time was at about midday, with a peak between 11 00–13 00 h. Around 17 00 h, the number of vicuñas in the vega started to decline as they moved back towards the mountain foothills, probably searching for resting sites.

Vicuñas behaviour showed significant differences between vegetation types ($F_{2,5} = 9{\cdot}41$, $p = 0{\cdot}02$) but not between hours ($F_{4,20} = 0{\cdot}47$, $p = 0{\cdot}47$) and there was no interaction ($F_{8,20} = 1{\cdot}78$ $p = 0{\cdot}14$). The proportion of vicuñas grazing in relation to walking was higher in the vega ($F_{2,5} = 9{\cdot}41$, $p = 0{\cdot}02$) than in the tolar and the lagoon (Fig. 3).

The behaviour of vicuñas inside and outside the manga differed. Family groups were found grazing significantly less often inside the manga ($t_2 = 8{\cdot}99$, $p = 0{\cdot}012$) and

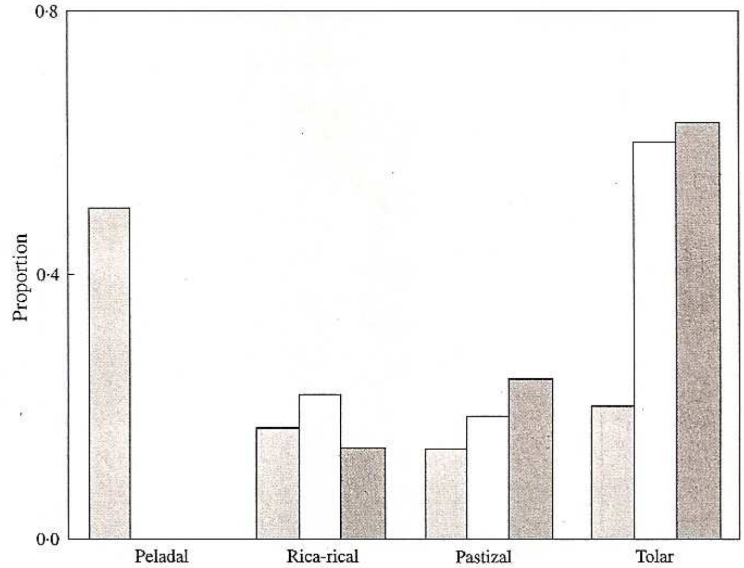

Figure 1. Proportion of the habitats available and use by vicuñas as individuals and groups. ▒ available; □ used by individuals; ▩ used by groups.

they were more often alert, running or fighting when inside ($t_2 = 4{\cdot}38$, $p = 0{\cdot}048$) the manga than when outside (Fig. 4). There was no significant difference between the size of groups inside (mean = 3·37 S.E. = 0·38) and outside (mean = 3·72 S.E. = 0·23) the manga ($t_2 = 0{\cdot}8$ $p = 0{\cdot}47$).

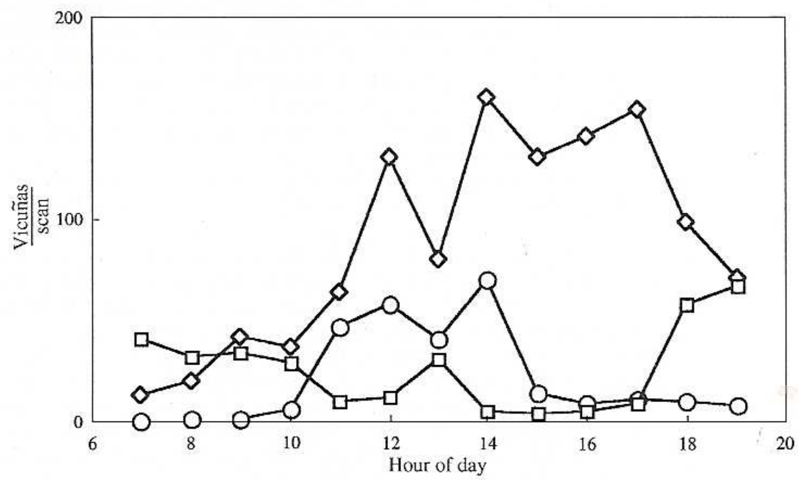

Figure 2. Total number of vicuñas per scan in each habitat in relation with time of day. —□— tolar; —◇— vega; —○— salar-lagoon.

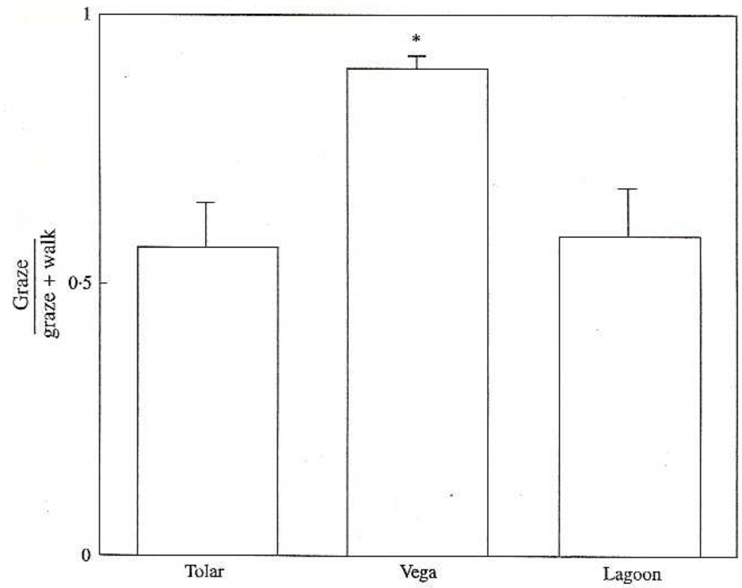

Figure 3. Mean (± S.E.) number of vicuñas grazing in proportion to the number of vicuñas grazing and walking in the three habitats near the lagoon.

Discussion

The present study is limited by the short duration of the field work. Nevertheless, our data suggest that habitat use was selective at two ecological scales. At a large ecological scale, vicuñas were absent from the peladar, which was the commonest vegetation type in the study area, while the tolar was used more than was expected by its availability. Cajal (1989) also found that vicuñas were restricted to patches of grasses and dwarf shrubs in the San Guillermo reserve in Argentina. In a long-term study conducted in the Pampas Galeras reserve in Perú, Franklin (1983) estimated that 43% of the reserve was unusable or poor habitat of vicuñas, and that the highly productive and highly-preferred vegetation types were scarce, covering only about 15% of the study area. These scattered patches of preferred vegetation types, represented by the tolar in our study area, imposed a coarse level of habitat heterogeneity that affected vicuña distribution.

At a fine ecological scale, vicuñas showed a daily pattern of habitat selection, moving in the early morning from the tolar to the vega, where they spent most of the time grazing. We observed vicuñas in the tolar in the late afternoon and then again early in the morning, when they were still resting. We assume that the tolar was close to their night-time resting area, i.e. near the slopes. Nocturnal resting sites same distance from water have also been observed by Vila & Roig (1992) in another area of the same reserve.

Fahbrig & Merrian (1994) showed that even in habitats that are apparently homogeneous, it is possible to distinguish microhabitat patches. Water features (rivers and lagoons) in the Puna impose a fine scale of habitat heterogeneity, generally associated with the vegas. Vegas occupied a small proportion of the total area (Franklin, 1983; Cajal, 1989). Therefore, the observed daily aggregation of vicuñas at the vegas was difficult to observe at a large ecological scale. Although the relative use of habitat

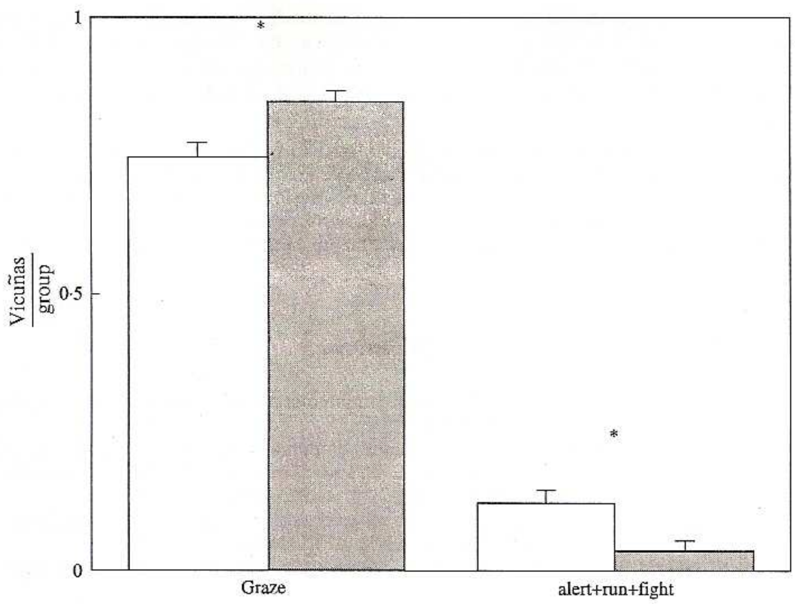

Figure 4. Mean (± S.E.) number of vicuñas in proportion to the total number of vicuñas in a group in different behaviours: grazing and disturbance behaviours (alert, running or fighting) inside and outside the manga. $*p < 0{\cdot}05$. □ Inside; ▒ outside.

types does not necessarily indicate habitat quality (Van Horne, 1983; Hobbs & Hanley, 1990), patterns of habitat use may reveal underlying ecological relationships (Arthur *et al.*, 1996). The vegas receive a ground-water supply, creating locally moist soils in which hardy grass grows abundantly (Rabinovich *et al.*, 1998). We suggest that vegas are the preferred habitat type in the study are because they provide good quality forage and water.

In conclusion, this and previous studies suggest that vegas are a habitat of fundamental importance to vicuñas. The conservation and management consequence is that vegas should be protected and vicuñas using them should be not disturbed. We observed that the vega surrounding the Laguna Blanca was used by both vicuñas and domestic livestock (mainly sheep and llamas). Vilá & Roig (1992) also observed that these areas were intensively used by people for feeding and watering their livestock. Vegas appear to be the best foraging areas for wild and domestic ungulates in the region, especially during the dry season because they provide a permanent source of water and grazing. Koford (1957) found that livestock competed with vicuñas and could displace them from their feeding grounds.

We observed that the location of the manga in the vega affected the behaviour of vicuñas, i.e. vicuñas became more aggressive and spent less time foraging. Although it was impossible to observe the behaviour of the vicuñas without the presence of the manga, we suggest that the location of the manga has probably disturbed their territories, increasing the overlap of territories of neighbouring family groups. At the time of this research, the local authorities of the Catamarca province had decided to exploit part of the vicuña population in Laguna Blanca Reserve on an experimental basis. Unfortunately, little was known about key aspects of the ecology and behaviour of vicuñas in this reserve. This study has tried to address this problem.

The following suggestions emerge from this study, bearing in mind the design and implementation of future plans to exploit the vicuña. We first suggest that the vega requires effective management of domestic livestock. Also, the vicuña population should be monitored and evaluated both before and after the intervention.

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