Habitat use by vicuña *Vicugna vicugna* in Laguna Pozuelos Reserve, Jujuy, Argentina

Yanina Arzamendia, Marcelo H. Cassini and Bibiana L. Vilá

Abstract Vicuña *Vicugna vicugna* are an emblematic species of one of the major arid ecosystems of the neotropics: the *puna* or *altiplano*. Excessive commercial hunting of vicuña for their valuable fleece in the past caused a severe decline in the population, with the vicuña almost becoming extinction by the mid 20th century. Effective protection resulted in the recovery of some populations and, recently, limited vicuña exploitation has been allowed. Research is urgently required to underpin the design of the management systems used for this exploitation. We present the result of a 2-year study on habitat utilization of vicuña in Laguna de Pozuelos UNESCO Biosphere Reserve in Argentina. Vicuña did not use the study area homogeneously but preferred vegetation communities dominated by grasses (known locally as *pajonal* and *esporal*) and with high overall plant cover. Vicuña were less selective in 2003, when overall habitat quality decreased, than in 2002. This change is predicted by habitat selection theory. We also found that members of family groups spend more time foraging than members of non-reproductive groups. Solitary vicuña spend more time standing up than members of groups, consistent with the observation that herding behaviour is related to protection against predators. Heterogeneous use and habitat selectivity suggest that exploitation of vicuña needs to take spatial behaviour into account in the establishment of the optimal location of capturing sites.

Keywords Argentina, habitat use, Jujuy, Pozuelos Reserve, sustainable use, *Vicugna vicugna*, vicuña.

Introduction

The vicuña *Vicugna vicugna* is a wild South American camelid that inhabits the *puna* or *altiplano* region (3,000–4,700 m altitude) of Perú, Bolivia, Chile and Argentina (Koford, 1957). Excessive commercial hunting of vicuña for their valuable fleece caused a severe decline in the population, almost to the point of extinction, by the mid 20th century. Effective protection, however, resulted in the recovery of some populations (Torres, 1992), and vicuña are now categorized as Lower Risk/conservation dependent on the IUCN Red List (IUCN, 2004).

In Argentina there are approximately 35,000–40,000 vicuña (Lichteinstein & Vilá, 2003), in the north-western provinces of Jujuy, Salta, Catamarca, La Rioja and San Juan. Argentine vicuña populations are on Appendix I of CITES, with the exception of those of Jujuy and Catamarca provinces, which were listed on Appendix II of CITES in 1997 and 2003, respectively (CITES, 2005). Several projects that involve the capturing and shearing of free-living vicuña have been initiated in both provinces. However, studies of key aspects of vicuña ecology are required to evaluate and, where necessary, minimize the impact of utilization and ensure sustainability of the populations.

One of these key aspects of vicuña ecology is habitat use. Previous studies, for example in Pampa Galeras Reserve, Perú (Franklin, 1983), and Laguna Blanca, Catamarca Province, Argentina (Renaudeau d'Arc et al, 2000), showed that vicuña use only a small proportion of their potential habitat in protected areas. This heterogeneous habitat use implies that the actual resources available for vicuña are significantly smaller than may be estimated by considering the reserve as a whole.

In this paper we present the result of a 2-year study on habitat utilization by vicuña in a protected area in Argentina. This study is part of the Cieneguillas Case Study in Proyecto MACS (*Sustainable economic utilization of wild South American camelids*). The objective is to develop science-based management plans for the wild management of vicuña, enhance cooperation between scientists and local communities, and design techniques for capture and shearing that provide economic returns, ensure a sustainable vicuña population, and have low environmental impact. The ultimate aim is to balance income generation with ecological sustainability.

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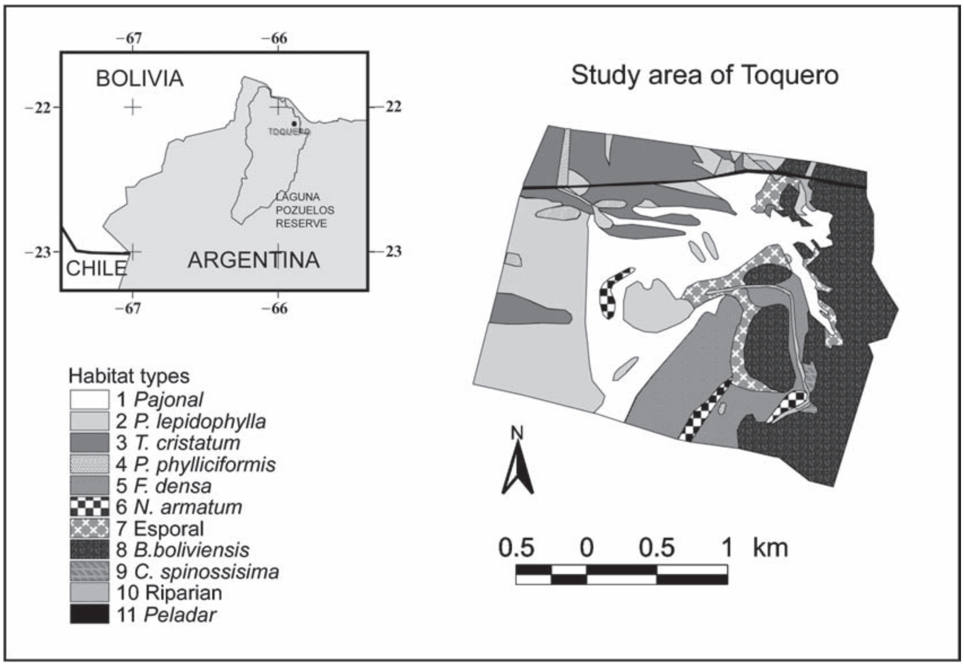

Fig. 1 The location of the Laguna Pozuelos Reserve in Argentina (inset) and the study area of Toquero with the distribution of the 11 identified habitat types (Table 1, see text for details).

Study area

The study area was in Toquero (800 ha, at elevations of 3600–3800 m), which is part of the Laguna de Pozuelos UNESCO Biosphere Reserve, Jujuy, Argentina (Fig. 1). The climate is extreme, with large diurnal fluctuations in temperature and frequent frosts. Rain falls mainly in December–March. Strong, dry winds are frequent. Soils are stony, sandy or saline. The reserve includes the *puna* and *altoandino* phytogeographic provinces (Cabrera, 1957). The closest meteorological station to the study area is at Mina Pirquitas, 93 km from Toqueros, which received a total rainfall of 147.0 and 2.5 mm in 2002 and 2003, respectively.

Methods

By the interpretation of 1:45000 aerial photographs we classified the study area into 11 habitat types (Table 1) distinguished by vegetation physiognomy and dominant plant species (Matteucci & Colma, 1982). We made 15 field trips from 16 April 2002 to 31 October 2003, covering all seasons. Data were collected from a high fixed point, between 07.00 and 19.00. On each of 43 days we used binoculars to scan the whole study area six times, on average, each time for one hour, for a total of 253 hours of observations (121 and 132 in 2002 and 2003, respectively). We also continued observations between scans. The daily observation period was divided into four time periods (07.00–10.00, 10.00–13.00, 13.00–16.00, 16.00–19.00) and scans were distributed evenly between these periods. The following variables were recorded for each group of vicuña: location, behaviour of most members of the group, type and size of group (Altman, 1974; Martin & Bateson, 1986).

The area of each of the 11 habitat types was determined from locations taken with a geographical positioning system. Within each habitat type 2 * 2 m quadrats (following Matteuchi & Colma, 1982) were surveyed, in each season, for vegetation composition, height, cover and dominance. There were 105 quadrats in total, with the number in each habitat type proportional to its area.

Habitat use was determined by the frequency with which groups of vicuña were observed in each habitat type during the 253 hours of observation, and habitat availability was the proportion of the area occupied by each vegetation community. Habitat selection was analysed using the methodology of Manly *et al.* (1993) in which the relationship between the use of a resource and its availability are combined in a selection index that is compared using a log-likelihood χ^2 test. The selection index was calculated as $a = r_i/n_i\,(1/(\Sigma r_j/n_j))$, where r_i and r_j are proportions of prey type i or j in diet, and n_i and n_j are proportions of prey types i or j in the environment. The a values are normalized so that the sum of all values equals 1. When selective feeding does not occur a is equal to the inverse of the total number of food types. Bonferroni confidence intervals were estimated to evaluate the significance of each index (Manly *et al.*, 1993). The effects of environmental variables on the number of vicuña were analysed using general lineal models (GLM) with type III sum of squares, which are the most robust for unbalanced designs.

Table 1 The 11 habitat types identified in the study area of Toquerof (Fig. 1), with the area, associated species and total percentage cover of vegetation.

Habitat type	Area (ha)	Associated species	Total cover (%)
1 *Pajonal**, dominated by tall grasses (*Festuca* spp.)	223	*Parastrephia lepidophylla*, with a low stratum of *Adesmia* sp., *Aristida* sp. & *Boutelowa simplex*	50–80
2 Shrub steppe of *P. lepidophylla*	195	The grass *Stipa neesiana* & the shrub *Tetraglochin cristatum*, with a low stratum of grasses such as *B. simplex*, *Aristida* sp. & *Cynodon* sp.	50–80
3 Shrub steppe of *T. cristatum*	133	*Aristida* sp. & *Adesmia* sp. in the lower stratum	20–45
4 Shrub steppe of *Parastrephia phylliciformis*	0.5	Tall (*Festuca* sp.) & short grasses (*Mulembergia* sp. & *Alchemilla* sp.)	85–90
5 Shrub steppe of *Fabiana densa*	40	*Baccharis incarum* & *Adesmia* sp.	50–70
6 Shrub steppe of *Nardophyllum armatum*	15	*Adesmia* sp, *Ephedra* sp., *B. Incarum* & *T. cristatum*	20–40
7 *Esporal**, dominated by *Penissetum chilense*	29	*Festuca* sp. & *P. lepidophylla*	30–50
8 Shrub steppe of *Baccharis boliviensis*, on mountain slopes	151	Grass (*Stipa* sp.) &/or shrubs (*Adesmia* sp. & *T. cristatum*)	15–30
9 Shrub steppe of *Colletia spinossisima* on the steepest slopes	2		50
10 Riparian	10	Groves of *Cortaderia speciosa*, small swamp areas with dense, low vegetation & grassland of *Deyeuxia* sp. & *Mulembergia* sp.	60–85
11 *Peladar**, open rocky areas at the edges of roads with *B. simplex* and *Aristida* sp.	2		10–60

*Local names for these habitat types.

Results

In a GLM analysis with number of vicuña per scan as the dependent variable and year and habitat types as independent variables (Fig. 2) there were no significant differences in number of vicuña between years ($F_{1,2761}$ = 2.34, P = 0.126), but there were significant differences ($F_{10,2761}$ = 272.5, P < 0.0001) in the use of habitat types. The interaction term (year * habitat type) was highly significant ($F_{10,2761}$ = 7.5, P < 0.0001), indicating that the habitat use of vicuña was different between years.

The comparison between habitat use and availability, using the method of Manly *et al.* (1993), indicated that vicuña were selective in their use of habitat types in both years (χ^2_{10} = 44.3 and χ^2_{10} = 61.8, for 2002 and 2003, respectively, P < 0.01). However, statistical analysis of the selectivity indices for each habitat type using Bonferroni confidence intervals indicated that vicuña were more selective in their habitat use in 2002 than in 2003. In 2002 the mean percentage of vegetation cover per habitat (53.3%) was significantly higher (Paired *t*-test, t_{11} = 8.2, P < 0.0001) than in 2003 (46.1%). There was a significant positive correlation (r^2 = 0.38, P = 0.04) between the selectivity index and percentage of vegetation cover of vegetation types, suggesting that vicuñas more intensively used those habitats with greater abundance of vegetation.

In a GLM analysis with number of vicuña per scan as the dependent variable and season (spring, summer, autumn, and winter) and time period as independent variables (Fig. 3) season was non-significant ($F_{3,119}$ = 2.30, P = 0.08). Time period was highly significant ($F_{3,119}$ = 13.71, P < 0.0001) and there was generally an increase of vicuña in the study area as the day progressed. The interaction term (season * hour) was non significant ($F_{10,2761}$ = 0.99, P = 0.44), but vicuña appeared to arrive in the study area earlier in winter than in summer.

As the behaviour of vicuña was sampled by group and not by individual, a two-way contingency analysis was conducted with absolute frequency of groups as the dependent variable and type of group (family, bachelors or solo vicuña) and behaviour (forage, walk, social/maintenance, run, stand and lie) as grouping factors (Fig. 4). This was highly significant (χ^2_{10} = 179.5, P < 0.0001), suggesting that the occurrence of behaviours differed between groups. Bachelors groups and solo vicuña foraged less and moved more than vicuña in family groups. Solo animals were more frequently observed standing up than members of groups.

Discussion

During 2 years of study in the Toqueros area of the Laguna Pozuelos Reserve vicuña did not use the study area homogeneously. They spent more time in habitats dominated by grasses (*pajonal* and *esporal*) and with high overall plant cover than in habitats with low cover dominated by bushes such as *P. lepidophylla* and *B. incarum* (with poor digestibility) or *Tetraglochin cristatum* (an indicator of grassland degradation; Alzerreca, 2003).

The preference of vicuña for habitats dominated by grasses and with high plant cover has been noted

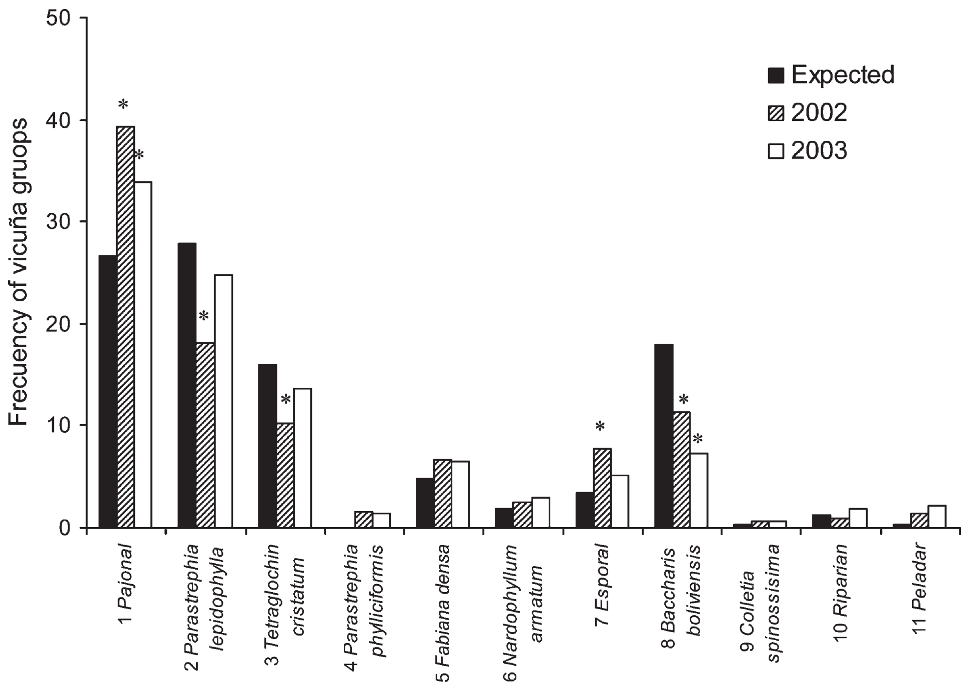

Fig. 2 Actual and expected frequencies of groups of vicuña observed during 2002–2003 in the 11 habitat types (Table 1) of Laguna Pozuelos Reserve. *Indicates $P < 0.05$ for Bonferroni confidence intervals of the selectivity index (see text for details).

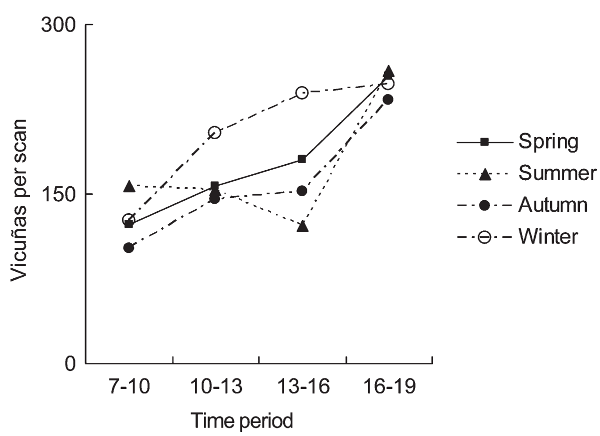

Fig. 3 Mean numbers of vicuña observed per scan at different time periods during the day in each season.

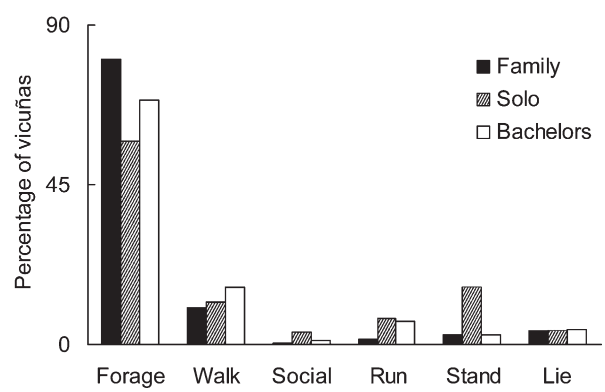

Fig. 4 Percentage of group types (family, bachelor groups and solitary individulas) of vicuña exhibiting different behaviours.

elsewhere. In Pampas Galeras, Perú, vicuña prefer to forage in grass steppe dominated by either *Festuca rigesens* or *Calamagrostis vicunarum*, or in *vegas*, a type of wetland (Franklin, 1983). *Vegas* are composed of plants that grow close to the ground, with high ground cover and biodiversity, and deep, wet topsoil. Of the two main habitats in Ulla-Ulla, Bolivia (grass steppe and *vegas*), vicuña prefer vegas, although the availability of this habitat for vicuña depended on the presence of people and alpacas (Villalba, 2003). Of the three main habitats in San Guillermo Reserve, Argentina (plains with tussock grassland, gentle grassy slopes, and rocky slopes), vicuña are more abundant in the grassland plains and there is a positive correlation between vicuña density and plant cover (Cajal, 1989). This preference for grassland steppes and *vegas* is consistent with the known preference of vicuña for Poaceae and Cyperaceae (Koford, 1957; Franklin, 1983; Cajal, 1989; FIDA, 1991; Aguilar, *et al.* 1999).

The change in habitat selectivity that we observed between years is a temporal pattern that has not been previously described for vicuña . Because the number of individuals did not vary between years, the reduction in selectivity observed from 2002 to 2003 implies a change in vicuña distribution between plant communities. In 2002 we found that availability of vegetation (grossly estimated from plant cover) was higher than in 2003 (a dry year) for all habitat types. Habitat selection theory predicts that when resources are concentrated in good habitats most individuals will use these habitats, but when the availability of resources decreases in good habitats, less competitive individuals will move to low quality habitats (Sutherland, 1996). The result is a more homogeneous distribution between habitats, as we observed in 2003. This intensity of this phenomenon, known as the buffer effect, depends on the nature of intraspecific competition (Gill *et al.*, 2001).

Bonacic *et al*. (2002) recognized the role of competition in the population ecology of vicuña. They found evidence of density dependence and suggested that long-term density-dependent relationships are modulated by between year changes in precipitation and food availability. Our results suggest that the buffer effect is a possible spatial mechanism that mediates density-dependency in vicuña. Our other findings confirmed the results of earlier studies of vicuña in Argentina, with daily changes in activity (Vilá & Roig, 1992; Renaudeau d'Arc *et al.*, 2000) and with members of family groups (mostly females with calves) spening more time foraging than non-reproductive groups (Vilá & Cassini, 1993).

Solitary vicuña spent more time standing up than members of groups. This posture is normally used for vigilance and implies a cost in terms of reduction in foraging time (Vilá & Cassini, 1994). This negative trend between vigilant behaviour and group size has repeatedly been found in species where group formation is associated with predator defence (Krause & Ruxton, 2002). Behavioural ecology theory postulates that one selective pressure for the evolution of group formation is the benefit obtained from the vigilant behaviour of other members of the group, which permits an increase in time spent foraging (Krause & Ruxton, 2002).

The vicuña of Jujuy province are the subject of a number of existing and planned projects for *in situ* and *ex situ* commercial exploitation. In particular, the area under study has become a management area for wild vicuña in which the prehispanic *chaku* method (Custred, 1979), which consists in a drive, capture, shearing and release of wild vicuña, is operated within a modern animal welfare framework (Bonacic & MacDonald 2003). It is important that sound science underlies management because sustainable exploitation must take biological and ecological principles into account (Taylor & Dunstone, 1996). The data presented here on vegetation, habitat use, vegetation preferences and daily activities helped us to plan the location and structure of the capture facilities for vicuña in Toquero. We believe this is the first instance in which such research has been carried out prior to the capture of vicuña for sustainable use. The research was designed to provide a baseline for comparisons after management had commenced, and will help us to evaluate the biological impact of management, especially in the long-term.

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