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Nature Conservation
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Moorland pools as refugia for endangered species characteristic of raised bog gradients
Hein H. van Kleef, Gert-Jan A. van Duinen, Wilco C.E.P. Verberk, Rob S.E.W. Leuven, Gerard van der Velde and Hans Esselink
Using species distribution modeling to set management priorities for mammals in northern Thailand
Yongyut Trisurat, Naris Bhumpakphan, David H. Reed and Budsabong Kanchanasaka
An expert-based approach to invertebrate conservation: Identification of priority areas in central-eastern Alps
Mauro Gobbi, Elisa Riservato, Natalia Bragalanti and Valeria Lencioni
Guanaco (Lama guanicoe) mortality by entanglement in wire fences
Andrés Rey, Andrés J. Novaro and María L. Guichón
Factors influencing perception of protected areas—The case of Natura 2000 in Polish Carpathian communities
Agata Pietrzyk-Kaszyńska, Joanna Cent, Małgorzata Grodzińska-Jurczak and Magdalena Szymańska
Distance models in ecological network management: A case study of patch connectivity in a grassland network
Szilárd Szabó, Tibor Novák and Zoltán Elek
A meta-analysis of spatial relationships in species richness across taxa: Birds as indicators of wider biodiversity in temperate regions
Sarah M. Eglington, David G. Noble and Robert J. Fuller
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Short communication

Guanaco (*Lama guanicoe*) mortality by entanglement in wire fences

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ABSTRACT

Wire fences are widely used in rangelands around the world and may have a negative impact on wildlife that varies among species and habitats. The guanaco (*Lama guanicoe*) is the largest Patagonian ungulate and though entanglement in wire fences is frequently reported, its impact on guanaco populations has not been previously evaluated. We estimated annual mortality rate of wild guanacos due to entanglement in wire fences and evaluated whether the frequency of entanglement was age-dependent in the two wire-fence designs traditionally used in Patagonian sheep ranches. We found that annual yearling mortality on fences (5.53%) was higher than adult mortality (0.84%) and was more frequent in ovine (93 cm high) than bovine (113 cm) fences. Most guanacos died entangled by their legs in the highest wire when trying to jump over the fence. Our results suggest that guanacos are more likely to die due to fence entanglement than ungulates studied in other regions. Indirect effects of wire fences should also be considered as they may act as semi-permeable barriers for guanaco populations. We suggest removal of unnecessary wire fences and replacement by guanaco-friendly fences, like high-tensile electric fences that may reduce mortality and barrier-effect on guanaco populations.

Introduction

Wire fences are widely used to restrict animal movement (Harrington & Conover 2006; Hayward & Kerley 2009; Hobbs et al. 2008). Holding or excluding animals using wire fences can contribute to the management, protection and conservation of habitats (i.e. wetlands, pastures, forests) (Doupé et al. 2010; Golluscio et al. 1998; Husheer et al. 2003), animals (i.e. livestock, threatened species) (Hayward & Kerley 2009; Ikuta & Blumstein 2003; Islam et al. 2010) and particular habitat resources (i.e. crops, native grasslands) (Gonzales & Clements 2010; Gordon 2009; Hobbs et al. 2008). However, when wire fences are built for productive purposes ignoring wildlife requirements, they may become a serious threat to wildlife, mainly ungulates (Gordon 2009; Islam et al. 2010) and birds (Drewitt & Langston 2008; Wolfe et al. 2007).

Wire fences used for livestock usually limit wild ungulate access to vital resources (Mbaiwa & Mbaiwa 2006; Loarie et al. 2009), fragment their habitats (Hobbs et al. 2008), and restrict their movements as they respond to variable environmental conditions (Islam et al. 2010) and along migratory routes (Bolger et al. 2008; Fox et al. 2009). Wire fences that are unfriendly toward wild ungulates can also provoke injuries and death during crossing attempts (Harrington & Conover 2006; Paige 2008). Although fence location and design to allow or prevent movement of wild ungulates have been evaluated (Karhu & Anderson 2006; Knight et al. 1997; VerCauteren et al. 2007), few studies have estimated ungulate mortality during fence crossing or have described forms of entanglement (Harrington & Conover 2006).

The guanaco (*Lama guanicoe*) is a monomorphic South American native ungulate that reached 30–50 million individuals (Raedeke 1979) but its abundance and distribution have drastically declined since Europeans arrived to this continent (Baldi et al. 2010; González et al. 2006). Nowadays, more than 70% of the 500,000–1,000,000 remnant guanacos inhabit Argentinean Patagonia, mainly in private lands where extensive sheep husbandry has been the main productive activity since the XIX century (Baldi et al. 2010). Patagonia extends over >500,000 km^2 of arid land (INDEC 2002) and wire fences for livestock divide 25 to 100-km^2 ranch sections used for sheep grazing (Baldi et al. 2001; Guevara et al. 2009), reaching >164.000 km of wire fences. Although adult guanacos can jump over 2 m-high fences (Montes et al. 2006), entangled guanacos in wire fences are reported (Baldi et al. 2010; Bank et al. 2002; Raedeke 1979). However, the relative importance of mortality due to entanglement remains largely unknown and the belief that wire fences pose no threat to guanacos is still widespread in Patagonia (Baldi et al. 2001). Therefore, we estimated annual mortality rate of guanacos due to entanglement in wire fences and evaluated whether the frequency of entanglement varied according to fence design and guanaco age. We also described the most common forms of guanaco entanglement and suggest

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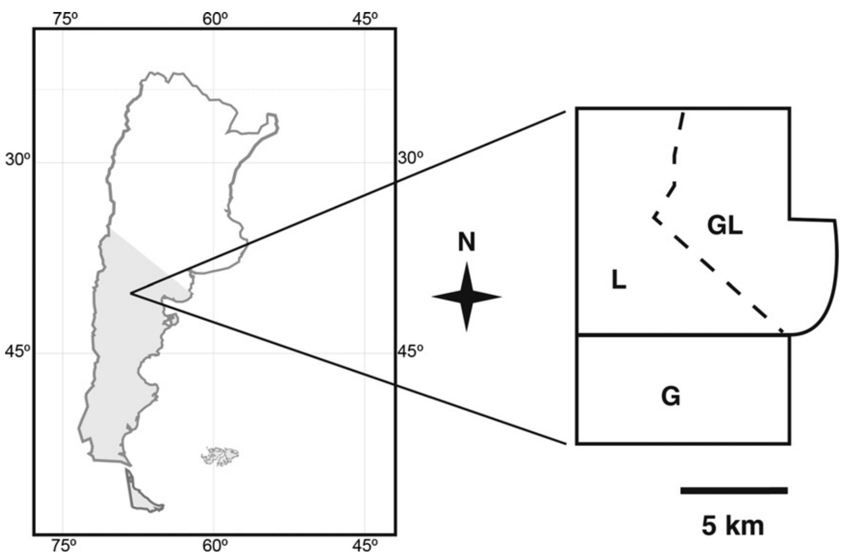

Fig. 1. Location of our study site within Cabeza de Vaca ranch located in Argentinean Patagonia and the three 5000–5500 ha surveyed sections (G, L, and GL) showing bovine (solid line) and ovine (doted line) wire fences.

modifications aimed at reducing mortality associated with wire fences.

Methods

We carried out this work in Cabeza de Vaca ranch (40°S, 66°W), a traditional sheep ranch located in Río Negro province, Patagonia, Argentina (Fig. 1). The region is characterised by a relatively flat topography at 400–500 m asl and an open shrub steppe with tall and low shrubs, grasses and abundant bare soil, locally called 'monte' desert (Guevara et al. 2009; Paruelo et al. 1998a). Mean annual temperature is 12 °C and mean annual precipitation is 200 mm (Paruelo et al. 1998b).

From October 2005 to June 2007 we recorded bimonthly, except in winter, all guanaco carcasses entangled on bovine (65 km) and ovine (13 km) wire fences that divided three 5000–5500-ha contiguous sections (G, L and GL) of the ranch (Fig. 1). Bovine fences have seven wires that reach 113 cm in height, whereas ovine fences have five wires 93 cm high. For each entangled carcass we recorded: (1) relative age, yearling (≤1 year old) and adult (>1 year old) according to body size (de Lamo 1995); (2) sex, through observation of genitals in fresh carcasses or suspensor structures of male genitalia in adult hip bones (Raedeke, 1978 cited in Saba et al. 1995); (3) type of fence, bovine or ovine, and height of each wire; and (4) entanglement form, by identifying which body part (front legs, hind legs or other part) was caught in which wire. We removed old carcasses to avoid double recording. We evaluated if the frequency of entanglement differed between the highest wire and the lower wires of the fence using a χ^2 test with Yates' correction. We tested if the frequency of entanglement of young and adult guanacos was independent of fence design, i.e. bovine or ovine fence, using χ^2 independence test with Yates' correction (Zar 1996).

We estimated annual mortality rate due to entanglement as the total number of carcasses found between June 2006 and June 2007 over the estimated guanaco abundance in this period. We estimated guanaco abundance bimonthly, except in winter, in G, L, and GL sections through five to eight pedestrian 6–9-km long line transects per section (Buckland et al. 2001; Rey 2010). We recorded the number of yearlings and adults in all guanaco groups (using 12 × 60 Nikon binoculars and 20–60 × 80 Shilba telescope), their distance from the observer (using laser rangefinder Buschnell Yardage Pro 1000 ± 1 m), and their angle from the line transect (using a hand compass). We estimated guanaco abundance using DISTANCE version 5.0 release 2 (Buckland et al. 2001; Thomas et al. 2006) and extrapolated average densities estimated in G and L for missing surveys in section GL. We used the observed yearling × adult^{-1} ratio to estimate relative abundance of each age category and estimate annual mortality per age class. We estimated annual mortality rates of adult and yearling guanacos as the accumulated frequencies of carcasses recorded during the year over the mean adult abundance and yearling abundance at the end of the 2006–2007 breeding season (March), respectively. Mean and standard errors are reported, unless otherwise stated.

Results

From December 2005 to June 2007 we recorded a total of 124 guanaco carcasses entangled in wire fences that yielded an annual entanglement frequency of 1.0 per km of fence (yearlings: 0.4 per km; adults: 0.5 per km). We recorded similar entanglement frequency between fences design, 1.7 carcasses per km of ovine fence (n = 22 carcasses) and 1.6 carcasses per km of bovine fence (n = 102). Most guanacos were entangled by their front or hind legs (97 out of 111), indicating failed jumping attempts. We identified the sex of 78 carcasses, which showed a balanced sex ratio (1M:1.05F). Deaths of guanacos were most frequently due to entanglement in the highest wire (80 out of 111; $\chi^2_{0.05(2)1} = 10.41$; $p < 0.01$). Entanglement of young and adult guanacos was dependent on fence design ($\chi^2_{0.05(2)1} = 12.77$; $p < 0.001$), being more frequent for adults in bovine fences and for yearlings in ovine fences (Table 1).

From June 2006 to June 2007, we estimated an annual guanaco mortality rate due to fence entanglement of 1.6% (59 carcasses; 3698 ± 211 live guanacos). Annual mortality rate was 5.5% in

Table 1
Yearling and adult frequency of entanglement on bovine (65 km) and ovine (13 km) wire fences from December 2005 to June 2007 in Cabeza de Vaca ranch, Patagonia, Argentina.

	Ovine fence		Bovine fence		Total
	Yearlings	Adults	Yearlings	Adults	
Male	4	1	5	28	38
Female	2	3	6	29	40
Unsexed	12		27	7	46
Total	18	4	38	64	124

Table 2
Annual wire-fence mortality rate (number entangled × 100/abundance × year), wire-fence relative mortality (%) in relation to total mortality (%) shown in brackets, and entanglement frequency (number entangled/km × year) reported for guanaco populations and others ungulates.

Species	Annual wire-fence mortality rate (%)	Relative mortality (%) [total mortality rate (%)]	Annual entanglement frequency (*n*/km × year)	Source
Lama guanicoe	1.60	6.65 [24][a]	1.0	Present study
	1.55	7.40 [21]	–	Raedeke (1979)
	0.06	2.00 [3][b]	–	Bank et al. (2002)
Yearlings	5.53	8.50 [65][a]	0.45	Present study
	0.98	1.58 [62]	–	Sarno et al. (1999)
Adults	0.84	4.66 [18][c]	0.55	Present study
Odocoileus hemionus	–	–	0.08	Harrington and Conover (2006)
Antilocapra americana	–	–	0.11	Harrington and Conover (2006)
Cervus elaphus	–	–	0.06	Harrington and Conover (2006)

[a] Based on annual adult mortality estimated for the studied population (Rey 2010) and yearling mortality reported for other guanaco populations (de Lamo et al., 1982 cited in Saba et al. 1995; Sarno et al., 1999).
[b] Eight months mortality rate.
[c] Annual adult mortality estimated for the studied population (Rey 2010).

yearlings (31 carcasses; 561 ± 55 live yearling guanacos) and 0.8% in adults (28 carcasses; 3340 ± 137 live adult guanacos).

Discussion

Our results indicate that the typical wire fences in the Patagonian sheep ranch studied were semi-permeable barriers for wild guanacos that caused direct mortality, especially in yearlings, and that fence height was a key risk factor. Annual guanaco entanglement frequency was higher than reported in the red deer (*Cervus elaphus*), mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*) (Harrington & Conover 2006) (Table 2). We found that annual yearling wire-fence mortality was five times higher than adult mortality. Yearling mortality, however, should be considered a minimum estimate given the fast decomposition and consumption by scavengers of yearling carcasses (Harrington & Conover 2006; A.R. pers. observations). The higher yearling than adult entanglement frequency recorded in ovine fences has also been reported for juveniles of mule deer, pronghorn and red deer that were eight times more likely to die in fences than adults (Harrington & Conover 2006). This finding suggests that small body size and limited experience increase the likelihood of yearling entanglement and that successful crossing of low, ovine fences by adult guanacos could increase yearling attempts to jump these fences. Similarly to guanacos, frequent entanglement by the legs in the highest wire was observed in red deer, mule deer, pronghorn, and white tailed deer (*Odocoileus virginianus*) (Bauman et al. 1999; Harrington & Conover 2006).

Mortality rate of guanacos due to fence entanglement represented 6.7% out of the total annual mortality estimated for this population (24%) (Table 2). Fence entanglement was the second cause of guanaco mortality (7.4% of all deaths), after inanition (85%), in a guanaco population free of puma predation in Tierra del Fuego (Raedeke 1979), though it was the third cause (2%), after inanition (13%) and puma predation (74%) in a population in Torres del Paine National Park (with only 8 km of fences in 60 km^2) (Bank et al. 2002). Few fences also may explain the low yearling entanglement mortality (<2%) in Torres del Paine (Sarno et al., 1999) (Table 2). In our study site we expect yearling mortality due to entanglement to be approximately 9% of the overall mortality rate if we assume an annual yearling mortality similar to other guanaco populations (60–70%) (de Lamo et al., 1982 cited in Saba et al. 1995; Sarno et al., 1999) (Table 2).

Mortality due to fence entanglement may underestimate the overall negative effects of fences on guanaco populations. The barrier-effect reported in this study could contribute to fragmentation of the population into sub-populations. Semi-permeable barriers could affect the dynamic of either migratory or sedentary guanaco populations that respond to environmental stress; however, we have insufficient data on wire-fence effect at a landscape scale. Wire fences can limit access to water or forage, increasing dehydration mortality as reported during drought periods for giraffes (*Giraffa camelopardalis*) (Mbaiwa & Mbaiwa 2006) and Arabian oryx (*Oryx leucoryx*) (Islam et al. 2010), starvation mortality as reported for mule deer, pronghorn and red deer (Harrington & Conover 2006), and predation or poaching, as reported for Tibetan antelope (*Pantholops hodgsonii*) (Fox et al. 2009). These indirect wire fence mortality sources could also be higher in yearling than adult guanacos and together with high entanglement frequency, mainly in ovine fences, would affect population recruitment

The development of wildlife-friendly fences that replace traditional wire fences on Patagonian ranches is necessary to minimise their incidence, particularly in a region where ongoing and predicted aridification (Labraga & Villalba 2009) may increase wildlife movement in search of vital resources. High-tensile electric fences are the least restrictive wildlife fences (Karhu & Anderson 2006) and should be tested to replace traditional wire fences in Patagonia. A three-wire high-tensile electric fence with one negative wire (Fig. 2), as described by Karhu and Anderson (2006) and VerCauteren et al. (2006), may work best due to the dry weather and poorly-conductive soil in the Patagonia steppe and scrub. This design would facilitate guanaco fence crossing by reducing the maximum height and increasing distances among wires to reduce the likelihood of entanglement. Adjustable electrical discharges would produce harmless aversion. Additionally, wildlife passage

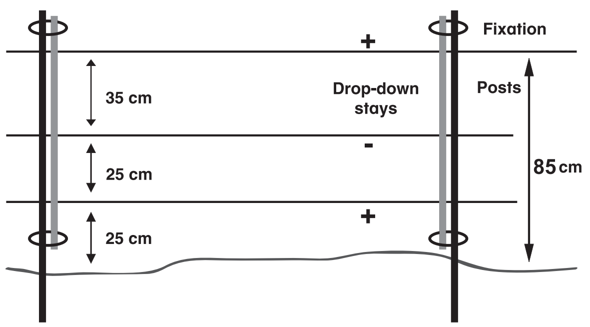

Fig. 2. Design proposal of a guanaco friendly high tensile electric fence for livestock in arid Patagonia. Hot and ground wires are attached to drop-down stays that are fixed to posts. Top wire height is lower than current ovine design and larger space between wires would allow crossing of yearling and reduce entanglement.

structures at frequently used crossing sites along fences such as temporary drop-down stays, gates, and deer-ladder stiles (Paige 2008; VerCauteren et al. 2007), could improve fence crossing success and reduce barrier effects on guanaco populations. Red deer can remember the location and selectively use low risk crossing sites (Knight et al. 1997). We observed hundreds of guanaco footprints that indicated successful fence crossing within 24 h at a particular site with low fences due to broken stays or wires (A.R. pers. observation just after an intense volcanic ash rain in May 2008), suggesting that crossing sites strategically located (e.g. to ensure access to water) could be successfully used by guanacos. Minimising guanaco mortality by fence entanglement in Patagonia will also require removing wire fences in disuse or that do not fulfill their intended function (i.e. territorial boundaries, preventing vehicular access) (Hayward and Kerley, 2006; Paige 2008). Monitoring the success of guanaco-friendly fences would provide new insights for the conservation of this species in Patagonian rangelands.

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