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NEW DATA ON THE PRESENCE OF *VICUGNA VICUGNA* (MOLINA, 1782) IN EXTRA-ANDEAN AREAS

NUEVOS DATOS SOBRE LA PRESENCIA DE *VICUGNA VICUGNA* (MOLINA, 1782) EN AREAS EXTRA-ANDINAS

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Abstract. This work provides the evidence that the vicuña (*Vicugna vicugna*) occurred in extra-Andean areas of southern Argentina and Chile as reported by early European explorers between the 18th and 19th centuries. The localities of historical observations in southern Patagonia show similar analogies with the arid ecosystems of the Puna. In view of the recent molecular work indicating that fossil remains of *Lama* (*Vicugna) gracilis* might actually belong to *Vicugna vicugna*, the related data and climate change information are included for discussion purposes. The evidence presented here challenges the strictly orophilic character of the vicuña.

Key words: Extra-Andean occurrence, historical records, vicuña.

Resumen: Este trabajo provee evidencia de la presencia de la vicuña (*Vicugna vicugna)* en áreas extra-andinas del sur de la Argentina de acuerdo a reportes de viajeros Europeos desde los siglos XVIII y XIX. Los lugares de observación histórica en el sur de la Patagonia presentan analogías similares con los ecosistemas áridos de la Puna. En vista de los recientes trabajos moleculares según los cuales restos fósiles de *Lama* (*Vicugna) gracilis* podrían pertenecer a *Vicugna vicugna*, se incluyen también estos resultados e información de cambio climático como marco a la discusión. La evidencia presentada aquí desafía el carácter estrictamente orofílico de la vicuña.

Palabras clave: Presencia extra-andina, registros históricos, vicuña.

INTRODUCTION

The vicuña (*Vicugna vicugna*), one of the two wild South American camelids, is restricted in distribution to the Central Andes of southern Peru, northern Chile, western Bolivia, and northwestern Argentina at altitudes that range between 3,700-4,900 meters (Koford 1957). In Chile, 95% of the populations are concentrated in the XV Region of Arica and Parinacota (Laker 2004). In Argentina, the vicuña occurs in the provinces of Jujuy, Catamarca, Salta, La Rioja and San Juan with relictual populations in the province of Tucumán (Lichtenstein et al. 2008). Modern vicuñas are strictly orophylic (Weinstock et al. 2009). The limits of range are apparently determined by availability of food and by freedom from disturbance (Koford 1957). There is some evidence that the vicuña used to be more widely distributed, but it has not been well documented. In 1782, Ignacio Molina reported the southernmost population of vicuñas at Coquimbo and Copiapo, Chile, but Ricardo Latchman (1922) suggested that at the

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time of the Conquest the vicuña's range extended as far south as the Strait of Magellan, Chile. The purpose of this study is to present the evidence of the occurrence of the vicuña in extra-Andean areas in southern Patagonia. The importance of this work is that it challenges the strict orophylic character of the species.

MATERIALS AND METHODS

Study Area

Patagonia encompasses over 900,000 km^2 and extends between latitudes 39º and 55º South in South America. The topography of this territory is dominated in the west by the mountain chain of the Andes. Patagonia includes the Pacific and Atlantic lowlands and coasts, the southern archipielagos, and the valleys, tablelands, and high plains extending between the Andes and the Atlantic coast (Coronato et al. 2008). The Andes play a crucial role in determining the climate of Patagonia since they form a barrier to moist air masses from the Pacific Ocean, producing an abrupt precipitation gradient from west to east. Along this gradient, starting from the subantarctic forest border, grass steppes give way to shrub-grass steppes and then to deserts (Soriano 1983). The vegetation of arid and semiarid Argentine Patagonia includes 45% shrub desert, 30% shrub-grass semi-desert, and 20% grass steppe and 5% other types like meadows and water (Soriano 1983). Southern Patagonia is characterized by above average rainfall and abundance of productive pastures (Gonzalez and Rial 2004). The Chilean Patagonia steppe is dominated by dry and cold climate with vegetation consisting mainly of grassland steppe (Luebert and Pliscoff 2006). In Chile, all main hydrographic watersheds run from the Andes mountains to the Pacific Ocean, forming parallel watersheds. In Argentina eight main rivers of Atlantic drainage discharge in estuaries where the most important floristic richness is concentrated (Coronato et al. 2008).

Historical Literature Review

The comprehensive analysis of historical texts included: i) accounts of early explorers, ii) conquest chronicles, and iii) Jesuit relations. For this study, I have taken "historical" to mean as far back as 1520, the year in which Hernando de Magallanes was the first white man to land on Patagonia. Some European publications of comparable quality that compile information from early chronicles refer to the hunting of vicuñas for their meat and skins by the Mapuches (Araucanians). However, they have been removed from the analysis because they are not as accurate as first person journals written at the time of the event. The historical sources have been chosen based on a rigorous evaluation of the descriptive quality of the text, especially as far as descriptions of fauna is concerned. Then each record was evaluated in terms of the correctness of identification and precision of the location.

Study species

Vicuñas are primarily grazers (Franklin 1983), but in the dry Puna of Argentina they behave as generalist ungulates (Borgnia et al. 2010). They exhibit broad tolerance to poor environments, yet water is regarded as an important component of the species' habitat requirements. Vicuñas need water daily (Franklin 1974, 1983; Vila and Roig 1992; Bonacic 2005). Several studies showed that the vicuña's distribution is mainly linked with marshy areas, lagoons or streams called "bofedales" or "vegas" (Koford 1957; Glade 1988; Lucherini 1996; Bonacic 2005; Rojo

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et al. 2012), especially in the dry season (Renandeau d'Arc et al. 2000). Presence or absence of water affects their movement patterns and social activities (Franklin 1974, 1983; Menard 1984; Bosch and Svendsen 1987; Vila and Roig 1992; Vila and Cassini 1993; Davies 2003). Vicuñas need withstand neither extreme cold, extreme heat, nor extreme variations in air temperature (Koford 1957). Research by Koford (1957) and Franklin (1974, 1983) in Peru showed that the vicuña is territorial all year round.

RESULTS

Historical Records

A total of 25 records have been collected for the historical period under review. The evidence shows that vicuñas were present in the southernmost tip of Patagonia as late as 1876. The most descriptive accounts are from the 18th century explorations of Louis de Bougainville (1771). An interesting piece of information is the account of Victor de Rochas (1861), surgeon of the French Navy. During his voyage to the Magellanic channels, Rochas described both the vicuña and the guanaco, and included a drawing representing a vicuña being preyed upon by a puma (*Felis concolor*). With two exceptions, in no case do the records provide evidence of the abundance of the species, and there are no accounts of vicuña in Tierra del Fuego. The historical records are shown in Table 1 in chronological order. The level of certainty of these data is high because the observers were able to identify both the vicuña and the guanaco. All the citations appear between brackets in their original language to reduce errors due to translation. Half of the records are sight observations, and the rest refer to the vicuña as a source of meat, skins and bezoar stones. All records, except two, contain specific geographic localities. Despite the reported absence of the vicuña in Argentina after 1768, it is recorded as persisting in Magallanes, Chile, until around the second half of the 19th century.

Table 1. Historical records of *Vicugna vicugna* in Patagonia. An empty cell in the table indicates that the data in the above cell applies.

#	Source	Year	Location	Evidence	Authors	Ref.
1	Pedro Lozano	1745	B. San Julian	"Hallaron siete u ocho vicuñas y un guanaco...".	Lozano 1972	B
2			P. Santa Cruz	"y en tierra se hallan avestruces, guanacos, vicuñas, quirquinchos y zorillos".		C
3	José Quiroga	1746	B. S. Julián	"A esta laguna bajan algunas vicuñas, y guanacos a comer sal".	CSIC 1943	B
4				"… y de los animales cuadrúpedos guanacos, vicuñas, zorrillos, y quirquinchos, …".		
5	Jorge Barne	1753		The natives offered them "… muchas de aquellas pieles, piedras bezares, lana de guanaco, aunque algunos dicen que era de vicuña".	Barne 1969	
6	Thomas Falkner	1760	Patagonia	"There are likewise considerable quantities of the occidental bezoar, found not only in the stomach of the guanacoes and vicuñas...".	Falkner 1935	-
7	Francois C.de la Gyraudais	1763-64	C. San Gregorio	"Plusieurs de nos gens ont été à la chasse … y ont tué quelques perdrix, et vu des carcasses de vigognes".	Pernety 1769	F
8				"Après avoir parcouru environ une lieue, rencontré deux troupeaux de vigognes de 3 ou 400 chacun …".		
9				"On pourrait aisément faire avec eux la traite de … des peaux de vigognes, dont la laine est si estimée et si chère en Europe, celle des guanacos est aussi excellente, quoique moins fine".		
10				"Ils sont vêtus de peaux de guanacos, de vigognes, …".		
11	Alexandre Duclos Guyot	1766	P. Del Hambre	"Ce sont des hommes …. n'ayant pour habillement que des peaux de loups-marins, guanacos et vigognes".		G
12				"Les hommes et les femmes n'ont pour habillements que des peaux, soit de vigogne, guanacos, …".		
13			C. San	"Ils sont revenus le soir, sans avoir rien pris, ni tué, excepté M. de		F

#	Source	Year	Location	Evidence	Authors	Ref.
			Gregorio	la Gyraudais, qui a tué une vigogne galeuse".		
14				"Il y a beaucoup de vigognes sur le terrain, qui forme un beau pays".		
15				“Ils sont couverts de peaux de chevreuils, de guanacos, de vigognes, de loutres et d'autres animaux".		
16	Louis A. de Bougainville	1767		"Les sauvages, … leur apportèrent quelques morceaux de chair de vigogne à moitié crus, mais qui furent trouvés excellents".	Bougainville 1771	
17			B. de la Posesion	"Nous échangeâmes quelques bagatelles, … contre des peaux de guanaques et de vigognes".		D
18				The Patagons: "Leur nourriture principale paraît être la moelle et la chair de guanaques et de vigognes".		
19	Domingo Perler	1767-68	P. Deseado	"Se hallan con abundancia vicuñas, guanacos, venados…".	Perler (n/d)	A
20			B. San Julian	"Guanacos, vicuñas, venados, perdices, abundancia de gaviotas,..".		B
21	Victor de Rochas	1856	C. San Gregorio	"Le Cap Gregory est un des points ou il est le plus facile d'entrer... et de s'y procurer, moyennant quelques galettes de biscuit et quelques litres d’eau-de-vie, de la chair de guanaco, de vigogne ou d'autruche".	Rochas 1861	F
22				"Les Patagons étaient de braves gens qui fournissaient les ménages de la viande de guanaco, d'autruche, de vigogne ...".		
23				"La vigogne est aussi un animal fort élégant, de la taille et de la forme de la chèvre, mais sans cornes et avec des pattes doublement longues”.		
24			Strait of Magellan	"... on trouve des especes animales d'un ordre supérieur, jaguar, couguar, guanaco, vigogne …".	Simonot 1862	-
25	Juan Bosco	1876	Patagonia	"Ahora el alimento más común es la carne de yegua, y sólo rara vez comen otra clase de carne, como la de vicuña y de guanaco…".	Bosco 1986	-

The vicuña was reported in Argentina on the Atlantic coast of Santa Cruz Province in locations that correspond to the Central and Magellanic Districts of the Patagonian phytogeographic province (see Figure 1 for locations). The Central District encompasses the most arid portion of the territory, with an average annual rainfall up to 200 mm (Paruelo et al. 1998). The most extensive vegetation unit is a semidesert dominated by dwarf shrubs, and the rest of the district is occupied by shrub steppes (Paruelo et al. 2007). The Magellanic District, with rainfall that ranges between 180 and 250 mm, has a colder, oceanic climate. Shrubs are common constituents of the grass steppe, differing between the most xeric and the most humid soils (Collantes et al. 1999). Climatically, this province is characterized as template-cold arid, with mean annual temperatures between 8° and 10°C. Flood meadows “mallines” in Santa Cruz province are associated with rivers, valley bottoms or springs and cover a surface area of 276,900 ha (Mazzoni and Vazquez 2004).

In Chile, the occurrence records correspond to the continental area of the Magellanic steppe. The climate of the eastern Strait falls within the Köppen classification of a modified middle latitude steppe type, characterized by short and cool summers, and slightly cold winters (Huber 1977a, 1977b). Rainfall averages 250-300 mm annually, and mean temperature is 6.8º C. The Magellanic steppe is characterized by grassland with occasional shrubs. It can be divided into a moister (mesic) type located closer to the Andes and a dryer (xeric) type located in the east (Pisano 1985; Roig 1998). In this ecoregion the low mean temperature, high cloud amount, and soils characteristics favour the presence of mallines that occupy between 15%

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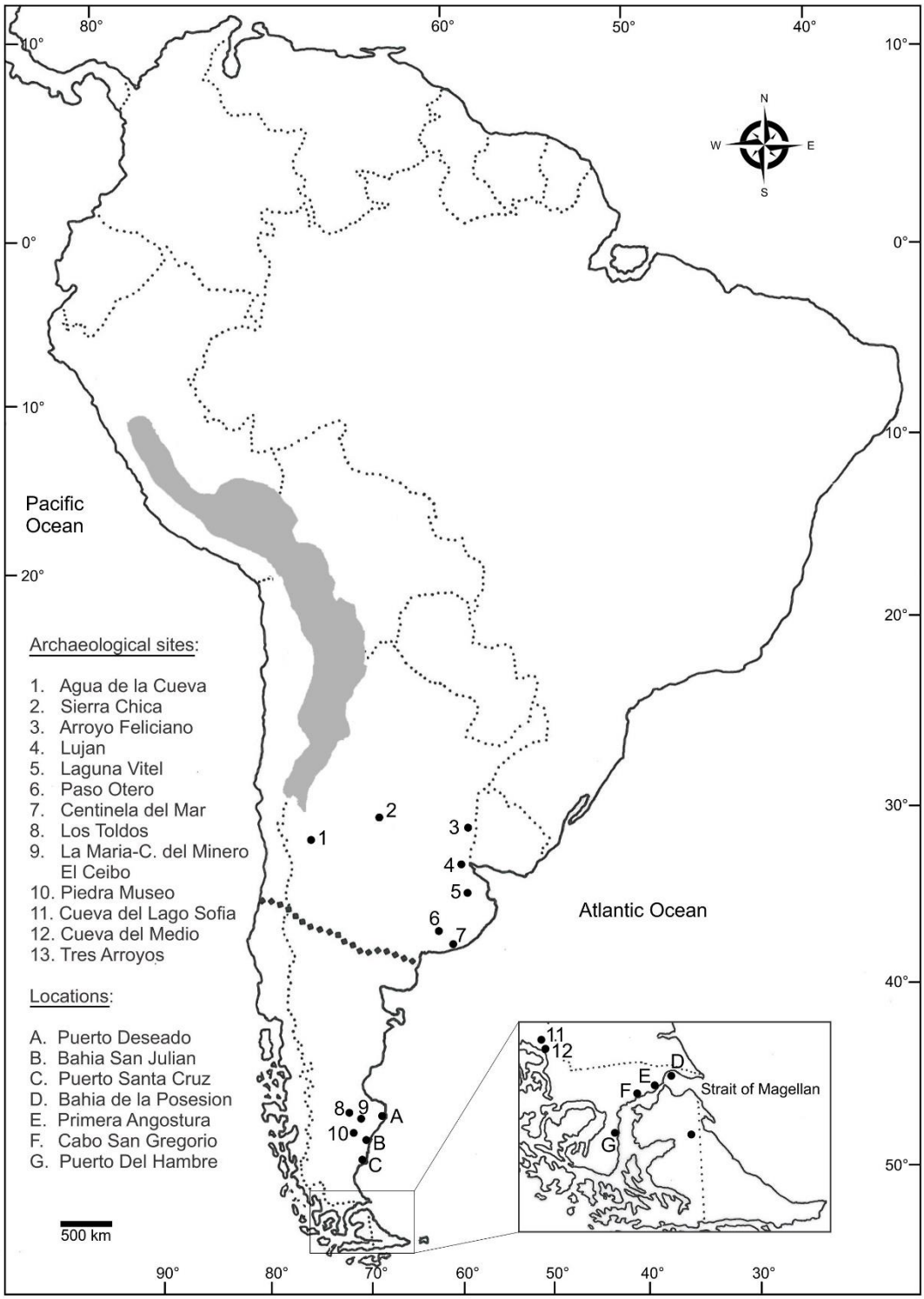

Figure 1. Map of South America. Bold dotted line = northern limit of Argentine and Chilean Patagonia. Gray shaded area = current distribution of *Vicugna vicugna*. Numbers indicate the archaeological sites with reported specimens of *Lama gracilis*. Letters indicate the locations mentioned in the text and Tables.

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and 20% of the landscape (Roig et al. 1985). Both in Argentina and Chile, the sheep herding started in the late 19th century in the steppe and steppe-forest ecotone (Rey Balmaceda 1976; Martinic 1984) in areas that coincide with the historical records of vicuña.

The interior of South America displays similar ecological conditions between very distant geosystems. One of these cases is the arid tropical Puna and the most oceanic extreme of Patagonia, the Santa Cruz province (Morello 1984). From a physiognomic point of view, the Puna vegetation is very closely related to that of Patagonia (Cabrera 1976). Many of the dominant genera are frequent in both regions (*Junellia*, *Fabiana*, *Chuquiraga*, *Nardophyllum*, *Adesmia* and *Mulinum*) (Fernandez and Busso 1999), and few of the Puna's genera are not present in Patagonia (Cabrera 1976). Both regions have similar patterns of mean annual precipitation, but different rainfall regime, mainly during fall and winter in Patagonia (Jobbagy and Sala 2000), and summer in the Puna (Cabrera 1957, 1976).

Archaeology and Climate Change

Recent DNA molecular analysis of dental pieces recovered from Chilean Patagonian excavations revealed that fossil remains of a small vicuña-like genus, *Lama (Vicugna) gracilis* (Gervais and Ameghino, 1880) might belong to *V. vicugna* (Weinstock et al. 2009). *Lama gracilis* inhabited the low plains from the east Pampean region to Patagonia during the late Pleistocene and early Holocene (see Table 2). Menegaz et al. (1989) posed that the dental specialization of *L. gracilis* suggested an optimization of the ingestion of Microthermic grasses. These authors further observed that the South American camelids and the Microthermic grasses could have experienced a coevolutionary process that goes back as far as their arrival in South America. No fossil remains of this species have been reported for Mid- to Late-Holocene. Even though the lack of evidence for this period could be interpreted as a sampling bias, this issue remains a challenge to the scientists in various fields.

Climatic fluctuations in Patagonia have been a fundamental characteristic of the Holocene. Paleoclimatic records suggest the occurrence of conditions related to the Medieval Warm Period (MWP, ~800-1,300 AD) and the Little Ice Age (LIA, ~1,300-1,800 AD). There is multiple evidence of the Medieval Climate Anomaly (MCA) in Patagonia as a dry period (e.g. Markgraf 1988; Stine and Stine 1990; Villalba 1990, 1994; Stine 1994, 2000). Although there are different opinions regarding the precise chronology of the local expression of the MCA, the central point here is the existence itself of such climate changes. According to Menegaz et al. (1989), the postglacial climatic changes associated with the latest phases of the last glacial cycle affected the distribution of grasses of the Microthermic group, today distributed in the Andean Puna and the Patagonian steppe. The authors further assumed that this, in turn, influenced deeply in the retraction and the extinction of *L. gracilis*.

DISCUSSION

Documenting historical occurrence of taxa has been widely used to estimate the previous distributions of mammals (see, for example, Koch 1990; Loehle and Eschenbach 2011; Tyler and Anderson 1990). It is important, though, to recognize the paucity of records prior to the 18th century, the lack of systematic observations and an unequal spatial coverage in written sources. The early European explorations to the South Seas combined mainly political and economic motivations. After a first period of discoveries (1520-1580) followed another of

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Table 2. Archaeological sites with evidence of *Lama gracilis*.

Site	Location	Years BP/Age	Author/s	Map #
Agua de la Cueva	Mendoza	ca. 11,000 and 9,000	Gil et al. 2011	1
Sierra Chica	Córdoba	Pleistocene	Tauber 1999	2
Arroyo Feliciano	Entre Ríos	Late Pleistocene	Ferrero 2005	3
Lujan	Buenos Aires	Late Pleistocene	Menegaz et al. 1989	4
Laguna Vitel	Buenos Aires	Late Pleistocene	Menegaz y Ortiz-Jaureguizar 1995	5
Paso Otero	Buenos Aires	Late Pleistocene	Menegaz y Ortiz-Jaureguizar 1995	6
Centinela del Mar	Buenos Aires	Late Pleistocene-Holocene	Menegaz y Ortiz-Jaureguizar 1995	7
Los Toldos	Santa Cruz	12,600±650	Cardich et al 1973	8
La María Casa del Minero	Santa Cruz	10,967±55	Paunero et al. 2004	9
El Ceibo	Santa Cruz	ca. 11,000	Cardich 1987	9
Piedra Museo	Santa Cruz	ca. 12,890 to 10,400	Miotti et al. 1999; Ramírez Rozzi et al. 2000	10
Cueva Lago Sofía	Magallanes	ca 10,140 to 10,780	Prieto and Canto 1997, Massone and Prieto 2004	11
Cueva del Medio	Magallanes	10,450±100; 10,710±190; 10,850±130	Nami and Nakamura 1995	12
Tres Arroyos 1	Tierra del Fuego	10,630±90	Massone and Prieto 2004	13

mainly French and English exploring voyages (1587-1670), always south of 44º south latitude, and limited to few natural ports. The vast interior of Patagonia started to be traversed by naturalists and scientists only in the second half of the 18th century (1861-1900).

However, the major strength of the historical records in this study is the precise sighting locations, and the identification of the vicuña and the guanaco, being the latter the only extant camelid in Patagonia. Furthermore, the observations were made in a territory with low human population density, and prior to the impact of human activities. The reporting of the vicuña would be expected to increase in more recent periods as more voyages took place. This was not the case, and the most plausible explanation is that the vicuña was extirpated from Patagonia before the inland explorations took place. The lack of information on non-detection locations does not allow an analysis of the distribution, extinction, and persistence of vicuña in Patagonia. Yet, the historical evidence still contributes to the knowledge of its distribution.

Further research in the archaeological domain may someday shed light on the above issue. If the remains previously classified as *L. gracilis* correspond to *V. vicugna*, then the vicuña had a wider geographical distribution during the Pleistocene and early Holocene, and used not only the high plains but also the non-Andean region. Menegaz et al. (1989) suggested that the adaptation of *L. gracilis* is not related to high altitude conditions, but to the distribution of Microthermic grass groups, which in southern Patagonia, with lower temperatures, form grasslands down to sea level (Burkart 1975). It is highly probable that some drier inland areas of Patagonia were insufficient to satisfy the needs of the vicuña, whereas the grasses of more

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humid areas in some locations, and nearer the coast, such as southern Patagonia, were suitable habitats.

It has been proved that precipitation is associated to both individual and population performance of some herbivores in arid and semiarid environments (i.e. mule-deer (Bender et al. 2010), pronghorn (Simpson et al. 2007)). Some research has shown that precipitation patterns also seem to be important variables driving the population dynamics of vicuña. An analysis of a 31-year census data from northern Chile proved that vicuñas were following exponential (Cattan and Glade 1989) or simple logistic (Bonacic et al. 2002) growth. A further study by Shaw et al. (2012) allowed the carrying capacity to fluctuate as a function of rainfall, thereby accounting for the links between rainfall, primary productivity, and vicuña carrying capacity. Thus, precipitation might affect the vicuña through resource acquisition, which is ultimately manifested in individual body condition. This might have been the scenario in the Patagonia steppe where a manipulative experiment that resembled dry and wet years showed important lagged effects of precipitation with higher production after consecutive wet years than in a wet year that followed a dry year (Yahdjian and Sala 2006).

Extreme climatic events may also influence population dynamics of vicuñas. In 1978-79, the vicuña population of Pampa Galeras (Peru) suffered a decline of 13.9% after a prolonged drought (Menard 1984), the pregnancy rates decreased from 85% to 58%, and recruitment dropped from 76% to 27% (Otte and Hofmann 1981, in Wheeler 1995). At the San Guillermo Biosphere Reserve, Argentina, severe winter storms in 1984 caused a higher mortality of vicuñas (4.5%) than guanacos (1.0%). In addition, at Hacienda Calacala, Peru, young vicuñas, as well as lambs, are sometimes found dead after snow storms (Koford 1957). Cajal and Ojeda (1994) reported that the causes of mortality in camelids have been studied, but not the unpredictable climatic events which may increase mortality in the vicuña. Prolonged drought conditions might have even exterminated the species in certain areas. Interestingly, Gil et al. (2011) highlighted the association between increasing aridity in layer 2c of Agua de la Cueva, Mendoza (9,000-7,500 BP), and the absence of *Vicugna* sp. We may question why the species persisted in the Tropical Andes and northwestern Argentina where an aridization episode is traceable during the Mid-Holocene according to the review of Tchilinguirian and Morales (2013). These authors claim that several localities seem to have retained wetter conditions. Although much debate still remains on the paleoenvironment of this region, it is presumable to think that certain areas might have functioned as ecological refuges for the vicuña.

CONCLUSION

Historical records confirm the occurrence of the vicuña in certain coastal locations of Santa Cruz province, Argentina, and in the northern and western coast of the Strait of Magellan, Chile. In the latter region it persisted as late as the second half of the mid-19th century. The similar ecological conditions between the identification areas and the arid Tropical Puna lead us to speculate that this region might have served as a refuge for the species. The paleontological evidence of the vicuña is poor and restricted to the areas of its modern distribution. If further research confirms that *Vicugna gracilis* is the actual vicuña, then its distribution has been notably more extensive in South America. Although the former distribution of the vicuña cannot be fully restored in Patagonia, the available historical evidence challenges the current views on its strict orophylic character in historical times, and contributes to the knowledge of the species distribution.

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