



# El Niño Southern Oscillation drives conflict between wild carnivores and livestock farmers in a semiarid area in Chile



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## ABSTRACT

The warm phase of El Niño-Southern Oscillation (ENSO) events results in greatly elevated rainfall in north-central Chile, with dramatic effects on small mammals and vertebrate carnivore abundances. In ensuing cool phases of ENSO, plant cover decreases, followed by small mammal densities, in turn affecting the resource availability for their predators. Wild carnivores such as foxes are one of the main predators of small mammals; when the latter decline, foxes could exhibit functional responses, increasing their consumption of domestic livestock. To our knowledge, the influence of native prey abundance on livestock predation has not been assessed. We hypothesize that periods of scarce native prey increases conflicts between carnivores and farmers outside protected areas, especially during drought years. From 1990 to 2005 we used live trapping to determine monthly density of small mammals in a national park (Bosque Fray Jorge National Park, BFJNP) in north-central Chile; rainfall was also monitored. We calculated an index of predation as the number of sheep predated by foxes annually on one farm (encompassing ca. 45,000 ha) located in the vicinity of BFJNP. Path analysis was carried out to assess factors influencing sheep predation by wild foxes. Factors included precipitation and small mammal density. Small mammal density correlated positively with two years moving average of rainfall. Sheep predation by foxes increased after of two years of low rainfall. Our findings suggest that wild carnivores employ functional responses in response to varying prey availability, shifting from wild to domestic prey during periods of drought, which could have important conservation and management implications.

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## 1. Introduction

Carnivores can respond both functionally and numerically to fluctuations in the prey base (Carbone and Gittleman, 2002). The capacity for wild carnivores to adapt to anthropogenic landscapes depends on behavioural plasticity of each species within the modified environment (Cardillo et al., 2004). In such conditions, carnivores may shift from natural to domestic prey (Stoddart et al., 2001). In this scenario, predation upon livestock by carnivores should be perceived as a functional response to the reduction in

natural prey, which otherwise may act as a buffer against livestock predation by carnivores; however, in spite of the fact that predation upon livestock has been reported for a number of carnivore species worldwide (Butler, 2000; Holmern et al., 2007; Kolowski and Holekamp, 2006; Ogada et al., 2003; Patterson et al., 2004; Woodroffe et al., 2005), very few empirical studies have analysed this hypothesis (eg. Sacks and Neale, 2007; Stoddart et al., 2001).

In semiarid ecosystems, the density of the most common prey for carnivores (small mammals) usually is driven by factors such as precipitation (Previtali et al., 2009), which impact resource availability for prey populations. Some authors have indicated that extreme variation in weather patterns may induce a reduction in wild prey, resulting in variation in predation success and inducing a shift from wild to domestic prey (Butler, 2000; Kolowski and Holekamp,

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2006; Patterson et al., 2004; Woodroffe and Frank, 2005). At least some studies have documented that wild carnivores are more likely to attack livestock during the dry season or during years of drought (Butler, 2000; Patterson et al., 2004; Sacks and Neale, 2007).

The north-central region of Chile is semiarid and highly dependent on rainfall. In this area, large rainfall events that occur during the warm phase of the El Niño Southern Oscillation (ENSO) result in increased primary productivity, especially by ephemerals (Gutiérrez et al., 2000; Meserve et al., 2003). Following this vegetative response, small mammal numbers increase in response to the abundance of food resources (Meserve et al., 2003), and predators subsequently increase as well (Farías and Jaksic, 2007; Previtali et al., 2009).

North-central Chile supports a number of terrestrial predators, including one skunk (the chingue, *Conepatus chinga*), a mustelid (the quique, *Galictis cuja*), two wild felids (the colocolo, *Leopardus colocolo*, and the puma, *Puma concolor*), and two wild canids (the culpeo, *Lycalopex culpaeus*, and chilla, *L. griseus*). Most of these species are rare or at best uncommon and very localized; the two foxes are locally or regionally common. The culpeo is the larger of these and weighs between 4 and 14 kg while the chilla fox weighs between 2 and 5 kg (Jiménez and Novaro, 2004). These foxes are opportunistic predators that hunt prey according to their availability in the environment, consuming mainly small mammals (Johnson and Franklin, 1994) and occasionally livestock species in areas near human settlements (González del Solar and Rau, 2004; Pía et al., 2003). Likely reflecting size-dependent hunting abilities, chillas mainly forage on poultry, while culpeos can hunt on larger animals such as lambs and goats (González del Solar and Rau, 2004; Jiménez and Novaro, 2004).

Across four regions of Chile farmers reported that they lost about 10% of their sheep and lambs to predation by wild carnivores (mainly puma and culpeo fox) (Acosta-Jamett et al., 2014). Understanding whether this conflict is increased during different seasons or years, such as during droughts, would be useful to promote measures to avoid the attack of wild carnivores on livestock and thus help farmers to reduce their economic losses. We posit that wild carnivores living in an anthropogenic landscape may be more affected by climate-related nutritional restrictions than animals living in more natural areas, and may be more likely to attack livestock (Pía et al., 2003).

If the above proposition is true then human-wildlife conflict, in the form of predation on livestock, is expected to vary temporally in semiarid regions of north-central Chile, in turn reflecting on the dependence of wildlife in this region on precipitation driven by the ENSO phenomenon. We predict that during periods of prolonged droughts, when small mammal abundance is extremely low, foxes would search for alternative prey, such as exotic mammals (e.g., rabbits, rats), refuse, and livestock. In contrast, in wetter years, predation pressure on livestock would be attenuated as foxes resume foraging on native prey. Given this background, we tested for a link between rainfall and/or prey on reports of livestock predation in a semiarid environment in the Coquimbo Region of Chile. We focus our attention on culpeo foxes as they are one of the most important predators on goats and sheep in Chile (Acosta-Jamett et al., 2014), and they are widespread throughout this region.

## 2. Methods

### 2.1. Study area

The study area is the Coquimbo Region in north-central Chile (71° 12' to 71° 40' W, 29° 58' to 30° 39' S), comprising about 1600 km<sup>2</sup> and including Bosque Fray Jorge National Park (BFJNP) with a surface of 9959 ha and the “El Tangué” ranch, a private land

of nearly 45,000 ha situated 25 km north of the park (Fig. 1). Historically, the vegetation of much of the region was a thorn shrub community characterized by spiny drought-deciduous and evergreen shrubs, with a herbaceous understory (Gajardo, 1994); however, except for within BFJNP, most of this has been replaced by badly overgrazed shrubland and plantations of exotic *Atriplex* spp. planted to ameliorate erosion and restore shrub cover.

The climate is arid mediterranean, with a mean annual precipitation of 122.6 ± 91.8 mm (±1SE) in BFJNP, 90% concentrated in the winter months (May–September). Precipitation patterns in the area show a periodicity of approximately 3–4 years which is thought to be associated with the ENSO phenomenon (Dillon and Rundel, 1990).

### 2.2. Data collection

#### 2.2.1. Precipitation.

Rainfall data for the period 1990–2005 was obtained from a meteorological station existing at FJNP and managed by the University of La Serena (e.g. Gutiérrez et al., 2010). Monthly data was only recorded from 1999 onward, therefore we used these data to calculate annual rainfall. Previous studies have reported small mammals density increasing during and after years of high rainfall (Meserve et al., 2003), therefore we calculated a two-year moving average of rainfall for assessing its effect on small mammal density and sheep predation.

#### 2.2.2. Small mammal density

Small mammals were monitored monthly from 1990 until 2005 in the park, using four 5 × 5 trapping grids with 15 m intervals (hence, 0.56 ha) and two live traps/station (For further details see Meserve et al., 1996, 2003; 1999). Small mammals were surveyed for four days and nights per month on each grid, and all captured animals were marked with ear tags or leg bands with a unique numbered and released at the point of capture. The average minimum number known alive (MNKA) of small mammals per year was calculated by adding the MNKAs calculated for each sampling period (all species combined) in a year and dividing the result by 12. MNKA was justified in this system as mean monthly trappability for most species exceeds 90%.

#### 2.2.3. Predation on livestock

We obtained data on the numbers of sheep raised annually and the numbers of animals reported to be killed by carnivores in the El Tangué ranch (Fig. 1). These data spanned the period 1990–2005. The causes of loss were assigned to either predation by “dogs”, “fox” or “puma” when signs of predation of these carnivores were found. In such cases, the species of predator was identified via analysis of footprints around the kill (see Acosta and Simonetti, 1999) and the wounds on the carcass.

Because Chile has no program for financial compensation to farmers losing livestock to wild carnivores there was no apparent incentive for exaggerating or fabricating claims; the only purpose of the records on causes of mortality was to register the disappearance/death of sheep and thus reduce the animal losses from the ranch inventory. We calculated a livestock predation index (LPI) using the data on sheep reported to be killed by wild carnivores using the formula:

$$LPI = \frac{a}{(b + c)/2} \times 100$$

where, *a* is the number of sheep killed by foxes each year, *b* is the number of sheep at the beginning of the year and *c* the number of sheep at the end of the year.

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