

Environmentalities of coexistence with wolves in the Cantabrian Mountains of Spain

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Supplementary material

Supplementary materials 1 - Details on study sites and their wolf management systems

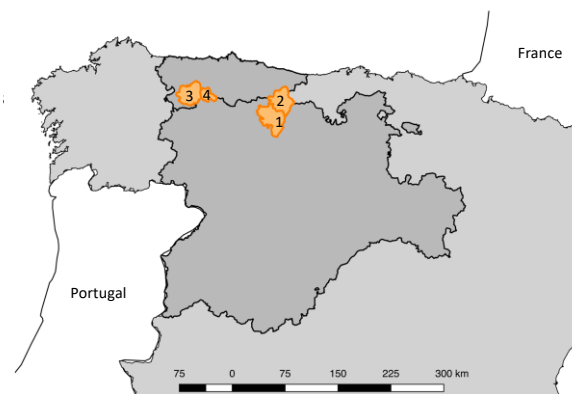


Figure 1 Map of the study sites.

1. Private Hunting Grounds (PHGs) of León, Castilla y León; 2. Regional Hunting Reserve (RHR) of Riaño, Castilla y León; 3. Cangas del Narcea, Asturias; 4. Somiedo, Asturias.

Management strategies	PHGs of León	RHR of Riaño	Cangas del Narcea	Somiedo
Hunting system	private	regional administration	in-between	regional administration
Ranger presence	low	medium/high	medium/high	high
Damage compensation system	private insurance	regional administration	regional administration	regional administration
Wolf protection status	game species	game species	special regime, culling by rangers	special regime, culling by rangers
Wolves hunted or culled /year	2.5*	12.5*	0**	0.33**
Stakeholder participation		None	Committee with stakeholder representatives	

Table 1- Summary of wolf management in each study site at the time in which field work took place (2015-2017).

**Average number of wolves hunted/ year, calculated using data from the hunting seasons 2014-2015 and 2015-2016 (provided by the Provincial Administration of León)*

***Average number of wolves hunted/ year, calculated using data from the years 2014-2016 (provided by the Regional Government of Asturias)*

Private Hunting Grounds (PHGs) of León, Castilla y León

In the PHGs of León, most land is public and hunting rights belong to the Neighbourhood Associations, who either lease them to local hunters or auction them out to private holders. Hunting represents a significant source of revenue for the Neighbourhood Associations, who normally invest it in public works and habitat/hunting management. At the time of the study, wolves were listed as a game species in the regional hunting law, and the private hunting grounds that included the wolf in their hunting plan automatically held a wolf hunting permit, which they could use until quotas for the year were reached. Compensation for wolf damages largely functions through private and voluntary insurance, and even though regional funds are theoretically available to compensate part of the damage incurred by insured farmers, in reality few farmers in the PHGs of León claim the regional compensation (Marino et al., 2018). The Wolf Working Group that was instituted after our fieldwork shows elements of corporativism as the elected members are nominated by the main stakeholder associations.

Wolf hunting permits can be bought and sold just like any other hunting permit. Hunting Plans are subject to regulations and approval from the Regional Administration, but their management is devolved to the license holders. Private rangers are hired by the license holders whilst the presence of rangers employed by the Regional Administration is limited. However, wolf hunting quotas were still decided by the regional government, which was required to comply with national and supra-national regulations.

Regional Hunting Reserve (RHR) of Riaño, Castilla y León

The RHR of Riaño is subject to the same Hunting Law and Wolf Management plan as the PHGs of León, but the Regional Administration is much more closely involved in hunting management. Although hunting revenue still reverts back to the reserve, and represents an important source of income, most of it is managed by the Regional

Administration. Wolf permits were sometimes auctioned but usually wolves were hunted by wild boar hunters who did not pay specifically to hunt wolves unless they wished to keep the trophy. In addition, the Regional Administration fully compensates wolf damages. Finally, an eco-tourism company based in the site attracts national and foreign tourists, many of whom travel there specifically to see wolves.

Cangas del Narcea, Asturias

In Asturias, wolves are not a game species, but their population at the time in which the research took place was controlled by rangers, and their damages are still compensated by the Regional Administration. Quotas for population control were set at the regional level and presented to the Wolf Consultation Committee, which includes members of the regional administration, representatives of municipalities and interest groups (livestock associations, tourism companies etc.). Part of Cangas falls within a protected area that is being contested by private landowners. Due to these legal challenges, several policies of the protected area were not effectively in place at the time in which the study took place. Land tenure is mostly private, but parts of the municipality are public and others owned at the neighbourhood level.

Somiedo, Asturias

Somiedo Natural Park is subject to the same Hunting Law and Wolf Management Plan as Cangas, and therefore wolf management does not vary. The main difference from Cangas is marked by the fact that the whole municipality of Somiedo falls within a long-established protected area, which has based much of its development prospects on the protection of natural and cultural heritage, through promotion of traditional livestock breeding and tourism. Additional subsidies are handed out to farmers who carry out their activities in the protected area, and the park is a known destination for bear sightings. The majority of land is public, and the park is patrolled by several rangers who also accompany hunting parties of wild boar and other ungulates (as they do inside the protected area of Cangas).

Supplementary materials 2 - Sampling of farmers and wolf depredations on livestock

Methods to sample farmers

We designed a geographically stratified sample of farmers using the online Common Agricultural Policy (CAP) registry of 2015, which includes the names and municipality of residence of the farmers that received subsidies (above €1,500) that year. In the larger municipalities, mayors or other key informants provided information on where farmers resided across the various villages, in order to sample them accordingly. In the case of Asturias, this information was provided by the Regional Administration. Therefore, sampling was stratified at the village level, and a random sample of farmers was selected from each village (Table 1). When farmers present in the registry actually turned out to be retired or, in the case of PHGs of León, when they did not own livestock because they were involved in other agricultural activities, they were excluded from the sample. We aimed to interview at least 30 hunters and 70 farmers in each site, but in the case of the RHR of Riaño we came farther from achieving this target (n=59 farmers) due to the low number of active farmers present. Although it was difficult to quantify drop-out rates, the large majority of farmers we approached accepted to participate in the interviews.

The sample of livestock owners consists mainly of males (Table 1). When it was clear that both males and females of the household participated in livestock activities, we proceeded by proposing to carry out the interview with the women, but they would often delegate their husbands or sons to speak. This is likely traceable to gender norms and a gendered division of labour resulting in some males having more experience in the livestock-wildlife interface, either because they were more often responsible for outdoor activities or because legal ownership of livestock made males the default point of reference for official tasks. The situation was somewhat different in Cangas (Table 1), where livestock was more often owned by female heads of households whose husbands received early retirement mining pensions and could not officially earn other income.

	PHGs of León	RHR of Riaño	Cangas	Somiedo
Interviewed farmers	n=69	n=59	n=76	n=67
% male interviewed farmers	85%	82%	64%	84%
n farmers in CAP registry	n=310 /km ² =0.29	n=149 /km ² =0.18	n=882 /km ² =1.07	n=166 /km ² =0.57
% of interviewed farmers from CAP registry	22%	40%	9%	40%

Table 1. Details on the livestock farmer sample

Methods to estimate depredations

To understand the context and drivers of resource users' attitudes towards wolves, we measured the level of damages experienced by each interviewed livestock owner. We did this to obtain an estimate of damages that would be comparable across study sites, given that the different damage compensation systems present in each site are likely to have promoted different incentives to officially declare damages. Particularly in the PHGs of León, where damage compensation is conditional on private insurance, previous research using the same data has shown that official damage claims are well below actual depredation levels (Marino et al., 2018).

The following data represents only self-reported damages, which have not necessarily been verified by veterinarians or rangers. Although we accept that these may not always be accurate, they represent the best comparable set of data available, as there is no reason to believe that accuracy should vary across study area. We use two measures to summarize damages in this analysis. The first is whether farmers claimed to have suffered damages in the current or in the two full years previous to the interview (represented by a yes or no answer). The second is an estimate of the number of livestock heads farmers claim to have lost to wolves in the year 2015. This was the year immediately prior to the fieldwork, which most farmers could easily refer back to. This estimate only includes livestock that farmers claimed to have found dead or injured, and therefore leaves out missing livestock, which farmers could often not attribute to wolf depredations with certainty. Data on the number of depredated livestock heads in 2015 was available from all but 16 farmers, whose memory or accounts of depredations were too confused to calculate an estimate.

To gauge the respective influence of wolf damages and study site on respondent's attitudes and beliefs toward wolves, linear regression analyses were carried out, using a set of 5 key attitude and belief items as response variables, and damages and study area as predictors (Table 2). The impact of damages on the key set of selected variables was furthermore explored in each site independently (Table 3).

Results of depredation data

Wolf depredations varied considerably across the study sites. Out of the interviewed farmers, 38% suffered damages in the PHGs of León; 66% did in the RHR of Riaño, 51% did in Cangas, and 71% did in Somiedo (Table 3). On average, in 2015 livestock owners lost between 0.31 and 1.89 livestock heads, and between 0.13 and 1.53 meat cattle heads, in each site (Fig. 1 and 2). Damages per livestock holder were highest in Somiedo, followed by the RHR of Riaño, the PHGs of León, and Cangas.

Results show that damages were significant predictors of certain attitudes and beliefs about wolves, but did not explain the totality of variation occurring across the study sites (Table 2). Both the study area and the experience of wolf damages were significant predictors of farmers' beliefs regarding whether there are too many wolves in the area, whether wolves are compatible with livestock breeding, and whether they cause a lot of damage to livestock. Only the study area was a significant predictor of whether wolves enriched farmers' experience of nature, whilst neither the study area nor damages were significant predictors regarding whether farmers thought that it is important to conserve wolves. This means that even when the level of damages is accounted for, there are still several significant differences in attitudes and beliefs across the study sites.

Moreover, the experience of damage did not influence farmers' attitudes and beliefs about wolves in the same way across all study sites (Table 3). Whilst the experience of damage did influence farmers' beliefs regarding whether there are too many wolves in the area, whether wolves are compatible with livestock breeding, and whether they cause a lot of damages to livestock in both the PHGs of León and in Somiedo, opinions in the RHR of Riaño and Cangas appear to be less dependent on whether farmers had experienced damages or not. Out of the set of 5 key variables that were selected for this analysis, only the belief regarding whether there are too many wolves in area was influenced by the experience of damages in the RHR of Riaño, and only respondent's feeling as to whether

wolves enrich their experience of nature was influenced by the experience of damages in Cangas. This provides further evidence that the experience of damages alone does not explain the variation of attitudes and beliefs across the four study sites. Together, these results suggests that other contextual factors are at play in influencing local experiences of coexistence.

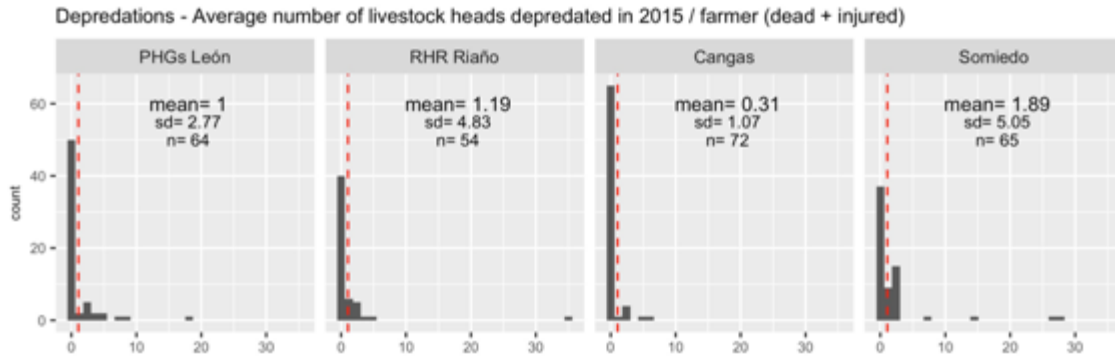


Figure 1 Average number of livestock heads depredated by wolves in 2015 per farmer, in each site. Representing only cattle, sheep, goats and horses that were claimed to have been found dead or injured (not missing).

A significant difference was detected between the sites (Kruskal-Wallis chi-squared = 18.63, $df = 3$, p -value = 0.0003). Pairwise comparisons using Wilcoxon rank sum test showed there was a significant difference between: the PHGs of León and Cangas (p -value= 0.048); the PHGs of León and Somiedo (p -value= 0.029); the RHR of Riaño and Cangas (p -value = 0.021); and Cangas and Somiedo (p -value= 1.9e-05).

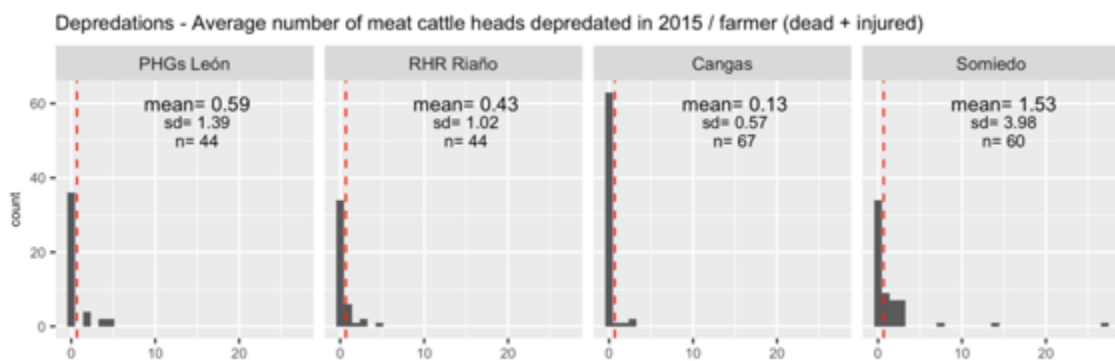


Figure 2 Average number of meat cattle heads depredated by wolves in 2015 per farmer, in each site, representing only cattle that was claimed to have been found dead or injured (not missing). A significant difference was detected between the sites (Kruskal-Wallis chi-squared = 24.833, $df = 3$, p -value = 1.673e-05). Pairwise comparisons using Wilcoxon rank sum test showed there was a significant difference between: the PHGs of León and Cangas (p -value= 0.038); the PHGs of León and Somiedo (p -value= 0.020); the RHR of Riaño and Cangas (p -value= 0.012); the RHR of Riaño and Somiedo (p -value= 0.020); Cangas and Somiedo (p -value= 1.3e-06).

Key variables (y):	study area (anova p-value)	damages (anova p-value)	lm (y ~ study area + has had damages)
It is important to conserve wolves in my area	0.156	0.118	Res. SE: 0.9508; R2: 0.029, F-stat: 1.93, 260 DF, p-value: 0.1057
Wolves enrich my experience of nature	1.35E-05***	0.052	Res. SE: 0.8846; R2: 0.104; F-stat: 7.58, 261 DF, p-value: 8.66e-06***
There are too many wolves in my area	1.85E-06***	1.7E-04***	Res. SE: 0.6947; R2: 0.149; F-stat: 11.40, 261 DF, p-value: 1.53e-08***
Wolves are compatible with the livestock breeding world	3.28E-06***	0.003**	Res. SE: 0.7925; R2: 0.129; F-stat: 9.68, 261 DF, p-value: 2.57e-07***
Wolves cause a lot of damages to livestock	6.03E-08***	2.94E-06***	Res. SE: 0.7349; R2: 0.192; F-stat: 15.47, 261 DF, p-value: 2.28e-11***

Table 2 Summary results of linear regressions carried out to test the significance of a) study area and b) damages, on a selection of key variables measuring attitudes and beliefs about wolves.

The key variables are measured on a Likert scale (1=disagree; 2=neutral; 3=agree). The study area variable includes the four study sites. The damages variable measures whether or not respondents claimed to have suffered livestock depredations from wolves in the current and two full years previous to the interview. A measure of the number of depredated livestock per farmer, in 2015, was initially included as a predictor but later dropped as it was not found to be significant in any of the models.

	All damages (yes= 56%)	n preyed livestock (2015)	PHGSs of León damages (yes= 38%)	n preyed livestock (2015)	RHR of Riaño damages (yes= 66%)	n preyed livestock (2015)	Cangas damages (yes= 51%)	n preyed livestock (2015)	Somiedo damages (yes= 71%)	n preyed livestock (2015)
It is important to conserve wolves in my area	0.183	0.448	0.908	0.390	0.506	0.373	0.079	0.620	0.037	0.125
Wolves enrich my experience of nature	(-0.32) 0.005	(-0.03) 0.023	0.578	0.147	0.976	0.276	(-0.64) 0.002	0.453	0.150	0.163
There are too many wolves in my area	(0.43) 2.58E-06	(0.03) 0.022	(0.55) 0.011	(0.10) 0.012	(0.22) 0.0415	0.634	0.444	0.214	(0.46) 9.9E-03	0.283
Wolves are compatible with the livestock breeding world	(-0.38) 2.17E-04	(-0.03) 0.029	0.126	(-0.10) 0.020	0.196	0.380	0.381	0.260	(-0.44) 0.018	0.387
Wolves cause a lot of damages to livestock	(0.54) 4.04E-08	0.126	(0.61) 0.009	0.322	0.058	0.598	0.135	0.295	(0.623) 5.0E-04	0.246

Table 3 Summary of p-values and effect sizes resulting from ANOVAs carried out separately, to test the influence of a) whether respondents experienced damages and b) how many livestock they lost to wolf depredations in 2015, on a selection of key variables measuring attitudes and beliefs towards wolves

The key variables are measured on a Likert scale (1=disagree; 2=neutral; 3=agree). The damages variable measures whether or not respondents claimed to have suffered livestock depredations from wolves in the current and two full years since the interview. The table represents p-values. Significant values are signalled in bold and their effect sizes are included in parentheses.

Supplementary materials 3 - Farmer's attitudes towards wolves (details on statistical test results)

		Kruskal-Wallis test (df=3)		Pairwise Wilcoxon test (p-values)					
		Chi-square	p-values	PHGs León: RHR Riaño	PHGs León: Cangas	PHGs León: Somiedo	RHR Riaño: Cangas	RHR Riaño: Somiedo	Cangas: Somiedo
a	It is important to conserve wolves in my area	5.618	0.132						
b	Wolves enrich my experience of nature	23.710	2.871e-05	0.009	0.0002	9.20E-06	0.299	0.097	0.551
c	Wolves belong to the nature of this area	4.048	0.256						
d	Wolves contribute to maintain nature's equilibrium	5.417	0.144						
e	Wolves are compatible with the livestock breeding world	25.900	1.001e-05	0.011	2.60E-05	2.30E-05	0.188	0.127	0.757
f	Wolves could be compatible with the livestock breeding world	26.977	5.953e-06	0.170	3.70E-07	0.0009	0.018	0.277	0.072
g	Wolves are a significant threat to hunting opportunities	6.593	0.086						
h	Wolves incentivize tourism	54.623	8.265e-12	2.80E-09	0.44	0.370	1.70E-07	4.20E-07	0.89
i	Wolves should be used more to incentivize tourism	13.108	0.004	0.556	0.007	0.082	0.002	0.026	0.307
j	The wolf population has increased over the past 10 years	33.938	2.042e-07	5.10E-07	0.003	0.0002	0.002	0.0112	0.389
k	There are too many wolves in my area	29.545	1.72e-06	6.20E-07	0.006	0.0005	0.008	0.059	0.401
l	The wolf population will keep increasing if it is not kept under control	7.262	0.064						
m	My tolerance would increase with greater wolf control	67.427	1.517e-14	1.30E-09	1.80E-08	6.10E-12	0.555	0.255	0.087
n	My tolerance would increase with an improved compensation system	8.265	0.041	0.716	0.164	0.027	0.088	0.013	0.372

Table 1. Details on the statistical tests represented in fig. 2 of the manuscript.

Supplementary materials 4 - Hunters' attitudes towards wolves



Figure 1 Descriptive plots of the items measuring hunters' attitudes towards wolves on a 3-point Likert scale.

Significance stars ($*$ = $p<0.05$; $**$ = $p<0.01$; $***$ = $p<0.001$) are added: a) to the title of each plot to represent significant p values of Kruskal-Wallis tests, carried out to detect differences between study sites; and b) on top of each figure to represent significant p values of additional Wilcoxon post hoc tests, with Bonferroni adjustments, to identify which study site differ from each other. These results should be interpreted with caution because they were collected through snowball sampling. $N=44$ in PHGs of León; 41 in RHR of Riaño; 38 in Cangas; 34 in Somiedo.

		Kruskal-Wallis test (df=3)		Pairwise Wilcoxon test (p-values)					
		Chi-square	p-values	PHGs León: RHR Riaño	PHGs León: Cangas	PHGs León: Somiedo	RHR Riaño: Cangas	RHR Riaño: Somiedo	Cangas: Somiedo
<i>a</i>	It is important to conserve wolves in my area	3.430	0.330						
<i>b</i>	Wolves enrich my experience of nature	3.150	0.369						
<i>c</i>	Wolves belong to the nature of this area	7.352	0.062						
<i>d</i>	Wolves contribute to maintain nature's equilibrium	4.802	0.190						
<i>e</i>	Wolves are compatible with the livestock breeding world	23.280	3.531e-05	0.233	8.50E-05	0.0001	0.008	0.011	0.906
<i>f</i>	Wolves could be compatible with the livestock breeding world	2.855	0.415						
<i>g</i>	Wolves are a significant threat to hunting opportunities	3.732	0.292						
<i>h</i>	Wolves incentivize tourism	51.747	3.391e-11	1.40E-09	0.910	0.310	3.80E-08	4.40E-06	0.410
<i>i</i>	Wolves should be used more to incentivize tourism	5.670	0.129						
<i>j</i>	The wolf population has increased over the past 10 years	7.923	0.048	0.008	0.736	0.173	0.016	0.123	0.296
<i>k</i>	There are too many wolves in my area	15.045	0.002	0.0007	0.018	0.0176	0.356	0.317	0.965
<i>l</i>	The wolf population will keep increasing if it is not kept under control	3.484	0.323						
<i>m</i>	My tolerance would increase with greater wolf control	37.360	3.861e-08	1.40E-06	3.50E-05	1.90E-06	0.470	0.830	0.360
<i>n</i>	My tolerance would increase with an improved compensation system	9.287	0.026	0.541	0.127	0.003	0.359	0.021	0.183

Table 1. Details on the statistical tests represented in fig. 1 of this appendix.

Supplementary materials 5 - Damage prevention measures

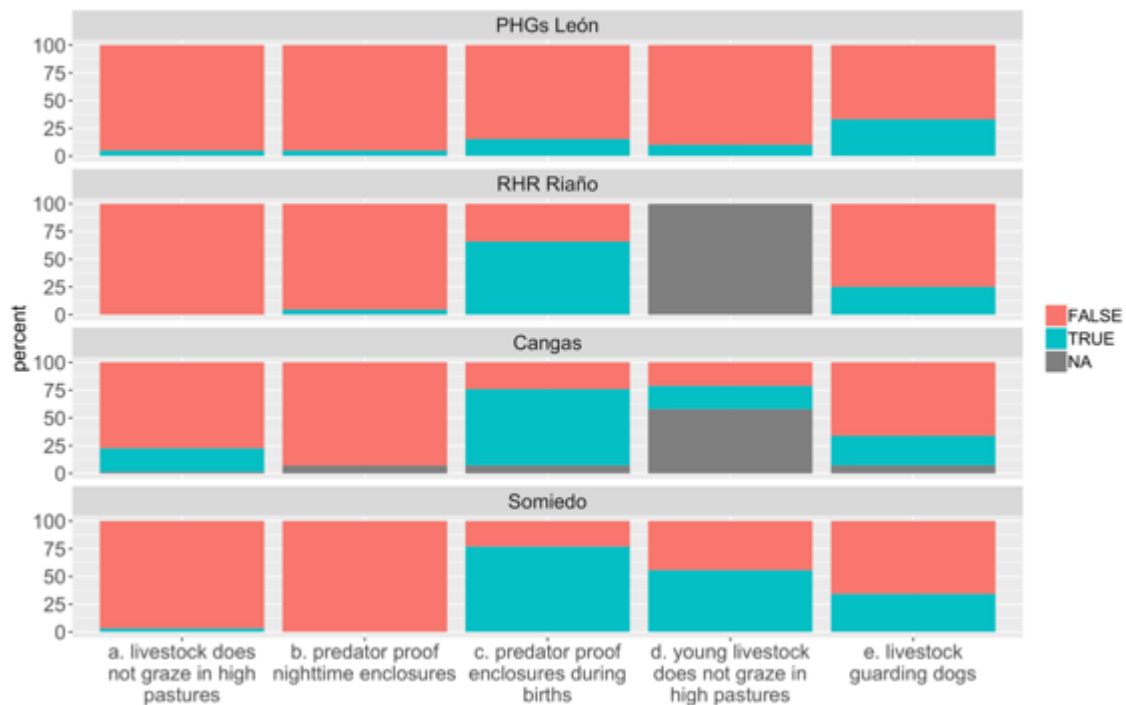


Figure 1 Measures employed to protect meat cattle from carnivore damages

a) Cattle is not grazed in higher pastures but instead is kept in in-by land, where it is theoretically safer; b) Cattle are kept in predator-proof night-time enclosures year-round; c) Cattle are kept in predator-proof enclosures when giving birth (as a general rule but exceptions allowed); d) Young cattle do not graze in high pastures (but what constitutes as “young” was determined by the livestock farmers themselves; this variable contains several missing values because it was added after the survey had begun); e) The farmer owns livestock guarding dogs.

N= 41 in PHGs of León; 46 in RHR of Riaño; 71 in Cangas; 61 in Somiedo.

Supplementary materials 6 - Perceptions on the illegal killing of wolves

Informants were asked about their perceptions of illegal killing of wolves always in hypothetical terms and never by asking about personal or other people's involvement in the practice. The majority of farmers in the PHGs of León claimed wolves are poached (61%) and that illegal killing is acceptable when there are a lot of damages (79%), while only a small fraction claimed that it is never acceptable to kill wolves illegally (21%). In comparison, the portion of respondents that claimed that wolves are killed illegally in the RHR of Riaño, Cangas and Somiedo was considerably lower (17%, 13% and 6%; Wilcoxon p-values for the PHGs of León: the RHR of Riaño = $1.74\text{E-}05$; the PHGs of León: Cangas = $1.26\text{E-}07$; and the PHGs of León: Somiedo = $5.97\text{E-}10$), and respondents in these sites were more or less split between those that claimed it is acceptable to kill wolves illegally when there are many damages (54% in the RHR of Riaño; 39% in Cangas and 58% in Somiedo), and those that claimed it is never acceptable (52% in the RHR of Riaño; 60% in Cangas and 44% in Somiedo).