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## Land of wolves, school of shepherds: the importance of pastoral knowledge on co-existence with large carnivores

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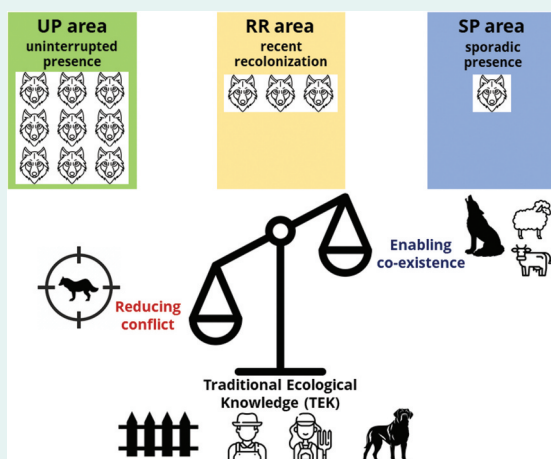
### ABSTRACT

The wolf (*Canis lupus*) is recovering and recolonizing its historic range in Europe. In places where wolves have long been absent, their recent recolonization could potentially provoke extensive livestock farmers' opposition. To understand the conditions for extensive grazing-wolf co-existence, we conducted interviews with livestock farmers and shepherds to compare three Spanish regions in different wolf presence states: uninterrupted wolf presence, recent wolf recolonization and sporadic wolf presence. Our results show the importance of Traditional Ecological Knowledge (TEK) for reducing conflict and enabling co-existence. In areas where wolves were extinct and have been recently recolonized, loss of TEK has led to less of both tolerance to wolves and awareness of the benefits they provide. Conversely, in areas where wolf presence has been uninterrupted, maintaining the TEK associated with livestock management, such as use of mastiff dogs and shepherd's role, has favored the co-existence of extensive grazing systems with wolves. Our findings have important implications for the EU Common Agricultural Policy by highlighting the urgent need to integrate the close link between TEK and the co-existence of extensive grazing systems with large carnivores. Furthermore, the EU Nature Restoration Law could reinforce these same approaches.

### KEY POLICY HIGHLIGHTS

- Policies emphasizing the preservation and revitalization of Traditional Ecological Knowledge (TEK) might be essential to promote co-existence between wolves and livestock, as TEK effectively reduces conflicts.
- In areas with recent wolf recolonization, initiatives to reintroduce TEK are vital for reducing conflicts and fostering harmonious relationships between wolves and extensive grazing systems.
- Incorporating TEK in the EU Common Agricultural Policy and the EU Nature Restoration Law can support sustainable livestock farming practices and promote co-existence with large carnivores across Europe.

### GRAPHICAL ABSTRACT



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## 1. Introduction

Wolf populations are recolonizing part of their former territories in Europe (Chapron et al. 2014; Boitani and Linnell 2015). Although this return can be seen in a positive light (Breyne et al. 2021), wolf presence in places where they were extinct often provokes strong social rejection. This rejection has multiple dimensions (Linnell and Cretois 2018), which emphasizes the need to address the full conflict spectrum rather than solely focusing on material or economic issues (Madden and McQuinn 2014). Studies often focus on quantifying control measures' risks and effectiveness, but the negative impacts of predators are culturally and emotionally influenced by co-existing communities (Talbert et al. 2020). All this highlights the importance of understanding the social dimensions of wolf-human co-existence.

Human-large carnivore co-existence in European human-dominated landscapes depends more on factors like human tolerance and policy than on habitat availability (Cimatti et al. 2021). Tolerance widely varies among countries, regions and individuals (Gangaas et al. 2013; Dressel et al. 2015), which emphasizes the need to understand why some areas more easily accept large carnivores than others. Notably, areas with a long history of large carnivore-human interactions tend to exhibit more tolerance (Campbell and Lancaster 2010), while regions where large carnivores have recently returned often voice negative attitudes (Houston et al. 2010). In the Iberian Peninsula, extended co-existence with wolves suggests widespread acceptance (Espírito-Santo and Petrucci-Fonseca 2017; Pettersson et al. 2021, 2022). Additionally, areas where large carnivores are continuously present have lower depredation levels than those where they have recently recolonized in the last 50 years after extinction (Gervasi et al. 2021).

In Spain, the territory of the Iberian wolf (*Canis lupus signatus*) has been recovered and expanded since the 1970s, when its range and population size were at their lowest point (Blanco and Cortés 2009). As a result, complaints and conflicts have increased in areas where wolves have been recently recolonized. Historically, management policies varied: until 2021, the species could be hunted to the north of the Douro River in line with regional management plans, while the species was protected to the south of this river. Control measures (i.e. culling) could only be justified by demonstrating their impact on livestock activities, as allowed under Article 16 of the EU Habitats Directive. However, in 2021, Spanish law extended protection of the species to the entire national territory, resulting in a hunting ban. Since then, the administration is only authorized to implement control measures as a last resort, in accordance with the provisions of the Habitats Directive (Durá-Alemañ

et al. 2021; Appendix S1). These legislative changes have significantly impacted the wolf's expanded range and the prevalence of conflicts across different regions of Spain. Areas with proportionally more damage caused by wolves are those where extensive livestock is abundant and recent wolf recolonization has taken place (Blanco and Cortés 2009; Blanco 2017).

In this study, we embark on a novel exploration of the pivotal role that Traditional Ecological Knowledge (TEK) plays in mitigating conflicts between humans and large carnivores. Molnár & Babai (2021) described TEK as a cumulative and dynamic body of knowledge, practice, and belief, building on experience and adapting to change. Related terms to the concept of TEK include Local Ecological Knowledge (LEK) and Indigenous and Local Knowledge (ILK), as defined by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al. 2015).

Whereas prior research has underscored the crucial role of TEK in mitigating human-large carnivore conflicts (e.g. Kikvidze and Tevzadze 2015; Ivaşcu and Biro 2020), our approach stands out for introducing a fresh perspective. Specifically, our study combines three regions with varying cohabitation states with wolves and extends the research scope beyond using guardian dogs. We also encompass TEK associated with shepherd's roles and their extensive livestock farming practices. Promoting tolerance and co-existence with large carnivores is a cornerstone of their conservation efforts (Ripple et al. 2014). Dorresteijn et al. (2014) highlighted the significance of studying and understanding the dynamics of human-carnivore co-existence in areas where two groups shared landscapes over lengthy periods. Blanco and Cortés (2009) emphasized that, in Spain, beyond ecological factors, socio-cultural elements, including human-driven wolf persecution, enable wolf expansion in certain regions and impede it in others. Therefore, investigating the socio-cultural factors that influence the varying levels of acceptance of wolf presence in a given territory by paying particular attention to shepherd's roles and their livestock farming practices is a pertinent research objective.

Here we conducted in-depth interviews with shepherds and livestock farmers from three regions of Spain, each characterized by varying states of co-existence between extensive livestock farming and wolf populations. Our aim was to investigate shepherds and livestock farmers' attitudes toward wolves and to explore TEK related to livestock protection measures against wolves. By comparing the discourse of shepherds and livestock farmers from areas with uninterrupted, recent and sporadic wolf presence, we seek to gain insights into the conditions that lead to

co-existence. Ultimately, our research aims to generate recommendations that promote both the conservation of wolves and harmonious co-existence between this species and society, with direct implications for informing policies, such as the EU Common Agricultural Policy and the Nature Restoration Law, to address the sustainable management of these territories. This research is also intended to contribute to the new Strategy for the conservation and management of the wolf and its co-existence with rural activities at the state level (MITECO 2022).

## 2. Materials and methods

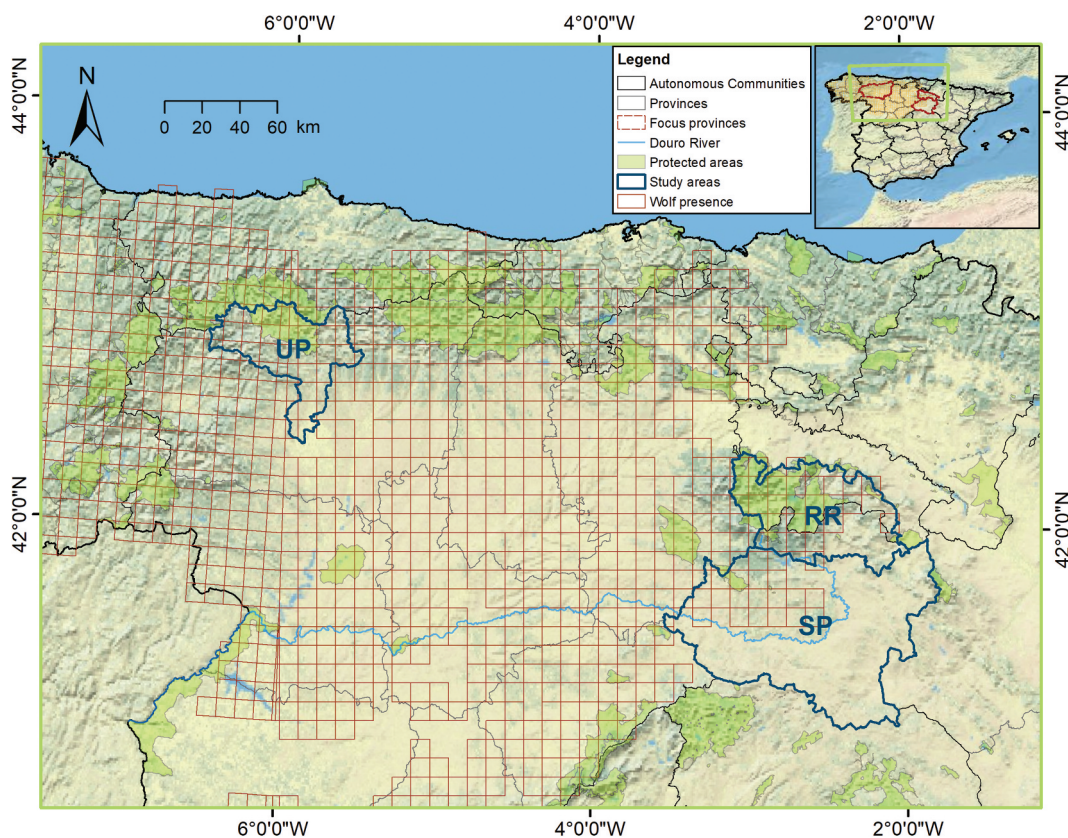
### 2.1. Study areas

Wolf populations in Europe have significantly recovered (Chapron et al. 2014), which has resulted in their widespread distribution across northwestern Spain. This country is home to one of the largest populations of wolves in Europe, estimated at 297 wolf packs (MITECO 2022). We examined three areas with extensive livestock in different states of co-existence with wolves: uninterrupted presence (hereafter *UP area*), recent recolonization (hereafter *RR area*) and sporadic presence (hereafter *SP area*) (see Figures 1–2). These

three areas share ecologically favorable habitats for wolves, with low human population density and good wild prey availability. Although the three study areas are in a region with a large wolf population in Spain (179 wolf packs; Fig. S1), the *UP area* within the Province of León (not covering the entire province) has a larger population (54 wolf packs) compared to the *RR area*, which includes the northern part of the Province of Soria and the Autonomous Community of La Rioja (3 wolf packs), and the *SP area*, which includes the rest of the Province of Soria, has no established wolf populations at present (García y Asensio 1997; Sáenz de Buruaga et al. 2015; MITECO 2022). See Appendix S2 for a detailed description of the study areas.

### 2.2. Data collection and analysis

From November 2020 to March 2023, we conducted semi-structured in-depth interviews with 21 shepherds and livestock farmers in the three study areas (7 interviews per study area). Our focus was on gathering insights from experienced key informants, prioritizing genuine expertise over a larger sample size. Semi-structured interviews are a well-recognized method for gaining an in-depth understanding of complex problems, and can be



**Figure 1.** Map of continental Spain showing the three study areas (UP, RR, SP), the location of the protected areas and the distribution of wolf populations. *UP area*: uninterrupted wolf presence; *RR area*: recent wolf recolonization; *SP area*: sporadic wolf presence. Wolf distribution was extracted and modified from the Spanish inventory of natural heritage and biodiversity (MITECO 2013). Maps were generated with ArcGIS 10.5. Additional information about the characteristics of each location can be found in the materials and methods section.



**Figure 2.** Photographs of the mountainous landscape (a) and the herd of sheep with leonese mastiff in *UP area* (b), mountainous landscape (c) and the herd of sheep in *RR area* (d), and the flat landscape (e) and the herd of sheep in *SP area* (f). Credits: C. Javier Durá (a, c, d, e, f) and Abel Flórez (b).

particularly useful for helping to explain conservation problems (Rust et al. 2017) that cannot be separated from the human social sphere (Whitehouse 2015). We structured our interview into four main sections: The first section focused on analyzing the main problems around farms that interviewees faced, which can be seen as reflecting TEK in understanding the factors that may hinder livestock operation. The second section centered on exploring shepherds and livestock farmers' perceptions and attitudes toward wolves, rooted in their knowledge and beliefs (TEK) regarding these carnivores. The third section was dedicated to exploring TEK concerning livestock husbandry practices, with a specific focus on strategies for protecting livestock from wolves. The fourth section concentrated on examining the characteristics of farms and interviewees' socio-demographic variables. The interview guide is presented in Table S1.

We applied snowball sampling, i.e. a non-probability sampling method used when potential participants are difficult to find or when the sample is limited to a very small subset of the population, to select interviewees (i.e. we asked interviewees to identify other livestock farmers in the area). Snowball sampling is a commonly used method in semi-structured interviews on biodiversity conservation and the study of ecosystem services and TEK (e.g. Anadón et al. 2009; Newing 2010; Martín-López et al. 2011; Morales-Reyes et al. 2018).

Most interviews (14 out of 21) were conducted by telephone due to mobility restrictions during the COVID-19 pandemic. However, we conducted some face-to-face interviews in *RR area* ( $n = 4$ ) and *SP area* ( $n = 3$ ). After the mobility restrictions were lifted, we complemented the telephone interviews with field visits to interviewees in all three study areas, which deepened the information already collected.

All the interviews were recorded and subsequently transcribed for the data analysis. We conducted a narrative analysis of transcripts by selecting and extracting fragments of the interviews that related to the themes of interest, i.e. interviewees' farming problems, which reflect TEK (knowledge) about factors that may hinder livestock operations; conflicts, perceptions, and attitudes toward wolves, rooted in their TEK (knowledge and beliefs) regarding these carnivores; and TEK concerning livestock husbandry practices (practices), with a particular focus on measures for protecting livestock from wolves. In the Results section, we use quotations from a sample of the extracted fragments to support the narrative analysis (see Table S2 for the complete list of quotations by topics). We also quantitatively described interviewees' main socio-demographic and farming characteristics, their perceptions and attitudes toward wolves and livestock husbandry practices in each study area based on their responses.

Semantic networks were analyzed using the binary counting method in VOSviewer (Van Eck and Waltman 2010), based on transcripts from interviews conducted at three study sites (*UP area*, *RR area*, and *SP area*). Prior to analysis, transcripts were pre-processed to remove stop words and special characters. VOSviewer generated three separate semantic maps for each area, depicting nodes (terms) representing significant keywords extracted from the interviews. Node size indicated term importance, and color represented clusters of related terms. The edges (links) between nodes reflected the co-occurrence of terms within the document. In binary counting, the occurrences attribute for each term indicated whether it appeared at least once in the document. This approach elucidated the thematic structures and common topics discussed, thereby providing insights into the semantic relationships among key terms.

Our approach aligns with recent recommendations in conservation research regarding interview methodology, as highlighted by Young et al. (2018), which emphasizes the importance of transparent sampling strategies, question design, and ethical considerations in interviews aimed at conservation decision-making. At the time of data collection, the institution responsible for the research did not require that research with minimal risk to subjects, such as this one, undergo a formal ethical review as long as it adhered to the ethical principles outlined in the Belmont report (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research 1979).

### 3. Results

#### 3.1. Interviewees and farming characteristics

The majority of respondents were male (85.7%) whose average age was  $51.9 \pm 12.7$  years ( $\pm$  standard deviation) and their average experience as shepherds and livestock farmers was  $33.9 \pm 14.3$  years

( $\pm$  SD). Most interviewees owned sheep (85.7%; average herd size: 918 heads), followed by cattle (38.1%; average herd size: 71 heads), goats (38.1%; average herd size: 18 heads) and horses (14.3%; average herd size: 1 head). Slightly more than half the interviewees were transhumant (all in *UP area*). Most of the respondents (76.2%) were shepherds by family tradition, but only in *UP area* did all the shepherds have livestock as their sole economic activity (Table 1).

All the interviewees in the three study areas expressed identical concerns about the low economic profitability of their work, lack of social recognition of their work, bureaucratic obstacles or no generational replacement (Table S2):

There is no generational replacement and there are no people who know the shepherd's trade. And you have to know it, especially in mountain passes. It's hard. If you know it, it's nice, but it's hard.

(Id 13, male, 50–59 years; *UP area*)

I remember hearing people talk about how livestock farmers were people they loved, how they were waiting for them to come back from the mountain pass, to come back home. And now we're in the way everywhere.

(Id 18, female, 30–39 years; *UP area*)

Prices have sharply dropped. Bear in mind that we're selling lamb much cheaper than 40 years ago. [...]

(Id 11, male,  $\geq 70$  years; *RR area*)

The problem is that sheep are more sacrificing and you have to be more vigilant if you're a shepherd. People don't want to be shepherds. Not even here in the areas more in valleys; there are no shepherds.

(Id 14, male, 30–39 years; *RR area*)

Our main problem with sheep is that they raise little money, but create a lot of work [...]. My main request to the administration is that we should not be abandoned in the way we are.

(Id 2, male, 60–69 years; *SP area*)

**Table 1.** Socio-demographic and farming characteristics of the interviewees in each study area: *UP area*, uninterrupted wolf presence; *RR area*, recent wolf recolonization; *SP area*, sporadic wolf presence. The mean (SE) is shown.

	UP area	RR area	SP area
<b>Socio-demographic characteristics</b>			
Age (years)	48.0 (3.9)	52.9 (4.9)	54.7 (5.7)
Experience (years)	32.1 (4.7)	33.0 (4.9)	37.0 (8.1)
Gender (female %)	28.6	0	14.3
<b>Farming characteristics</b>			
Number of livestock	1370.3 (112.2)	713.9 (280.3)	936.4 (278.6)
Number of sheep	1322.9 (104.5)	505.0 (205.2)	926.4 (283.9)
Number of goats	39.3 (15.5)	11.0 (9.9)	0
Number of cattle	6.7 (4.4)	195.7 (107.7)	10.0 (10.0)
Number of horses	1.4 (1.4)	2.5 (2.3)	0
Interviewees with sheep (%)	100	71.4	85.7
Interviewees with goats (%)	71.4	28.6	14.3
Interviewees with cattle (%)	28.6	71.4	14.3
Interviewees with horses (%)	14.3	28.6	0
Shepherds performing transhumance (%)	100	28.6	28.6
Being shepherds by family tradition (%)	71.4	100	57.1
Livestock as the sole economic activity of livestock owners (%)	100	28.6	57.1

These farming challenges identified by the interviewees reflect TEK about factors that may hinder livestock operations, thereby highlighting the ongoing influence of this knowledge in shaping their livelihood challenges.

### 3.2. Conflicts, perceptions and attitudes toward wolves

Most of the respondents in *RR area* (85.7%) had suffered wolf attacks, while only a few respondents had in *UP and SP areas*, and they were always anecdotal attacks that occurred either a long time ago or only once (Table 2). These experiences reflect diverse TEK perspectives on interactions with wolves, incorporating both practical knowledge and cultural beliefs.

In *UP area*, 83.3% of the respondents perceived some benefit associated with wolf presence, such as controlling diseases and regulating the abundance of ungulates, reflecting their TEK on the ecological roles of wolves. In *RR and SP areas*, this positive perception was rare or absent. So whereas all the livestock farmers in *UP area* considered co-existence of extensive livestock and wolves to be possible based on their TEK, in the other two areas they believed it was impossible or only possible under certain conditions, such as wolf lethal control (Table 2).

In *RR and SP areas*, overall the interviewees did not recognize any advantage from wolf presence (Table S2), highlighting contrasting TEK regarding the ecological roles of wolves:

The wolf has no advantage. The wolf doesn't manage red deer [...] There are those who think that wolves will control wild boars' tuberculosis [...] They really believe it, but don't know what wolves are. The wolf is the vilest animal that exists for humans because it lives off humans. It's a predator that lives at the expense of humans, a parasite of humans.

(Id 5, male, 60–69 years; *RR area*)

In the areas of uninterrupted wolf presence, they emphasized the regulating services that wolves provide and did not want wolves to disappear (Table S2), illustrating a strong TEK perspective on the ecological benefits of wolves:

If it weren't for wolves, mountain passes would be full of roe deer, wild boars, chamois and red deer.

The day you went there, they would have eaten everything.

(Id 15, male, 50–59 years; *UP area*)

If there is a sick wild boar or a wounded roe deer, the wolf will eat it. [...] It will kill it and eat it. So that's a disease that the wolf removes from the countryside. [...]

(Id 18, female, 30–39 years; *UP area*)

Wolves are necessary, just as bears, wild boars or others are necessary. [...]

(Id 13, male, 50–59 years; *UP area*)

Negative emotional consequences of wolf presence were strongly felt in *RR and SP areas* (Table S2):

An attack causes you tremendous psychological damage. And the Administration or no-one else compensates you. You see animals that you are fond of that wolves have destroyed. It's very painful. And you see how it has happened and you can't defend yourself.

(Id 1, male, 40–49 years; *SP area*)

The problem does not lie so much in [economic] losses, but in lost quality of life. When you're not at ease, animals aren't at ease, and losses... you cannot so much quantify in numbers as you can in that aspect. The cattle that go up to the mountains in summer seek peace, even for shepherds.

(Id 4, male, 50–59 years; *RR area*)

For the interviewees in *UP area*, the stress and worries caused by wolf presence were much less important (Table S2), reflecting differing perceptions and experiences related to human-wolf interactions shaped by TEK:

[...] I don't worry about he-wolves or she-wolves. I don't worry about anything having good mastiffs.

(Id 15, male, 50–59 years; *UP area*)

In fact, they normalized wolf attacks. They feel embarrassed about wolf attacks and blamed poor husbandry practices (Table S2), demonstrating their perceptions influenced by TEK:

Some livestock farmers lose one sheep or two or four by a wolf for whatever reason. But they don't report it because they have had mastiffs [...]

(Id 13, male, 50–59 years; *UP area*)

**Table 2.** Conflicts, perceptions and attitudes toward wolves in each study area: *UP area*, uninterrupted wolf presence; *RR area*, recent wolf recolonization; *SP area*, sporadic wolf presence.

	UP area	RR area	SP area
Have you suffered wolf attacks?			
Yes (%)	0	85.7	0
Yes, only one-off attacks (%)	42.9	0	28.6
Perceived benefits from wolves? (%)	83.3	28.6	0
Is wolf-livestock co-existence possible?			
Yes (%)	85.7	0	0
Yes, but under certain conditions (%)	14.3	42.9	28.6
No (%)	0	57.1	71.4

### 3.3. Livestock husbandry practices

Perceptions and conflicts seemed strongly associated with the livestock management practices followed in each type of area. The livestock farmers in *RR area* acknowledged that they had lost traditional ways of handling livestock that made attacks more uncontrollable (Table S2). This loss highlights the importance of TEK in guiding livestock management practices and mitigating conflicts with large carnivores:

But many wolf problems are also our fault. Because... and I'm shooting my own foot, we are abandoned. In the old days, the shepherd used to go with them, he locked them up, and whoever had cows knew what had to be done.  
(Id 6, male, 30–39 years; *RR area*)

Overall, whereas all the respondents in *UP area* considered the implementation of traditional husbandry practices (i.e. using guard dogs, presence of shepherds, shutting up livestock at night) as defensive measures against wolf attacks to be essential, in *RR and SP areas* they seemed reluctant to implement them and believed less in their effectiveness. Some of the livestock farmers in *RR and SP areas* had started applying new technologies (tracking livestock using global positioning systems; GPS), but those in *UP area* did not like using them (Table 3). This contrast underscores the influence of TEK in guiding livestock management practices, with the *UP area* respondents placing greater trust in traditional methods compared to the *RR and SP areas*. See Appendix S3 for a detailed description of interviewees' extensive livestock farming practices.

In *UP area*, the respondents recognized the value of having good mastiffs, and could not conceive doing their work without them, to which they attached vital importance, reflecting their deep-rooted TEK on using guard dogs for livestock management (Table S2):

The problem with wolves lies in the people who don't have mastiffs. Here with the mastiff culture, you see eight or ten mastiffs for every flock. As there have always been wolves, you simply take measures.  
(Id 13, male, 50–59 years; *UP area*)

However, lack of wolves for many years in *RR and SP areas* has meant that the use of mastiffs has been abandoned, and only a few livestock farmers remembered seeing them as children. The interviewees in *RR and SP areas* were rather skeptical about their effectiveness and livestock continue to graze unattended, highlighting a gap in the TEK related to livestock protection (Table S2):

Yes, I've heard that there were also mastiffs in the old days. But I've not experienced it.  
(Id 11, male, ≥ 70 years; *RR area*)

There have always been sheepdogs, but not mastiffs. Now the livestock around here have them. I haven't taken them because there are lots of roads here, a lot of tourism and I was very afraid.  
(Id 11, male, ≥ 70 years; *RR area*)

At night there are at least seven dogs, which help us, for a first attack, but it's not a solution because with dogs we've had wolf bites; it avoids a massive attack, which could kill twenty animals, but we still have attacks of two, three, one, and they are frequently repeated.  
(Id 4, male, 50–59 years; *RR area*)

Preventing attacks with mastiffs is not possible because wolves are smarter than dogs. There are times when one goes to a wolf pack, one takes the mastiffs and the others do the deed. This is inevitable.  
(Id 11, male, ≥ 70 years; *RR area*)

In *UP area*, the respondents considered not only it essential to have mastiffs present, but they also possess certain special characteristics. They were completely aware of the importance of their number, behavior, and other qualities that make guard dogs 'good mastiffs', reflecting a nuanced understanding of TEK in livestock protection (Table S2):

I'm 58 years old and I've never had any problems with wolves at any time in my life. But, of course, I've always had mastiffs. If you don't have mastiffs when you're up in the mountain, then you'll have problems every day. If you have good mastiffs, there'll be no wolves.  
(Id 15, male, 50–59 years; *UP area*)

**Table 3.** Livestock husbandry practices, including measures to protect livestock from wolves in each study area: *UP area*, uninterrupted wolf presence; *RR area*, recent wolf recolonization; *SP area*, sporadic wolf presence.

	UP area	RR area	SP area
Livestock guardian dogs (%)	100	57.1	42.9
Who is the shepherd?			
Owners as full-time shepherds (%)	100	14.3	71.4
Hired shepherd (%)	0	14.3	28.6
Owners occasionally as shepherds (%)	0	71.4	0
Livestock kept in fenced paddocks at night (%)	100	14.3	100
Tracking livestock using GPS (%)	0	28.6	14.3

Having half a dozen dogs is enough for about 700 sheep, but having more dogs is not better. The best thing is for them to be good dogs.  
(Id 13, male, 50–59 years; *UP area*)

I've never had one killed. But hey, wolves are much smarter than dogs. Wolves may arrive and one wolf leaves with the dogs, and then another wolf comes and kills your sheep. But of course some dogs always go out, perhaps one kilometer, after the wolves, and others at 200 meters return to the sheep. And that which returns to the sheep is as good as that which runs after wolves.  
(Id 15, male, 50–59 years; *UP area*)

Some people have mastiffs with herds of cows and mares, but have no casualties. Until recently they didn't, and they've realized that a mastiff is necessary. But if a dog is not good for anything, it makes no difference if you have it or not.  
(Id 13, male, 50–59 years; *UP area*)

Similarly, the need to have guard dogs and to pay the costs associated with them was taken for granted by the shepherds in *UP area* (Table S2):

'Of course mastiffs are expensive, but you have to have them. The mastiff must be with sheep, to defend them from a wolf [...]. Of course in León there have always been mastiffs. And the mastiff involves expenses all year round. Those who are not used to paying these expenses with mastiffs don't want mastiffs'. [...]  
(Id 15, male, 50–59 years; *UP area*)

Another measure used in *UP area* to prevent wolf attacks was leaving a shepherd with livestock, demonstrating their TEK on effective livestock management and protection (Table S2):

Any shepherd who is a real shepherd has to be with the livestock.  
(Id 13, male, 50–59 years; *UP area*)

I haven't had any problems with wolves. I have dogs and [...] But whoever makes a living from this has to keep their livestock under control. I sleep with the sheep when I'm out in the mountains, I sleep with them. Arriving, putting up a wire fence and going home is easy. But then if one day wolves have killed fifteen sheep, you'll cry and shed tears. No. You have to provide the means, don't you?  
(Id 17, male, 50–59 years; *UP area*)

One livestock farmer in *RR area* recognized the important role of shepherds for preventing wolf attacks (Table S2):

[...] As soon as June arrives they release them, they forget about cows and don't care if they stop, if a wolf kills them or not... But yes, when they see one of them is bitten, they place their hands on their heads. And that's the problem, yes supposedly wolves, but the problem is often ours.  
(Id 6, male, 30–39 years; *RR area*)

The respondents in *RR and SP areas* considered that this measure would imply a radical change in their daily routine and going back to remote times. This rejection is particularly important in *RR area*, where some respondents have other occupations besides livestock farming, indicating a disconnect from traditional practices or TEK loss associated (Table S2):

With the wolf problem, it's very hard hearing them demanding the return of types of grazing and livestock management employed 60 or 70 years ago. We all want leisure time, to be able to eat at home, to be able to sleep at home. [...]  
(Id 4, male, 50–59 years; *RR area*)

In the *RR area*, where the TEK associated with traditional livestock husbandry practices could have been lost, objections are raised about the traditional practice of shutting up livestock at night. It is argued that hardly anyone does this because it is difficult to practice given the orographic characteristics of the area and the nature of livestock management, which tends to be dispersed over wide areas (Table S2):

In the Rioja area they have considered building pens, but it is useless, because you're leaving them to be killed. They are herds of cows and flocks of sheep, which know the terrain like the back of their hand; putting them in pens makes no sense and goes against the very essence of extensive livestock farming and pasture rotation.  
(Id 4, male, 50–59 years; *RR area*)

The administration is building pens here. But pens are fine if you manage to get them all in. But if one night, one afternoon, with sleet and weather is bad, and you leave some outside, mastiffs remain with those inside pens and wolves kill those left outside. [...] Besides you can't always make them go in pens.  
(Id 5, male, 60–69 years; *RR area*)

### 3.4. Semantic networks

In the uninterrupted wolf presence (*UP area*) map (Figure 3), significant terms include 'wolf', closely associated with 'mastiff' and 'night' within the yellow cluster, highlighting the role of livestock practices such as mastiffs and nighttime strategies, rooted in TEK, in managing interactions with wolves. The red cluster further emphasizes terms related to traditional livestock production methods.

Moving to the recent wolf recolonization (*RR area*) map (Figure 4), prominent terms like 'attack' in the purple cluster, 'administration' in the green cluster, and 'environmental agent' in the blue cluster reveal a strong focus on addressing wolf-related conflicts through administrative channels. Notably, the term 'wolf' itself is less prominent, suggesting a narrative where the community primarily frames





worry, frustration, fear and pain of losing animals and/or work time (Almarcha et al. 2022). Marino et al. (2021) emphasized the importance of reducing these intangible costs to increase tolerance toward wolves, an emotional aspect that was evidenced in our work. Surprisingly, financial compensation paid to livestock farmers for implementing protective measures or for livestock losses did not seem to alleviate their distress (Zahl-Thanem et al. 2020) or influence people's attitudes towards predators (Dorresteijn et al. 2014). This is not solely due to financial losses, but also stems from factors like the need to change lifestyle, work situation, feelings of responsibility, emotional attachment to livestock or generally distrusting the carnivore management system. Recovering TEK about preventive measures, such as the mastiff culture, seems an indispensable tool for mitigating this distress.

Furthermore, the application of preventive control measures would imply a major change in livestock management. Most livestock farmers in the Iberian Peninsula acknowledge that, although livestock were always guarded in the daytime and kept in stalls at night in the past (Álvares et al. 2015), there are currently more unsupervised animals in extensive systems. As in other places with a long-standing tradition of selection and use of livestock guarding dogs (e.g. Plakhov et al. 2008), the herders in the uninterrupted wolf presence area recognized their value, could not conceive their work without mastiffs, and are even proud of having good mastiff dogs. These opinions fall in line with the study carried out by Landry et al. (2020), who pointed out that using guard dogs is important in reducing livestock attacks, but having a good number of dogs to defend herds is also desirable.

The potential disappearance of wolves might not only have led to loss of TEK associated with traditional livestock management, such as the mastiff culture in the areas recently recolonized by wolves, but could also have resulted in a significant loss of cultural heritage. This heritage includes legends, tales, orations, beliefs, popular medicine and other cultural manifestations linked with this animal that continue to thrive in regions where wolves never disappeared (e.g. Álvares et al. 2011; Almarcha Martínez 2019).

The transhumant lifestyle prevalent in areas with an uninterrupted wolf presence suggests a significant repository of TEK. However, the common concerns about the low profitability of the herder lifestyle indicate a conundrum situation: TEK and associated practices are threatened by social, cultural, and economic marginalization (Molnár et al. 2023). As noted by Hartel et al. (2023), TEK is often maintained due to poverty and lack of options, creating a paradox where deprivation helps conserve TEK. However, opportunities for modern development might lead some farmers to abandon the TEK. Addressing social

injustices faced by TEK holders and integrating their knowledge into conservation policies are essential for achieving long-term social-ecological sustainability.

#### 4.1. Tolerance of wolves and their consequences on livestock management

While predators offer significant benefits to ecosystem functioning (Miller et al. 2001; Ripple and Beschta 2012; Ripple et al. 2014; Hoy et al. 2022) and society through the provision of ecosystem services (Lozano et al. 2019; Aguilera-Alcalá et al. 2020; Raynor et al. 2021), wolves are still often perceived more as a problem than a valuable ecosystem element (Dressel et al. 2015). However, large carnivores do not always have such positive ecological effects, particularly in strongly human-modified ecosystems (Kuijper et al. 2016; Ausilio et al. 2021) making co-existence solutions complex and context specific. In general, much importance has been attached to the conflict in the relationship between humans and carnivores, while very little attention has been paid to the potential ecosystem services that they provide (Lozano et al. 2019). Enhancing tolerance towards predators by communicating the benefits they provide (Bruskotter and Wilson 2014; O'Bryan et al. 2018) is crucial for improving biodiversity conservation (Bennett 2016). For example, Kansky and Maassarani (2022) suggests that nonviolent communication (NVC), a method developed by Marshall Rosenberg to foster empathy, is a promising tool for promoting co-existence between humans and wildlife. In Spain, a higher percentage of livestock farmers perceive obligate scavengers (i.e. vultures) as the most beneficial scavengers, whereas facultative scavengers (including carnivores like wolves) are negatively perceived, with wolves being the worst rated species (Morales-Reyes et al. 2018). This highlights the need for effective communication strategies, like NVC, to shift perceptions and promote co-existence.

Exposure to a given species and experiences with it are reported to increase perceptions of benefits and costs, and ultimately tolerance (Marino et al. 2021). With wolves, based on Espirito-Santo and Petrucci-Fonseca (2017), there is a possible link between knowledge of the benefits of wolf presence in a territory and accepting the species more. In our research, we also observed more knowledge of the ecosystem services provided by wolves in those areas where shepherds have always co-existed with this canid. Furthermore, Arbieu et al. (2024) highlights how emotional responses, like surprise, interest, and fear evoked by wolf videos, significantly shape attitudes towards wolves. This emphasizes the importance of understanding emotional reactions in influencing perceptions of wolves and human-carnivore co-existence. A significant positive relation appeared between the intangible benefits that wolves can provide (i.e. the

positive emotions and perceived benefits of a species for the community, people and nature) and their tolerance (i.e. the stronger the influence of the positive emotions and perceived nonmonetary value, the greater tolerance is; Marino et al. 2021). Therefore, a better understanding of these benefits in recently colonized areas is an important element for facilitating co-existence, and for making the benefits of wolves visible through appropriate strategies is a priority.

Consistently with previous findings (see e.g. Morales-Reyes et al. 2018; Pettersson et al. 2021), we found that the perception of wolves as providers of ecosystem benefits depended partly on the maintenance of traditional livestock practices. Similarly in Portugal, in areas where wolves have long since been present, damage to livestock caused by wolves and issues of compensation for damage are not major concerns for livestock farmers, who often mention the importance of having wolves in the area (Espírito-Santo and Petrucci-Fonseca 2017). Slagle et al. (2012) found that perceptions of the benefits that wolves can offer were a better predictor (than perceptions of risk) of intentions to support wolf recovery in the United States. Bruskotter and Wilson (2014) emphasize that communication and public outreach that focus solely on how to avoid or reduce risks may actually decrease tolerance of large carnivores. Thus we see effective communication of the benefits that wolves can offer to newly recolonized areas as a priority.

Furthermore, the fact that wolves can cause greater damage to unprotected livestock during their recolonization means that these events receive more media attention, which contributes to further create a climate in which to reject this animal (Houston et al. 2010; Fernández-Gil et al. 2016). In contrast, media coverage tends to be more diverse in areas where the species has been present for a long time (Delibes-Mateos 2020). Arbieu et al. (2019) found that higher knowledge and trust in science-based information positively correlated with favorable attitudes towards wolves, while media sources like press or TV news tended to elicit more negative attitudes. Furthermore, Randler et al. (2020) revealed gender, age, and residency effects on attitudes and knowledge about wolves among secondary school students in Germany. In summary, these findings emphasize the key role of education and science-based information in shaping attitudes towards large carnivores.

#### 4.2. Management and conservation implications

The disappearance of wolves in certain areas of Spain for at least three decades, spanning from the late 1950s to the early 1990s, has led to loss of TEK about livestock management. This loss has made co-existence with this species more challenging and has fostered more intolerance of wolf presence.

Consequently, a cultural divide has emerged, which impedes full wolf settlement in a territory and wolves expanding in new areas. In regions recently colonized by wolves or where they sporadically appear, reluctance to adopt preventive measures also prevails. This hesitance stems from lack of confidence in the effectiveness of these measures for countering wolf attacks on livestock. For instance, while some livestock farmers have recently incorporated mastiff dogs into their practices, these dogs are not always adequately trained for livestock protection. Similarly, reluctance to implement other preventive measures in these areas, such as recovering shepherds or guarding livestock at night, is considerable.

In our study areas, where wolves have recently colonized or sporadically appear, respondents often engage in additional economic activities alongside livestock. This highlights the necessity of understanding how TEK can be reintroduced or adapted within varied economic contexts. Kovařík et al. (2014) found that in the Czech Republic, economic factors, rather than the presence of large carnivores, were the primary challenge for sheep farmers. This finding aligns with our results, emphasizing that economic viability is crucial for managing livestock predation and sustaining traditional farming practices. For example, in the Italian and French Alps, where wolves were extinct in the early 20th century and are now recovering with support from initiatives like the LIFE WOLFALPS EU project (<https://www.lifewolfalps.eu/en/>), efforts focus on promoting wolf-human co-existence through integrating TEK. This includes implementing strategies to minimize livestock impacts, educating communities about wolves to combat misinformation, collaborating with hunters on predator-prey dynamics, and developing sustainable ecotourism. These efforts underscore TEK's role in advancing effective conservation practices in culturally and economically diverse landscapes.

In contrast, in those areas with uninterrupted wolf presence, the continuous presence of this species has enabled the preservation of traditional husbandry practices, such as using livestock guardian dogs, which have remained largely unaltered since the origin of livestock farming. This is evidenced in the higher level of acceptance and tolerance of wolves, with some positive aspects of its presence even being highlighted. Undoubtedly, all this fosters co-existence with wolves in regions where the pastoralist culture linked with wolf presence has never been lost. Therefore, fostering exchanges of experiences between livestock farmers and shepherds between both areas would improve human-wolf co-existence in recently colonized areas. It is crucial to emphasize the significance of a peer-to-peer approach because the target group generally places more trust and

believes more in the experiences of those colleagues who face similar situations (e.g. Benciolini and Stauder 2022). Awareness campaigns are also essential for promoting an understanding of the benefits of wolf presence in a territory. Additionally, facilitating collaboration among diverse stakeholders, including scientists, policymakers, conservation organizations, and local communities, is crucial for developing effective management strategies that promote both human livelihoods and wolf conservation in strongly human-modified ecosystems (e.g. Marino et al. 2021).

In conclusion, our study underscores the intricate socio-ecological dynamics shaped by the presence or absence of wolves in different landscapes. Considering shifting baseline syndrome and potential hysteresis, the absence of wolves in certain landscapes may have entrenched social-ecological equilibrium states, making it challenging to revert to previous conditions even with their natural return. This resistance may arise from entrenched parameters and feedback mechanisms, highlighting the need for innovative approaches to facilitate the natural return of wolves and reshape socio-ecological dynamics (Lyver et al. 2019). These insights emphasize the critical need for nuanced wildlife management and conservation approaches in humanized landscapes, where fostering harmonious co-existence between humans and wolves is essential for ecosystem health and community resilience.

## 5. Conclusions

The traditional livestock husbandry practices in regions with uninterrupted wolf presence, characterized by using mastiff dogs, keeping livestock in fenced paddocks at night and, most notably, having a shepherd present, embody a continuous proactive approach to mitigate wolf attacks. This approach allows the harmonization of millenary economic practices associated with extensive livestock farming and tolerance of wolf presence and, ultimately facilitates co-existence. However, our study underscores the importance of recognizing the context-specific nature of large carnivore management. While these traditional practices are effective in some areas, they may not be universally applicable across all landscapes. Therefore, it is crucial to adopt a context-specific approach to large carnivore management, tailored to the unique ecological, social, and economic conditions of each region.

Our study provides practical recommendations for conserving wolf populations and promoting harmonious co-existence with society, with direct implications for EU policies such as the Common Agricultural Policy (CAP) and the recently approved Nature Restoration Law. We propose allocating CAP funds to support pastoral practices conducive to wolf co-existence, including funding for the acquisition and maintenance of mastiff dogs,

installing electric fencing and hiring shepherds. We suggest that compensation for livestock losses should depend on implementing protective measures against wolves. Additionally, we advocate for fostering knowledge exchange among shepherds across regions and integrating shepherd training programs into rural development strategies to promote effective co-existence. The Nature Restoration Law presents an opportunity to recognize wolves' role in ecosystem restoration and cultural preservation, advocating for habitat restoration and TEK-based wildlife management. Furthermore, in the Strategy for the management and conservation of the wolf and its co-existence with rural activities, led by the Government of Spain with an annual allocation of 20 million euros, half of which is specifically dedicated to funding investments in farms for preventive measures, such as purchasing mastiffs or installing fences, aimed at enhancing co-existence efforts. Integrating these recommendations into policy frameworks fosters ecological and social resilience in territories where wolves and humans coexist.

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## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Author contribution

C. Javier Durá-Alemañ, Francisco Almarcha and José A. Sánchez-Zapata conceived the ideas; Francisco Almarcha and Irene Pérez-Ibarra designed methodology; C. Javier Durá-Alemañ collected the data; C. Javier Durá-Alemañ, Francisco Almarcha and Zebensui Morales-Reyes analysed the data; C. Javier Durá-Alemañ and Zebensui Morales-Reyes funding acquisition; C. Javier Durá-Alemañ, Francisco Almarcha and Zebensui Morales-Reyes led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

## Data availability statement

To safeguard participants' privacy and comply with the General Data Protection Regulation of the European Union (Regulation EU 2016/679) and Spanish law (Organic Law 3/2018, of December 5, on the Protection of Personal Data and the Guarantee of Digital Rights), we

are unable to make the raw data used in the study publicly available. However, anonymized relevant quotes from the interviews are accessible in the Supplementary Material.

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