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ORIGINAL RESEARCH

Friend or foe, what do the locals say? Attitudes towards the endangered Iberian wolf in Central Portugal

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Abstract

The endangered Iberian wolf (*Canis lupus signatus*) populations have been decreasing in Portugal due to a combination of factors such as habitat destruction and human persecution. This is particularly worrying in Central Portugal, where packs are highly fragmented, isolated, and with few individuals. Human-Wildlife-Conflicts occur in this area due to high levels of livestock depredation, an outcome of the low diversity and density of wild prey. As a consequence, human persecution is relatively high and is considered a main threat to wolves' survival. Through studying public attitudes towards these wolf populations and discerning prevalent patterns, insights can be gained to guide management strategies in mitigating these factors. A total of 222 questionnaires were collected from populations inhabiting Central Portugal, divided into three interest groups (general public, livestock owners, and hunters).We estimated *Attitude*, *Fear*, and *Knowledge Indexes* regarding the wolf. Attitudes towards wolves were positive, with the fear being neutral but the knowledge being low; attitudes tend to be more positive with the decrease of fear and the increase of knowledge, and fear tends to decrease with the increase of knowledge. The main factor negatively influencing attitudes was fear, although age seemed to have more influence on livestock owners' attitudes. The factors influencing fear included gender, knowledge, and personal experience with wolves. These findings can be used to target specific groups with environmental awareness initiatives, aiming to increase knowledge and reduce sources of fear. It is crucial to develop tailored conservation measures considering stakeholders' viewpoints to effectively protect the Iberian wolf.

Keywords Conflicts · Conservation · Fear index · Human-wildlife interactions · Perceptions · Questionnaires

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Introduction

Large carnivores are often associated with the idea of wilderness and untamed nature (López-Bao et al. 2017). Nonetheless, there is mounting evidence that large carnivores are tolerant to human presence and adapt their behavior and feeding ecology to live in humanized landscapes (Carter and Linnell 2016; Morales-González et al. 2020), the coexistence of these animals with humans often involves conflicts (Chapron et al. 2014; Chapron and Lopez-Bao 2016), arriving from, among other factors, livestock depredation, competition for game species with hunters, and the fear of attacks. These negative interactions, usually called human-wildlife conflict (HWC), coupled with the legal, cultural, and socio-economic beliefs can result in direct persecution by humans, threatening the species' conservation and, ultimately, survival (Carter and Linnell 2016; Anand and Radhakrishna 2017). Humans are key actors in shaping species distribution and survival worldwide, and their inclusion in conservation and management programs is essential for a better understanding of the HWC dynamics and an efficient and sustainable conservation of biodiversity. Human perception of wildlife can be influenced by sociodemographic traits (e.g., education level, gender, age), financial context, emotions, social traditions, cultural beliefs, and proximity to wildlife (Dressel et al. 2015; Frank 2016; Torres et al. 2020). Knowing how this multifactorial network shapes the human perception of wildlife is crucial to creating tailor-made management programs focused on improving coexistence (Álvares et al. 2011; Bruskotter and Wilson 2014; Hill 2015).

Wolves (*Canis lupus*) are generalist predators–opportunistic, preying on all prey groups, and adapting their activity to share human-dominated landscapes (Mech and Boitani 2006; Figueiredo et al. 2020). These behavioral adaptations are particularly relevant in Portugal, a southern European country whose landscape has been historically impacted and fragmented by human activities (Blondel 2006). The Iberian wolf (*Canis lupus signatus*, Cabrera 1907) populations inhabiting Portugal have evidenced a systematic decline throughout the last decades (Cabral et al. 2005; Torres and Fonseca 2016; Pimenta et al. 2023), mainly driven by human persecution (due to the predation of livestock and concerns regarding attacks on humans—Torres et al. 2016). Due to the rapid decline in distribution range and number, wolves became protected by Portuguese law in 1988 (Decree-Law nº 90/88 1988). Currently, the species is classified as "Endangered" (Pimenta et al. 2023), and the last census, in 2002/2003, estimated an effective population of only 300 individuals (Pimenta et al. 2005), divided into two subpopulations—a stable sub-population located north of the Douro River, and another, more fragile, south of Douro River, in Central-North Portugal (Pimenta et al. 2023). The southerner packs are endangered, mainly due to their small population size, geographic isolation from other packs (Godinho et al. 2007; Álvares 2011), unstable reproduction, and low genetic flow and diversity between packs (Godinho et al. 2007; Torres and Fonseca 2016). Furthermore, wild prey are scarce in the area. Wild boar (*Sus scrofa*) is the most abundant prey species available, despite the efforts of roe deer (*Capreolus capreolus*) reintroduction in the region (Torres et al. 2018). Since wolves adapt their diet to prey availability (Vos 2000; Mech and Boitani 2006), these packs are highly dependent on livestock to survive (Torres et al. 2015). In fact, more than 90% of their diet is composed of domestic livestock (Torres et al. 2015). The high levels of livestock depredation are not solely a result of the scarcity and low population density of wild prey but also stem from inadequate husbandry practices (Karlsson and Johansson 2010) or the nonexistence of guard dogs (Espuno et al. 2004). Livestock often graze freely without proper protective measures in place, such as shepherds, shepherd dogs, or fences. This

behavior of livestock predation contributes to the perpetuation of the "killer wolf stigma", wherein the species is wrongfully accused of every livestock disappearance or predation event (although often other species are responsible for livestock depredation).

To gain insights into local attitudes and perceptions towards wolves, understand the underlying causes of those patterns, and develop tailored conservation programs that foster coexistence, this study aimed to identify the sociodemographic factors (such as age and gender) that shape the attitudes, fear levels, and knowledge of different stakeholders (i.e., interest groups, namely: livestock owners, hunters, and the general public) towards wolves. Additionally, we examined the influence of fear and knowledge levels on stakeholders' perceptions of the wolf. Overall, we expect livestock owners and older people to have higher levels of fear and to find a link between knowledge levels and attitudes (Røskaft et al. 2003; Kleiven et al. 2004; Espirito-Santo 2007; Torres et al. 2020). We also hypothesize that the place of residence (more or less than 1000 inhabitants) impacts attitudes, fear and knowledge (Karlsson and Sjöström 2007; Behr et al. 2017). By understanding the main factors contributing to the perceived conflict, our results will provide valuable information for developing tailored conservation measures that can yield higher success rates.

Methods

Study area

This study was conducted in Central-West Portugal on two Rede Natura 2000 sites, "Serra de Montemuro" (PTCON0025) and "Serra da Freita-Arada" (PTCON0047). With an area of 750 km^2, these sites correspond to ca. 30–50% of the wolf population habitat south of Douro River and are the habitat of three confirmed packs: Arada, Montemuro, and Cinfães (Fig. 1). The landscape is mainly characterized by forests (46%), scrubland (26%), agricultural land (20%) and urban areas (8%). The landscape showcases diverse vegetation, primarily composed of various scrubland species such as *Cytisus scoparius*, *Cytisus grandiflorus*, *Ulex* spp., *Genista triacanthos*, *Erica* spp., and *Pterospartum tridentatum*. Forests are composed of English oak (*Quercus robur*), Pyrenean oak (*Quercus pyrenaica*), sweet chestnut (*Castanea sativa*), Maritime pine (*Pinus pinaster*), both in separate stands and intermixed with eucalyptus (*Eucalyptus globulus*) also present throughout the area. The study area retains intermittent pastures and agricultural plots intersected by multiple rivers and streams. Along these watercourses, riparian vegetation predominantly consists of ash (*Fraxinus angustifolia*) and birch (*Betula alba*) (Torres et al. 2015). The wild boar and the recently reintroduced roe deer (Torres et al. 2018) are the only wild ungulate species inhabiting the study area, while there are high densities of domestic ungulates: domestic goats (*Capra hircus*), sheep (*Ovis aries*), horses (*Equus caballus*), and cattle (*Bos taurus*).

The main economic activity in the rural and suburban areas of the study area is agriculture, with the landscape encompassing a high number of pastures and agriculture fields (Cruz et al. 2014; Torres et al. 2015), as well as livestock grazing areas. Livestock ranges freely during daytime when they tend to roam alone throughout the mountains or are sometimes accompanied by a shepherd and/or sheepdog. During night-time, livestock is usually enclosed in barns (Torres et al. 2015). In the region used by the Arada pack, livestock is composed of 60% of sheep, 27% of domestic goats, and 13% of cows; in the Montemuro pack area, livestock is composed of 54% of sheep, 31% of domestic goats, and 15% of cows

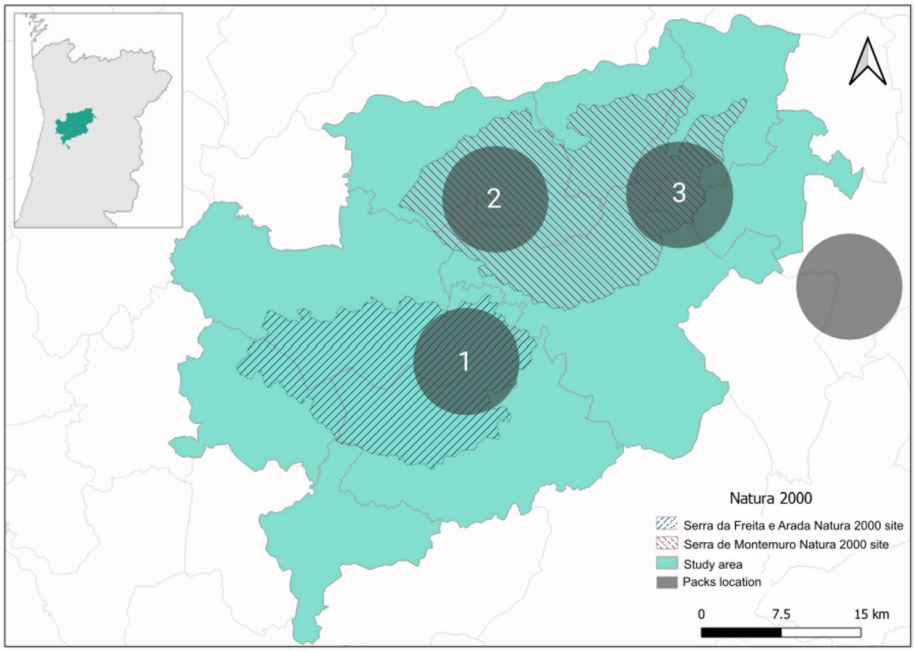

Fig. 1 Study area location in Central Portugal, Natura 2000 Network sites limits (striped areas), and wolf pack locations (1—Arada wolf pack; 2—Cinfães wolf pack; 3—Montemuro wolf pack)

and in the Cinfães pack, by 50% of sheep, 24% of domestic goats and 26% of cows (INE 2019).

Human settlements are generally limited to small towns and remote parishes scattered through rough valleys, with population densities lower than 150 inh/km^2 (FFMS 2021). The local population is aging, and the population density has been decreasing steadily (e.g., from 68 inh/km^2 in 2011 to 64 inh/km^2 in 2021 in Arouca and from 48 inh/km^2 in 2011 to 43 inh/km^2 in 2021 in São Pedro do Sul (FFMS 2021)). The territories of wolf packs are usually located in areas with low population density. As a result, a greater number of surveys were gathered in the surrounding regions.

Data collection

Data was collected from March 2018 to April 2019 through a questionnaire. The process of collecting the questionnaire took an extended duration due to challenges in securing participant responses. The aim was to ensure an ample sample size for making reliable assumptions. Questionnaires are an efficient method to collect social data that will allow assessing individuals' perceptions on an issue in a specific place in time (Dressel et al. 2015), thus helping to understand human attitudes toward wildlife (Gangaas et al. 2015). The questionnaire (see Supplementary Information 1) was structured in four distinct parts, containing a total of 38 questions related to (i) individual sociodemographic data (9 questions); (ii) personal experiences with wolves (9 questions with yes/no answers); (iii) personal opinions and ecological knowledge (15 questions); and (iv) influence of the media (5 questions). Part III and IV's answers followed a five-level Likert scale (ranging from 1—strongly

disagree; 2—disagree; 3—neutral; 4—agree; to 5—strongly agree). A final question was added to assess which data sources are used to obtain information regarding wolves (e.g., schools, media, books, stories).

The questionnaires were filled anonymously, using three simultaneous approaches to collect data: (i) printed copies of the questionnaire were left on villages' key points (e.g., coffee shops, cultural associations) to be filled by residents; (ii) face-to-face interviews with residents of the study area; and (iii) online questionnaires created using google forms and shared through various outreach sources (e.g., social networks and e-mails), inviting people from the municipalities within the study area to participate. All respondents freely agreed to be involved in the study, and only after their explicit consent was the questionnaire filled out. As different stakeholders (i.e., interest groups) may hold different perceptions towards wolves (a pattern linked, among other things, to their economic activity, experience, connection to nature, or their primary source of income—see, e.g., Franchini et al. 2021 or Janeiro-Otero et al. 2023), the questionnaires targeted three stakeholders groups: general public, livestock owners and hunters.

Data analysis

Attitude, knowledge, and fear index

We first estimated three indexes aiming to describe different dimensions of human perception regarding wolves: (i) *Attitude Index*—attitude towards wolves; (ii) *Knowledge Index*—knowledge about wolf ecology and legislation; (iii) *Fear Index*—level of fear towards wolves. The *Attitude Index* was calculated using the arithmetic mean of scores from questions III-2, III-4, III-8, III-9, III-10, III-11, and III-12 (see Supplementary Information 1). To standardize data analysis, the scale of answers had to be reversed so that the lowest value indicated the least positive attitude and the higher value indicated more positive attitudes (underlined questions of the questionnaire, Supplementary Information 1). Questions linked to the *Knowledge Index* regarding wolves' ecology and legislation (questions II-5, II-6, II-7; II-9; see Supplementary Information 1) had dichotomous answers (yes/no or 0/1). The index ranged from zero, the lowest level of knowledge (no correct answer), to four, the highest level of knowledge (all answers were correct), and was calculated by adding one for each correct answer. Regarding the *Fear Index* (questions III-3, III-6, and III-7; see Supplementary Information 1), the total score of the answers to all questions was counted and ranged from three (no fear) to fifteen (maximum level of fear). Similar to the *Attitude Index,* some answers' scores had to be reversed so that the lowest value indicated the least level of fear (underlined questions of the questionnaire; see Supplementary Information 1).

In order to understand the role of myths and local folklore as influencers of peoples' perception of wolves, for every answer higher than three to the question "III-3 Wolf presence near your residence causes you fear/unsafety", we assessed the reply to the question "III-5 Do myths/stories influence your opinion towards wolves" to evaluate if myths and local legends influence fear.

Variation of index values between stakeholders

Data was initially tested for normality using the Shapiro–Wilk test (Zar 2010). As the normality assumption was rejected (see Results), we used a Kruskal–Wallis, with a

0.5-significance level, to test for differences between stakeholders' index scores. Using Spearman's rank correlation coefficient, we also tested for possible correlations between indexes (Zar 2010). All data were analyzed using R software (R Core Team 2018).

Drivers of attitude and fear indexes

To test the main drivers explaining the variability in *Attitudes* and *Fear Indexes* within the three stakeholder groups, we used Cumulative Link Mixed Models (CLMMs) (Christensen 2019) since CLMMs are adequate to deal with our dataset's ordinal and non-independent character. These models were performed for each stakeholder group separately. The *Attitude* and *Fear Index* were used as dependent variables, while those associated with the demographic data (age, gender, and scholarship level) and the answer to the question "Do you know of any wolf attack on domestic animals?" (only for the general public and hunter's groups), were treated as independent candidate variables. To avoid introducing a bias linked to livestock owners' direct experience of domestic animal depredation, the answer to this question was removed from the independent variables of this group. The answer to the two other questions was added to this stakeholders' analysis: (i) "Do you have a shepherd dog?" and (ii) "Have you suffered a loss of domestic animals by wolf depredation?". For the analysis of fear drivers, the same process was used for all stakeholders, but the *Fear Index* score was excluded from the independent variables (as it was the dependent variable). A detailed list of variables included in the final models for each index driver and stakeholder group can be found in Tables 1, 2, 3, 4, 5, 6, along with relevant statistical parameters. Given the nested character of the data (i.e., the same participant answered several questions in the same questionnaire, and therefore, the answer is influenced by the person's experience/emotions/perspective), a random factor was considered—the participants' ID—in modeling procedures, used to assess the drivers of *Attitude* and *Fear Indexes* variation in each stakeholder groups.

Analyses were performed using R software (R Core Team 2018), and the modeling procedure was implemented with the 'ordinal' package (Christensen 2019). The models were produced using the function 'clmm' (Christensen 2019), with link function 'logit' and a symmetric threshold (i.e., the distance from the scale extremes is symmetric to its center).

Table 1 List of variables included in the average model, produced to assess the driver of general public attitudes variation

95% CI						
Independent variables	β	Std. Error	z-value	Pr(>|z|)	2.50%	97.50%
POPULATION_Size (1)	**0.858**	**0.288**	**2.983**	**0.003**	**0.294**	**1.422**
ID_Fear	**− 0.469**	**0.039**	**12.052**	**< 0.001**	**− 0.546**	**− 0.393**
GENDER (2)	− 0.256	0.256	1.001	0.317	− 0.757	0.245
ATTACKS (1)	− 0.206	0.260	0.790	0.429	− 0.715	0.304

β variable coefficient, *Std. Error* standard error, *z-value* score of the z-test, *Pr(>|z|)* significance of the z-test, *95% Confidence Interval* 95% confidence interval of each variable coefficient

In bold are highlighted variables whose 95% Confidence Interval of the coefficient does not include the zero*

*Where: POPULATION_SIZE (1) = > 1000 inhabitants; ID_FEAR = *Fear Index*; GENDER (2) = Female; ATTACKS (1) = Has knowledge of wolf depredation to livestock; CI = Confidence Interval

Table 2 List of variables included in the average model, produced to assess the driver of hunters attitudes variation

95% CI						
Independent variables	β	Std. Error	z-value	Pr(>|z|)	2.50%	97.50%
POPULATION_SIZE (1)	1.391	0.819	1.698	0.090	− 0.215	2.997
ID_FEAR	**− 0.662**	**0.159**	**4.162**	**0.000**	**− 0.973**	**− 0.350**
GENDER (2)	1.248	1.232	1.013	0.311	− 1.166	3.663

β variable coefficient, *Std. Error* standard error, *z-value* score of the z-test, *Pr(>|z|)* significance of the z-test, *95% Confidence Interval* 95% confidence interval of each variable coefficient

In bold are highlighted variables whose 95% Confidence Interval of the coefficient does not include the zero*

*Where: POPULATION_SIZE (1) = > 1000 inhabitants; ID_FEAR = *Fear Index*; GENDER (2) = Female; CI = Confidence Interval

Table 3 List of variables included in the average model, produced to assess the driver of livestock owners attitudes variation

95% CI						
Independent variables	β	Std. Error	z-value	Pr(>|z|)	2.50%	97.50%
DOGS (1)	0.546	0.312	1.751	0.080	− 0.065	1.157
ID_FEAR	**− 0.464**	**0.053**	**8.782**	**< 0.001**	**− 0.568**	**− 0.360**
AGE (2)	0.131	0.393	0.334	0.738	− 0.639	0.901
AGE (3)	− 0.191	0.471	0.406	0.685	− 1.115	0.733
AGE (4)	**− 1.616**	**0.555**	**2.913**	**0.004**	**− 2.703**	**− 0.528**
POPULATION_SIZE (1)	− 0.347	0.340	1.021	0.307	− 1.013	0.319
LOSS (1)	− 0.119	0.373	0.318	0.751	− 0.849	0.612
GENDER (2)	− 0.089	0.320	0.278	0.781	− 0.715	0.538
HUNTER (1)	− 0.144	0.528	0.272	0.786	− 1.179	0.891

β variable coefficient, *Std. Error* standard error, *z-value* score of the z-test, *Pr(>|z|)* significance of the z-test, *95% Confidence Interval* 95% confidence interval of each variable coefficient

In bold are highlighted variables whose 95% Confidence Interval of the coefficient does not include the zero*

*Where: DOGS (1) = livestock owners have guard dogs; ID_FEAR = *Fear Index*; AGE (2) = 31–45; AGE (3) = 46–60; AGE (4) = > 60; POPULATION_SIZE (1) = > 1000 inhabitants; LOSS (1) = Has suffered from wolf depredation to livestock; GENDER (2) = Female; HUNTER (1) = Livestock owners who are hunters; CI = Confidence Interval

For each dataset (general public, livestock owners, and hunters), we built a set of models corresponding to all possible combinations of the candidate variables using the package 'MuMin' (Bartoń 2019). The best models for each stakeholder and index dataset were selected based on the Akaike Information Criterion corrected for small samples (AICc; Burnham and Anderson 2002). The models with a delta AICc value lower than two (ΔAICc < 2; the difference between the AICc of the model and the lowest AICc) were considered the best models (Burnham and Anderson 2002). The goodness of fit for each best model was assessed through a likelihood-ratio test ('anova') that evaluated whether the

Table 4 List of variables included in the average model, produced to assess the driver of general public fear variation

Independent variables	β	Std. Error	z-value	Pr(>|z|)	0.025	0.975
ATTACKS (1)	**1.302**	**0.471**	**2.763**	**0.006**	**0.378**	**2.225**
GENDER (2)	**1.090**	**0.470**	**2.319**	**0.020**	**0.169**	**2.011**
ID_KNOWLEDGE (1)	**− 1.030**	**0.504**	**2.043**	**0.041**	**− 2.019**	**− 0.042**
ID_KNOWLEDGE (2)	**− 2.026**	**0.720**	**2.813**	**0.005**	**− 3.437**	**− 0.614**
ID_KNOWLEDGE (3)	− 1.959	1.038	1.888	0.059	− 3.993	0.074
POPULATION_SIZE (1)	− 0.796	0.538	1.480	0.139	− 1.850	0.258

β variable coefficient, *Std. Error* standard error, *z-value* score of the z-test, *Pr(>|z|)* significance of the z-test, *95% Confidence Interval* 95% confidence interval of each variable coefficient

In bold are highlighted variables whose 95% Confidence Interval of the coefficient does not include the zero*

*Where: ATTACKS (1) = Has knowledge of wolf predation to livestock; GENDER (2) = Female; ID_KNOWLEDGE (1) = *Knowledge Index* value 1; ID_KNOWLEDGE (2) = *Knowledge Index* value 2; ID_KNOWLEDGE (3) = *Knowledge Index* value 3; POPULATION_SIZE (1) = > 1000 inhabitants; CI = Confidence Interval

Table 5 List of variables included in the average model, produced to assess the driver of livestock owners fear variation

95% CI							
Independent variables	β	Std. Error	Adjusted SE	z-value	Pr(>|z|)	0.025	0.975
SCHOOL (3)	− 0.455	0.847	0.864	0.526	0.599	− 2.148	1.239
SCHOOL (4)	**− 1.806**	**0.696**	**0.709**	**2.547**	**0.011**	**− 3.196**	**− 0.416**
SCHOOL (5)	**− 1.873**	**0.722**	**0.735**	**2.548**	**0.011**	**− 3.314**	**− 0.432**
ID_KNOWLEDGE (1)	**− 1.193**	**0.553**	**0.564**	**2.114**	**0.035**	**− 2.299**	**− 0.087**
ID_KNOWLEDGE (2)	0.779	0.813	0.829	0.940	0.347	− 0.846	2.404
ID_KNOWLEDGE (3)	− 0.553	0.842	0.857	0.645	0.519	− 2.233	1.127
POPULATION_SIZE (1)	**1.578**	**0.548**	**0.557**	**2.834**	**0.005**	**0.487**	**2.669**
ATTACKS (1)	1.183	0.709	0.722	1.639	0.101	− 0.231	2.597
GENDER (2)	1.242	1.007	1.027	1.210	0.226	− 0.770	3.254
LIVESTOCK OWNER (1)	**0.910**	**0.454**	**0.462**	**1.969**	**0.049**	**0.004**	**1.816**

β variable coefficient, *Std. Error* standard error, *z-value* score of the z-test, *Pr(>|z|)* significance of the z-test, *95% Confidence Interval* 95% confidence interval of each variable coefficient

In bold are highlighted variables whose 95% Confidence Interval of the coefficient does not include the zero)

*Where: SCHOOL (3) = 3rd Cycle; SCHOOL (4) = Secondary education; SCHOOL (5) = Higher Education;; ID_KNOWLEDGE (1) = *Knowledge Index* value 1; ID_KNOWLEDGE (2) = *Knowledge Index* value 2; ID_KNOWLEDGE (3) = *Knowledge Index* value 3; POPULATION_SIZE (1) = > 1000 inhabitants; ATTACKS (1) = Has knowledge of wolf depredation to livestock; GENDER (2) = Female; LIVESTOCK OWNER (1) = Hunters who are livestock owners; CI = Confidence Interval

deviance between the null and the best models was significantly different. If the differences were statistically relevant, then the best models would be considered more fitted and those containing the most influential variables to explain the detected patterns. If more than one

Table 6 List of variables included in the average model, produced to assess the driver of livestock owners fear variation

95% CI							
Independent variables	β	Std. Error	Adjusted SE	z-value	Pr(>|z|)	2.50%	97.50%
SCHOOL (2)	− 0.387	0.512	0.514	0.754	0.451	− 1.395	0.620
SCHOOL (3)	**− 1.516**	**0.494**	**0.496**	**3.056**	**0.002**	**− 2.488**	**− 0.544**
SCHOOL (4)	**− 1.271**	**0.413**	**0.415**	**3.063**	**0.002**	**− 2.084**	**− 0.458**
SCHOOL (5)	**− 1.006**	**0.430**	**0.432**	**2.329**	**0.020**	**− 1.853**	**− 0.160**
GENDER (2)	**0.539**	**0.250**	**0.251**	**2.145**	**0.032**	**0.046**	**1.031**
ID_KNOWLEDGE (1)	**− 1.024**	**0.273**	**0.274**	**3.730**	**0.000**	**− 1.561**	**− 0.486**
ID_KNOWLEDGE (2)	**− 1.031**	**0.391**	**0.393**	**2.626**	**0.009**	**− 1.801**	**− 0.261**
ID_KNOWLEDGE (3)	**− 1.946**	**0.421**	**0.423**	**4.602**	**0.000**	**− 2.775**	**− 1.117**
LOSS (1)	**0.765**	**0.280**	**0.281**	**2.722**	**0.006**	**0.214**	**1.315**
POPULATION_SIZE (1)	**0.693**	**0.268**	**0.269**	**2.575**	**0.010**	**0.166**	**1.221**
DOGS (1)	− 0.330	0.240	0.241	1.368	0.171	− 0.802	0.143

β variable coefficient, *Std. Error* standard error, *z-value* score of the z-test, *Pr(>|z|)* significance of the z-test, *95% Confidence Interval* 95% confidence interval of each variable coefficient

In bold are highlighted variables whose 95% Confidence Interval of the coefficient does not include the zero*

*Where: SCHOOL (2) = 2nd Cycle; SCHOOL (3) = 3rd Cycle; SCHOOL (4) = Secondary education; SCHOOL (5) = Higher Education; GENDER (2) = Female; ID_KNOWLEDGE (1) = *Knowledge Index* value 1; ID_KNOWLEDGE (2) = *Knowledge Index* value 2; ID_KNOWLEDGE (3) = *Knowledge Index* value 3; LOSS (1) = Has suffered from wolf depredation to livestock; POPULATION_SIZE (1) = > 1000 inhabitants; DOGS (1) = Livestock owners have guard dogs; CI = Confidence Interval

model presented a ΔAICc < 2, we applied a model averaging procedure using the R package 'MuMin' (Bartoń 2019) to estimate the average coefficients of the variables included in the best models, as well as its 95% confidence intervals (95% CI). We also estimated the Akaike weight (w) for each model, representing the probability of that being the best model (Burnham and Anderson 2002). In the analysis, the variables that significantly influenced the dependent variable (such as the *Attitude Index* and *Fear Index*) were identified based on a 95% confidence interval (CI) that excluded zero. This allowed us to determine whether the influence was positive (if the 95% CI contained only positive values) or negative (if the 95% CI included negative estimates).

Results

Demographic characterization

A total of 222 questionnaires were collected in our study area (Fig. 2), but our data does not fully match the study area demography, which we deepen in the Discussion. For more detailed demographic descriptions, see Supplementary Information 2. We acknowledge the potential bias stemming from the under-representation of individuals with lower levels of education, however the real effect of this bias on our results is not clear. Older people could also be under-represented, which could lead to a sampled *Attitude Index* higher than the

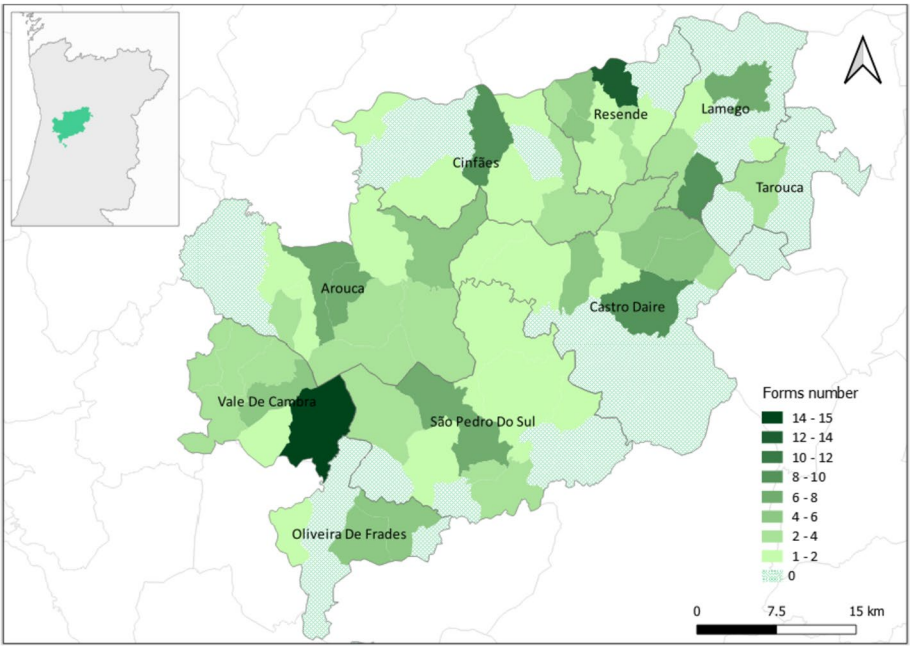

Fig. 2 Number of questionnaires implemented in each surveyed municipality

real one (according to our results). Despite these limitations, we maintain that our conclusions remain robust, recognizing that these factors may have an impact on specific results.

Index comparison between stakeholders

The average *Attitude Index* value (3.557; Fig. 3A) was considered neutral, tending to positive, with non-significant differences between stakeholders ($H = 5.319$, $df = 2$, p-value $= 0.070$), while the *Knowledge Index* (Fig. 3B) was low (0.946, in a scale from 0 to 5), with no respondent scoring higher than 3. No significant differences between groups were found ($H = 0.722$, $df = 2$, p-value $= 0.697$). The *Fear Index* (Fig. 3C), ranging from 3 to 15, shows that globally the fear towards wolves is neutral (average $= 8.140$). We did not detect any significant differences between the stakeholder groups' fear levels ($H = 0.112$, $df = 2$, p-value $= 0.945$).

Index correlation

We did not detect any significant correlation between the *Knowledge* and *Fear Indexes* ($\rho = 9.62E - 06$; p-value $= 0.292$), while the *Attitude* and *Fear Index* test showed a significant negative correlation ($\rho = -0.719$; p-value < 0.001), where individuals with higher levels of fear presented a negative attitude towards wolves. Inversely, the *Attitude* and *Knowledge Index* presented a significant positive correlation ($\rho = 0.221$; p-value < 0.001), indicating that individuals with higher knowledge about the wolf have a more positive attitude towards them.

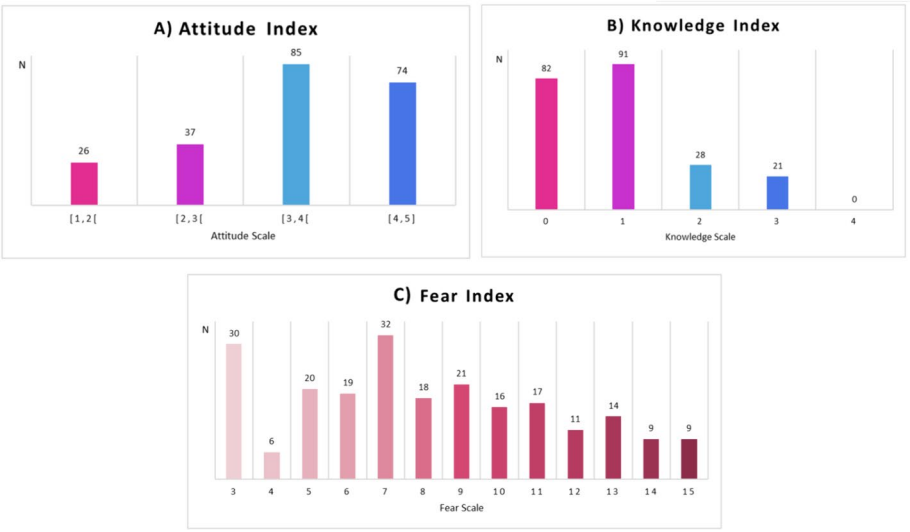

Fig. 3 Frequency (N) of each *Attitude Index* (**A**), *Knowledge Index* (**B**), and *Fear Index* (**C**) categories among the surveyed respondents

Driver of stakeholder's attitude

The general public attitude towards the wolf was mostly determined by the settlement's population size (people inhabiting areas with > 1000 inhabitants have a higher probability of exhibiting positive attitudes towards wolves) and the *Fear Index* (higher fear values increase the likelihood for someone to display more negatives attitudes towards wolves) (Table 1). The average model also identified that gender and attack knowledge (i.e., if the person has knowledge/experience regarding wolf depredation) influence the variation of the attitudes towards this carnivore, but their effect (i.e., positive or negative) is not clear (Table 1).

For hunters, the average model indicates that attitude was mostly dependent on the *Fear Index* values, as it increases the probability of displaying negative attitudes towards wolves. The population size and gender variables seem to influence stakeholder attitudes, but it is unclear in which way (i.e., positively or negatively) (Table 2).

Finally, for livestock owners, the average model included only two variables that seem to influence attitudes negatively: age (older people—> 65 years old) and *Fear Index* (people with a high *Fear Index* value present a higher probability of displaying negative attitudes towards wolves). The average model also incorporated other variables, including shepherd dogs, the loss of domestic animals, hunter presence (i.e., livestock owners who are hunters), population size, and gender, which demonstrated some level of influence on the variation of attitudes, although it is unclear how (Table 3).

Factors that influence stakeholders' fear

For the general public, gender, the perception of wolf attacks, and the *Knowledge Index* were the most important drivers of fear towards wolves. Females with information on wolf attacks on livestock and low knowledge regarding wolves' ecology and legislation have a higher probability of presenting fear towards them. Population size also influences people's fear of wolves, although it is unclear if this influence is positive or negative (Table 4).

Hunters' fear was mostly influenced by four drivers: education level, knowledge about wolf ecology, being a livestock owner, and (human) population size. Hunters who own livestock and reside in areas with > 1000 inhabitants are more likely to exhibit fear towards wolves. Conversely, the variables school level and *Knowledge Index* indicated that hunters with higher levels of education and/or higher knowledge levels about wolves are less likely to display fear. Attack knowledge and gender variables impact fear, although it is unclear if this influence is positive or negative (Table 5).

Finally, the livestock owners' average model showed that the variables gender, animal loss (i.e., depredation by wolves), *Knowledge Index*, education level, and population size were the most influential in determining the scale of fear. Women who experienced livestock losses to wolf depredation have lower knowledge regarding wolves' ecology and legislation and lower educational levels, and those who inhabit areas with > 1000 inhabitants have a higher probability of showing fear towards wolves. The variable dogs appear to influence the variation of fear, but the direction and nature of its influence remain unclear (Table 6).

Discussion

The inherent conflict between humans and apex predators revolves significantly around the depredation of livestock, especially prevalent in areas with scarce wild prey. The repercussions of livestock depredation extend globally, sparking conflicts and adversely affecting economic prosperity (Berger 2006). Portugal is not exempt from this phenomenon, particularly in regions south of the Douro River, where wolf populations are both smaller and more scattered (Godinho et al. 2007; Álvares 2011). In fact, the primary challenge in the interaction between the Iberian wolf and local populations lies in wolf depredation on livestock. This triggers the conflict with humans which we analyzed in this study. This study emphasizes that different factors influence the attitudes of various stakeholders coexisting with wolf populations. It underscores the fact that a one-size-fits-all approach is not suitable to solve conservation challenges, which holds significant implications for conservation efforts, particularly as these stakeholders' needs and expectations often fall outside the scope of traditional conservation discussions (Lute and Gore 2014). As a result, the study offers valuable insights that can inform localized conservation programs or target them to specific socioeconomic or cultural contexts.

Attitude

Attitudes toward the wolves were overall neutral, tending to be positive, which might be somewhat surprising considering the levels of depredation upon domestic prey

registered in the study area (Torres et al. 2015) and the historical-assumed conflict that derived from depredation events (Grilo et al. 2002). These findings corroborated previous research in Portugal (Milheiras and Hodge 2011; Torres et al. 2020) and in other countries where wolves have historically existed, such as Italy (Glikman et al. 2012). This pattern can result from increased environmental awareness and predation mitigation measures implemented in the study area (e.g., educational lectures and projects, such as the "Shepherd Dogs": http://www.grupolobo.pt/programa-cao-de-gado). Furthermore, the overall neutral or indifferent attitudes may also be influenced by the rural exodus that has affected Portugal in recent decades (Silva et al. 2021), potentially leading to a decreased connection to rural environments and wildlife.

The general public exhibited the most positive attitudes, as previously detected in Portugal and in other European countries (Dressel et al. 2015; Arbieu et al. 2019; Torres et al. 2020). This pattern is mainly determined by the interviewer settlement's size—residents of areas with > 1000 inhabitants are more likely to display positive attitudes. In fact, it has been argued that larger and more densely populated communities tend to have more positive attitudes toward wolves (Karlsson and Sjöström 2007; Behr et al. 2017). This could be attributed to several factors: firstly, individuals from the general public are less likely to have negative experiences with wolves, such as economic threats to their livelihood, as wolves tend to avoid densely populated human settlements (Carricondo-Sanchez et al. 2020); additionally, differences in cultural values may exist, with urban communities often having a certain detachment from the wilderness (Rosalino and Rosalino 2012; Rosalino et al. 2017).

The detected neutral/positive attitude in hunters may be due to the fact that Portuguese hunters traditionally prefer to focus on smaller game species, such as the wild rabbit (*Oryctolagus cuniculus*) and red partridge (*Alectoris rufa*). Thus, they do not compete directly with wolves for game species (Milheiras and Hodge 2011), which decreases the conflict risk. In contrast, Central and Northern European hunters that focus mostly their game activity on larger game species (e.g., deer; Apollonio et al. 2010), which are predated by wolves (Newsome et al. 2016), tend to display negative attitudes towards the wolves (Karlsson and Sjöström 2007; Behr et al. 2017). Besides the mentioned competition effect, the higher abundance of wolves in these North European areas (Bjerke et al. 1998; Williams et al. 2002) can also contribute to those negative attitudes.

Livestock owners are the least tolerant stakeholders, as registered in other European regions (Espirito-Santo 2007; Dressel et al. 2015; Torres et al. 2020), which can be due to negative direct experiences or reports of other livestock owners' experiences. Such experiences lead to the development of negative feelings towards the species by identifying wolves as harmful (Behr et al. 2017; van Heel et al. 2017). The most influential variable shaping livestock owners' attitudes was age—individuals older than 65 years are more likely to display negative attitudes toward wolves. This trend has been described in other European regions (Røskaft et al. 2003, 2007; Kleiven et al. 2004) and may be attributed to the fact that older livestock owners have likely been long-term residents of rural areas, increasing the probability of experiencing a depredation event.

A higher *Fear Index* was associated with a greater likelihood of exhibiting negative attitudes. This fear can be triggered by livestock depredation, which also has financial consequences, or by perceiving wolves as a threat to human lives. These fear-inducing triggers often result in negative attitudes due to the general concern people have for their safety and the well-being of their families (see, e.g., Røskaft et al. 2007), which are values that can overrule nature conservation (Rosalino and Rosalino 2012).

Fear

The *Fear Index* was considered neutral, tending to be low, which has already been reported in Portugal (Espirito-Santo 2007; Torres et al. 2020). As shown earlier, livestock owners exhibited higher levels of fear than other stakeholders (Espirito-Santo 2007; Torres et al. 2020). The majority of livestock owners live in rural regions where wolves coexist, leading to concerns about direct wolf encounters and the potential loss of livestock. Research has shown that individuals living in rural regions near wolf habitats tend to experience increased fear (Johansson et al. 2016a). Indeed, fear can be influenced by negative experiences, such as livestock depredation—for example, in Northeast Portugal, where wolves feed predominantly on wild prey (Figueiredo et al. 2020), livestock owners presented lower fear levels (Torres et al. 2020). In contrast, in our study area, where wolves depend highly on livestock to survive (Torres et al. 2015), livestock owners presented higher fear levels.

The education level influences livestock owners' and hunters' fear towards wolves (see also Zimmermann et al. 2001). People presenting a higher educational level are more predisposed to display lower levels of fear, as observed in other areas of Portugal (Espírito-Santo et al. 2016; Torres et al. 2020) and Europe (Røskaft et al. 2003; Gangaas et al. 2015). Scientifically correct information regarding wolf behavior and habits will demystify some of the myths from which fear is rooted. A Portuguese study targeting school children from the 6th to the 12th grade demonstrated that specific educational sessions focused on the species' ecology and role in ecosystems can improve the knowledge level, reduce fear, and enhance positive attitudes towards wolves (Ribeiro 2015). In fact, a less utilitarian perspective on the world, coupled with higher educational levels, is linked to enhanced recognition of the significance of key species, such as the Iberian wolf, within ecosystems (Røskaft et al. 2007).

Gender also influenced the scale of fear felt by livestock owners and the general public towards the wolf, with females demonstrating higher fear, a trait detected in other studies targeting the wolf (Røskaft et al. 2003; Johansson et al. 2016a; Torres et al. 2020). Women tend to be more emotionally honest than men when expressing their fear of wildlife (Kaltenborn et al. 2006), a fact that may result in the detected pattern. Torres et al. (2020) also stated that several studies highlighted that the perceived risk of a fatal carnivore attack is higher for women (Linnell et al. 2002; Treves and Naughton-Treves 1999) and that women often fear for the safety of their families (Røskaft et al. 2003). Additionally, having suffered or having knowledge of livestock depredation promotes the fear perception of livestock owners and the general public. Concurrently, hunters who are also livestock owners show a high fear perception. By simply being informed of wolf depredation events in their community, people may perceive the species as dangerous and harmful and associate the presence of wolves with economic damages (Røskaft et al. 2007). Such perception can even exacerbate a scenario of possible human attacks (Johansson et al. 2016b).

Knowledge

No significant differences were observed between stakeholders' knowledge levels, but the general public scored the lowest level of knowledge, as evidenced before in Croatia and Portugal (Bath and Majić 2000; Torres et al. 2020). This pattern can be explained by the distance to wilderness areas (Turner et al. 2004; Soga and Gaston 2016), as the general public in our study was composed mainly of people living in villages or small cities. In this

context, their knowledge is highly influenced by direct experiences (Røskaft et al. 2003). Hunters evidenced a higher level of knowledge regarding wolf ecology, which can be explained by their direct personal relationship with nature, as they more regularly visit wild landscapes during their hunting journeys (Majić et al. 2015; Torres et al. 2020).

The knowledge claimed by the studied stakeholders hinges on the quality, accuracy, and accessibility of their information sources. Most of our respondents highlighted television (18%), internet (16.3%), myths/stories (12.2%), and journals/magazines (11.9%) as their major information sources regarding wolves. In a recent study conducted in Hungary (Anthony and Tarr 2019), television was reported as the main source of information. However, other sources—e.g., the internet, myths, and stories- seem to be used to gather information regarding this predator (Anthony and Tarr 2019; Torres et al. 2020). Such outreach instruments can be effective and valuable tools in conservation planning if the information is based on unbiased and accurate data, without focusing on negative or even exaggerating particular traits (e.g., "wolf slaughtered a herd"). Conversely, exposure to negative media, social influence (Karlsson and Sjöström 2007), cultural portrayals of wolves as villains (Chapron et al. 2014; van Heel et al. 2017), and negative input from family and friends (Anthony and Tarr 2019) can foster negative attitudes. Arbieu et al. (2019) found that individuals who were more knowledgeable and reliant on books and films exhibited greater tolerance towards wolves.

Overall, we detected a correlation between *Knowledge Index* and attitudes, a pattern also reported in other European regions (Behr et al. 2017; Anthony and Tarr 2019; Arbieu et al. 2019; Expósito-Granados et al. 2019), which indicates that as knowledge increases, attitudes tend to become more positive. This is the first time that the relationship between knowledge and attitude was assessed in Portugal since previous studies have failed to establish any correlation (Espírito-Santo and Petrucci-Fonseca 2017; Torres et al. 2020).

Conclusions

This paper provides valuable and original information on the drivers, attitudes, knowledge, and fear towards wolves, which can be used to tailor environmental awareness actions to protect the endangered Iberian wolf in Portugal. Based on our findings, it is advisable to prioritize awareness initiatives targeting older individuals, women, and livestock owners. Nevertheless, there should be a concerted endeavor to enhance the understanding (and knowledge) of those residing in wolf-inhabited regions, as our research has shown a positive link between greater knowledge and reduced fear, along with more favorable attitudes. Such patterns highlight the importance of investing in disseminating accurate information among the stakeholders that directly or indirectly interact with wolves to reduce unjustified fear and achieve a more successful co-existence between this iconic large carnivore and human populations.

Subsequent research endeavors should investigate the influence of compensatory schemes on the coexistence between wolves and humans. In Portugal, these programs are exclusively government-led and are generally viewed positively (Milheiras and Hodge 2011; Torres and Fonseca 2016), despite notable shortcomings like delayed payments and the absence of compensation in cases where animals are taken by predators.

While it is essential to continue monitoring this species to ensure early detection of population tipping points, we believe that it is equally crucial to monitor people's perception trends, coupled with assessing the efficacy of targeted educational programs conducted by

the government in association with municipalities, universities, and stakeholders to assure that an effective holistic conservation strategy is implemented to guarantee Iberian wolf survival.

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Data availability The data will be fully available upon request.

Declarations

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