# Analysis of conflicts with wild carnivores in the Humid Chaco, Argentina

M. P. Kihn, N. Caruso, K. Iaconis, M. J. Palacios González, L. Soler

**Abstract**

*Analysis of conflicts with wild carnivores in the Humid Chaco, Argentina*. Interactions between humans and carnivores tend to be conflictual, especially due to predation on domestic animals. As certain landscape characteristics predispose the occurrence of carnivore attacks, spatial modelling of predation events can be particularly useful when developing management plans. In this study we determined the incidence of predation on the mortality of domestic animals by interviewing local inhabitants. In addition, we identified the spatial variables that explain the distribution of the conflicts and we created a two–scale model based on the Maxent algorithm. The results showed that *Puma concolor* (41.2 %) and the foxes *Lycalopex gymnocercus* and *Cerdocyon thou*s (33.3 %) were the most conflictive species. Predation accounted for only 5.6 % of the causes of domestic animal mortality. The distribution models showed that the most probable variables for predicting conflicts were the distance from the roads, livestock density and the proportion of anthropized areas. High–risk areas represented 28 % of the study area and were distributed in broad patches around the protected areas and in the eastern sector of the area.

Keys words: Predation, Livestock, Maxent, Spatial variables

**Resumen**

*Análisis de los conflictos con carnívoros silvestres en el Chaco Húmedo de Argentina.* Las interacciones entre humanos y carnívoros suelen tornarse conflictivas, en especial debido a la depredación de animales domésticos. Ciertas características del territorio favorecen que se produzcan ataques de carnívoros, por lo que puede ser muy útil elaborar modelos espaciales de los episodios de depredación a la hora de preparar planes de manejo. En este trabajo determinamos la incidencia de la depredación en la mortalidad de los animales domésticos a través de entrevistas a pobladores locales. Además, determinamos las variables espaciales que explican la distribución de los conflictos y construimos un modelo en dos escalas basado en el algoritmo de Maxent. Los resultados mostraron que el puma, *Puma concolor* (41,2 %) y los zorros *Lycalopex gymnocercus* y *Cerdocyon thous* (33,3 %) fueron las especies más conflictivas. La depredación representó solo el 5,6 % de las causas de mortalidad de los animales domésticos. Los modelos de distribución mostraron que las variables más probables para predecir los conflictos eran la distancia a carreteras, la densidad de ganado y la proporción de superficie antropizada. Las zonas de alto riesgo representaron el 28 % del área de estudio y se distribuyeron en amplios parches alrededor de las zonas protegidas y en el sector oriental del área.

Palabras clave: Depredación, Ganado, Maxent, Variables espaciales

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## Introduction

The expansion of human activities in many ecosystems has decreased the geographic range and populations of numerous carnivores and has also led to the fragmentation of their habitats (Morrison et al., 2007; Inskip and Zimmermann, 2009). As a consequence, predators are forced to live in anthropized environments where interactions with man may become conflictive (Rippel et al., 2014). Although there are other causes, such as the transmission of diseases, competition for game and direct attacks on humans, the predation of domestic animals is the greatest source of conflict between humans and carnivores, with lethal control being the most common method used to reduce the impact (Inskip and Zimmermann, 2009). Such control can have a devastating effect on the size and distribution of carnivore populations (Treves et al., 2011) and modify ecosystems, since they play an important role in their regulation (Prugh et al., 2009).

Numerous studies on conflicts between humans and carnivores due to livestock predation have identified characteristics of the landscape that favour such attacks (Zarco González et al., 2012; Miller, 2015; Sarmiento Giraldo et al., 2016). As these characteristics are distributed in non–random patterns, their study can be used to create predictive models and diagrams to develop conflict–mitigation strategies (Treves et al., 2011). Many researchers have used interviews or surveys with experts to determine the location of livestock attack events (Van Bommel et al., 2007; Zarco González, et al. 2012; Broekhuis et al., 2017). Surveys can provide valuable information that is often impossible to obtain from other sources at a relatively low cost (Masenga et al., 2017).

In the Humid Chaco of Argentina, much of the economy is based on agricultural production, generally carried out in natural environments where conflicts between humans and carnivores are often part of daily life. In many cases the subsistence of rural people is linked to raising livestock and poultry (Morello et al., 2012). The presence of these carnivores is therefore potentially conflictive, especially that of larger species. However, information on the relationship of the inhabitants with the carnivores in this region is scarcely documented. Soler et al. (2004) carried out the first diagnosis of the conservation situation of wild carnivores in the provinces of Chaco and Corrientes, showing that foxes *Cerdocyon thous* and *Lycalopex gymnocercus* were the species mentioned by the inhabitants as being the most conflictive, followed by small felines, *Herpailurus yagouaroundi* and *Leopardus geoffroyi*. In several regions of Argentina, Puma concolor is the carnivore that attacks domestic livestock most frequently. Farmers consider it is highly harmful and admit to hunting it regularly (e.g., Luengos Vidal et al., 2016).

In this study we explored the scope of conflicts between humans and carnivores and their spatial distribution in the Humid Chaco ecoregion in northern Argentina. Our main objectives were to identify the most conflictive species of wild carnivore and analyze their incidence on domestic animal mortality, and to develop spatial distribution models at different scales to determine which environmental variables are most associated with these conflicts.

## Material and methods

### Study area

The research was carried out in the northeast of Chaco province, an area belonging to the Humid Chaco ecoregion (fig. 1). In Argentina, this ecoregion encompasses the eastern half of the provinces of Chaco and Formosa, the north of Santa Fe and northwest of Corrientes (Morello et al., 2012). It is a plain with a slope slightly inclined towards the east in which depressed environments predominate, so it is prone to significant flooding. The predominant landscape is a mosaic of strips of well–drained high land with forests, accompanying the course of the rivers and alternating with low interfluves, estuaries and ravines, with features of grassland, savanna and scrubland (Naumann, 2006). The climate is temperate to humid and rainfall follows a longitudinal gradient, with maximum records in the east of more than 1,300 mm that decline in the west to 750 mm on the border with the Dry Chaco (Ginzburg and Adámoli, 2006). The ecoregion presents a remarkable diversity of wild fauna due to the heterogeneity of habitats, among which the community of carnivores includes fourteen species (Ginzburg and Adámoli, 2006).

The main livestock activity in Chaco province is the extensive breeding of cattle, which mostly graze on natural grassland. The other livestock species are mostly reared to complement other activities such as cotton cultivation, hunting, forestry and fishing. Livestock production in this area is characterized by a lack of planning, a lack of facilities, and and sanitary deficiencies (Subsecretaria de Planificación Económica, 2016).

### Surveys of local inhabitants

Data were obtained through surveys carried out in two stages. Surveys in 2016 carried out in rural areas were aimed at local inhabitants and were oral and semi–structured (see annex). The survey sites were chosen opportunistically based on the possibility of access with the vehicle used, and in each of them the location was recorded with a GPS device. In 2019, surveys were sent by the Google forms application to producers, extension workers of the National Institute of Agricultural Technology (INTA) and park rangers. The questions were structured or closed. The survey included a gridded and numbered image of the study area so that the respondents could identify cells with conflicts with carnivores (see annex). Each grid covered an area of 400 km$^2$, with a total of 44 grids covering an area of 17,600 km$^2$. The exact conflict site within the cell was located based on the information provided by the respondents about the particular environments where conflicts occurred (e.g. areas with dense vegetation, close to protected areas, far from towns, etc.) and with the help of a satellite image extracted from Google Earth.
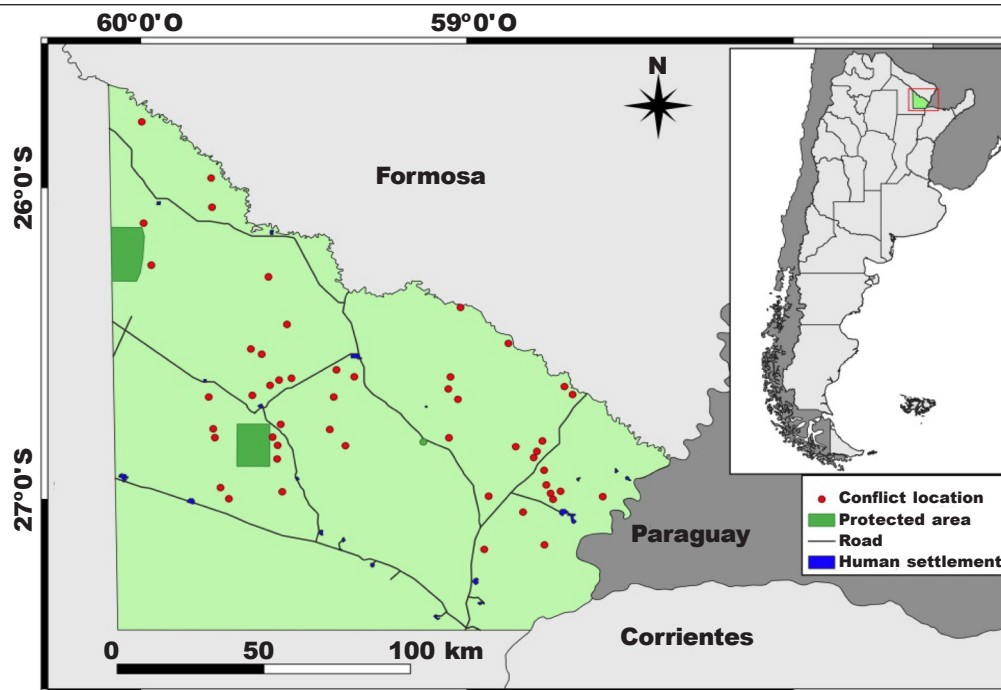
Fig. 1. Map showing the location of the study area in the province of Chaco, Argentina, and the location of the sites with conflicts, together with some spatial characteristics used in the analysis.

*Fig. 1. Mapa de la ubicación de la zona de estudio en la provincia del Chaco, en Argentina. Se muestran la ubicación de los lugares donde se produjeron conflictos y algunas características especiales utilizadas en el análisis.*

Spatial variables

Spatial data were processed using the QGIS program (version 3.10.0, QGIS Development Team, 2019) that included the geographical location of the points of conflicts indicated by the respondents, and the natural and anthropogenic variables, potentially determining factors of the spatial distribution of conflicts. To select the variables, we considered the interviewees' responses and various related studies (Treves et al., 2011; Karanth et al., 2013; Miller, 2015; Rostro García et al., 2016; Broekhuis et al., 2017). Populated areas with more than 200 inhabitants, estuaries and permanent water bodies were excluded from the analysis, as they are environments where there are no carnivores or livestock. For each selected variable, we constructed raster maps of 100 m resolution. Eight variables were included in the analysis (table 1).

To quantify the livestock density predictor variable, the total heads of cattle, sheep, goats, pigs and horses was extracted from the National Agricultural Census 2008 (INDEC, 2008). This information was used to create a vector map (heads/km$^2$) of the study area.

All the variables were reprojected to the WGS 84/ UTM zone 21S coordinate system, which corresponds to the reference system for the study area. The proportions of anthropized environment, herbaceous vegetation, arboreal vegetation, and livestock density were calculated using the neighborhood analysis with the average function in QGIS using two sizes of radius (846 m and 2877 m). The different radius distances were selected to represent the approximate size of the home range of *P. concolor* females: 26 km$^2$ (De Angelo et al., 2011), and of mesocarnivores: 2.25 km$^2$ (Maffei and Taber, 2003; Luengos Vidal, 2009; Castillo et al., 2019), because the carnivores' perception of the landscape is often related to the size of their home range (De Angelo et al., 2011).

We evaluated the correlation between pairs of variables using a Pearson correlation analysis (Legendre and Legendre, 2012) and no pair showed a correlation greater than 60 %. It was thus decided to use the entire set of variables in the models. They were then cropped to the same geographic extension and transformed into ASCII format for manipulation in the Maxent program.

Modeling and mapping of the probabilities of conflicts

The modeling of the spatial distribution of conflict risk was developed in the MaxEnt 3.4.1 program (Maximum Entropy Species Distribution Modeling: Phillips et al., 2006). This software uses the algorithm of maximum entropy (the most uniform distribution possible) to model the most probable geographic distribution of a species from data of occurrence. In this study we used

Table 1. Variables used in the spatial models of predation risk to predict the probability of the presence of conflicts between humans and carnivores.

*Tabla 1. Variables utilizadas en los modelos espaciales del riesgo de depredación para predecir la probabilidad de que se produzcan conflictos entre humanos y carnívoros.*

| Predictor variable (unit) | Prediction | Reference | Data source |
|---|---|---|---|
| Population density | Lower risk of conflicts (number of people/km$^2$) | There is a strong association between high human density and the loss of carnivore populations (Woodroffe, 2000) | INDEC (2010) |
| Distance from towns (m) | Greater risk at greater distance from towns | The greatest number of attacks on livestock occurs further away from human settlements because predators avoid contact with humans (Davie et al., 2014; Soh et al., 2014; Constant, et al., 2015; Loveridge et al., 2016) | IGN (2017) |
| Distance from roads (m) | Greater risk at greater distance from roads | The risk of predation is positively associated with the distance from roads (Zarco González et al., 2012; Balbuena Serrano, 2017; Soh et al., 2014; Constant et al., 2015; Miller et al., 2015) | IGN (2017) |
| Livestock density (number of heads/km$^2$) | Higher risk at higher density of livestock | Livestock density is one of the strongest predictors of predation by carnivore (Karanth et al. 2013; Carvalho et al., 2015) | INDEC (2008) |
| Distance from protected areas (m) | Greater risk at a shorter distance from protected areas | Human–wildlife conflicts of all kinds are concentrated on the borders of protected areas (Van Bommel et al. 2007; Karanth et al., 2013; Constant et al., 2015) | UNEP–WCMC (2019) |
| Proportion of anthropized environment | Lower risk to higher proportion of anthropized environment | Carnivores avoid highly modified environments preferring natural or relative conserved sites (Caruso et al., 2017) | IGN (2017) |
| Proportion of herbaceous vegetation | Lower risk to higher proportion of herbaceous vegetation | Open areas, such as grassland and wetlands, do not offer cover for hunters that stalk their prey, such as pumas and other cats (Miller et al., 2015; Zarco Gonzales et al., 2012) | IGN (2017) |
| Proportion of arboreal vegetation | Higher risk at intermediate proportion of arboreal vegetation (land covered by approximately 50% trees and shrubs) | Too much coverage can reduce the chance of finding prey and prevents the growth of grass consumed by livestock (Rostro García et al., 2016) | IGN (2017) |

it in an alternative context to measure the spatial risk of predation. The MaxEnt model requires two types of input data: georeferenced carnivore conflict cases and raster maps with environmental and anthropogenic data for the geographic area of interest. Based on this information, MaxEnt estimates the distribution of those areas that present the conditions for the occurrence of conflicts.
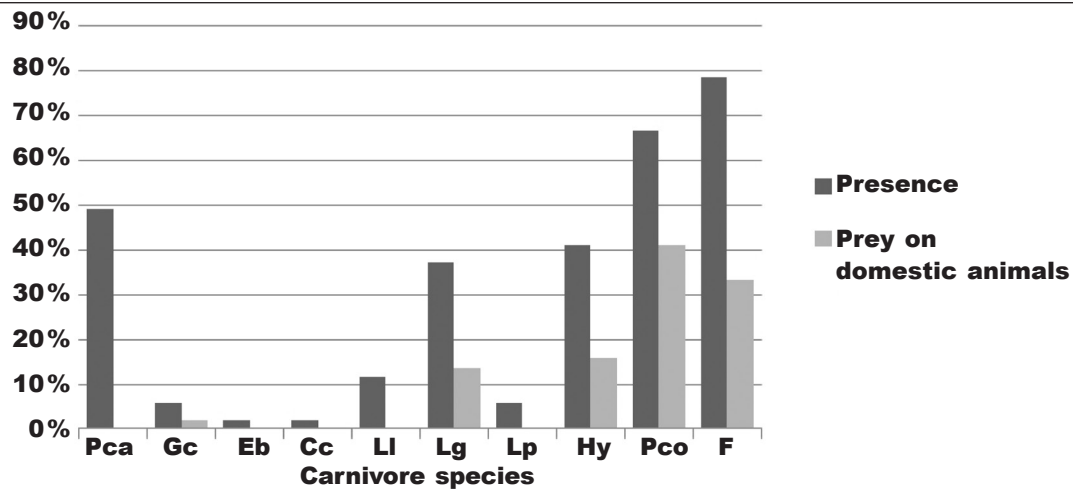
Fig. 2. Percentages of the responses of people interviewed concerning the presence of carnivore species and predation on domestic animals in the study area (N = 51): Pca, *P. cancrivorus*; Gc, *G. cuja*; Eb, *E. barbara*; Cc, *C. chinga*; Ll, *L. longicaudis*; Lg, *L. geoffroyi*; Lp, *L. pardalis*; Hy, *H. yagouaroundi*; Pco, *P. concolor*; F, foxes.

*Fig. 2. Porcentaje de las respuestas de las personas encuestadas sobre la presencia de especies de carnívoros y la depredación de animales domésticos en la zona de estudio (N = 51). (Para las abreviaturas de las especies de carnívoro, véase arriba.)*

Performance of the model was evaluated using Area Under the Curve (AUC) of Receiver Operating Characteristic (ROC). This tool is widely used to measure the predictive capacity of a logistic regression model, with the result obtained being a direct measure of the discrimination capacity of the model. AUC takes values close to 1 when there is a good fit with the evaluation data and close to 0.5 when the fit is not better than that obtained by chance (Benito de Pando and Peñas de Giles, 2007). The models with AUC values between 0.7–0.9 can be considered as moderate discrimination, whereas values > 0.9 indicate high discrimination (Rostro García et al., 2016).

Two models were made, one using the variables calculated with the scale less than 846 m in radius and the other with those obtained for the scale greater than 2,877 m in radius. The models were run using the automatic 'features' option, which uses an algorithm to
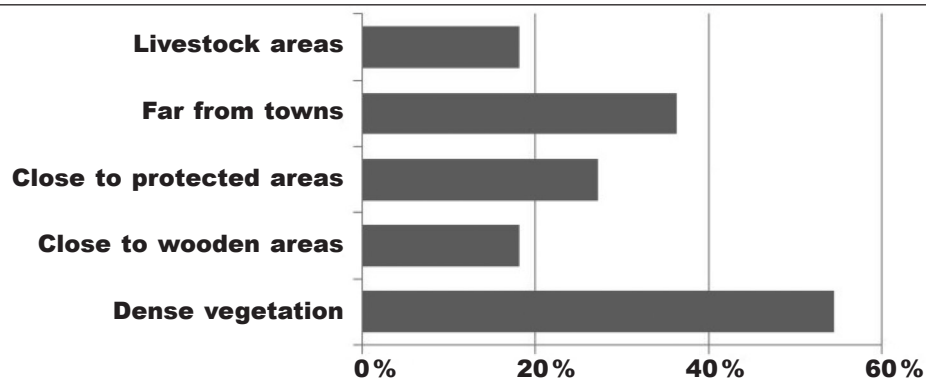


Fig. 3. Environments most conducive to attacks of domestic animals by carnivores based on the perception of the respondents (N = 16).

*Fig. 3. Entornos más propicios para los ataques de carnívoros a animales domésticos según la percepción de los encuestados (N = 16).*
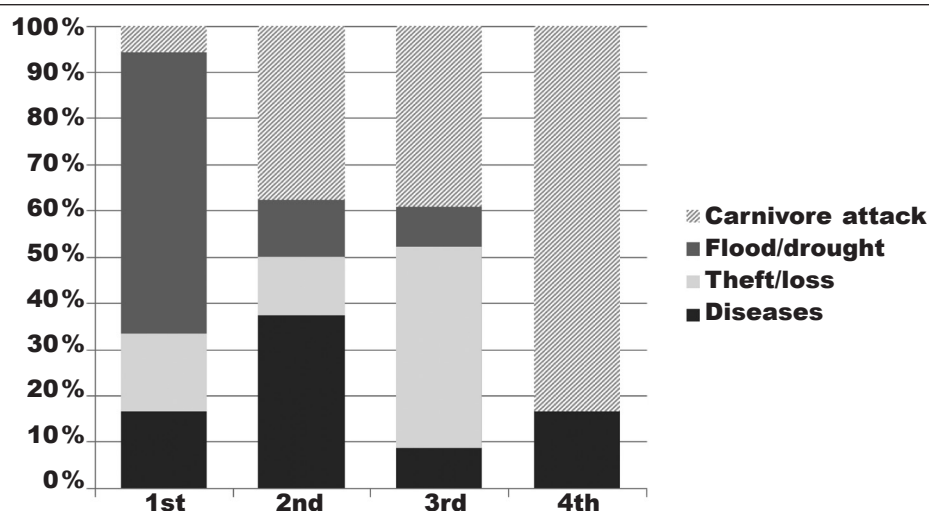
Fig. 4. Main causes of mortality of domestic animals ranked from 1st to 4th according to the respondents (N = 16).

*Fig. 4. Principales causas de mortalidad de los animales domésticos ordenadas de la primera a la cuarta por los encuestados (N = 16).*

determine the most appropriate complexity based on the number of presence records (Syfert et al., 2013). Default settings were used and 10 replicates were performed. A random subset corresponding to 75% of the presence data was used as training to create the model and the remaining 25% was used as test data to assess the precision of the training model. The 'bootstrap' resampling technique was selected and the 'Cloglog' output was obtained, which is proportional to the probability of conflicts (Rostro García et al., 2016). In addition, the response curves of each variable were obtained with graphs to illustrate how the prediction of the model changes with each variable studied. The maps obtained for each model were analyzed in QGIS. The probability of conflicts was divided into three quantiles to obtain the categories of conflict probability: high, medium, and low. Finally, we calculated the surface area that covered the category of high probability of the presence of conflicts in the study area.

## Results

### Surveys

A total of 51 inhabitants were surveyed, 35 in 2016 (62.8% rural inhabitants; 11.4% park rangers and security; 25.8% farm employees), and 16 in 2019 (75% producers and INTA extension workers and 25% park rangers). These surveys indicated that foxes were the most frequently observed carnivores (78.4%), but the respondents did not distinguish between the two species present in the area (*C. thous* and *L. gymnocercus*). Secondly, they mentioned *P. concolor* (66.7%) and

*P. cancrivorus* (49%). Regarding the predation of domestic animals, 64.7% of those surveyed knew of attacks by carnivores, with *P. concolor* being the most conflictive (41.2%), followed by foxes (33.3%) (fig. 2).

Among the total of respondents who mentioned cases of conflict (N = 43), 51% indicated that these were due to attacks on poultry, 44.2% on small livestock (goats, sheep and pigs) and 9.3% on large livestock (cows and horses). The latter cases occurred occasionally and the animals attacked were calves and foals.

In relation to the perception of carnivores, 41.5% of those surveyed expressed a positive perception, 39.2% considered them harmful, 9.8% showed indifference and 5.9% did not respond. In general, the negative opinions came from respondents linked to animal husbandry.

In the 2019 surveys, participants were also asked if the carnivore attacks occurred in particular environments, to which 68.75% answered yes, 12.5% no, and 18.75% did not know of any particular associations. The environments mentioned by those surveyed as being the most conducive to carnivore attacks were areas with dense vegetation (54.5%), areas far from towns (36.4%), and environments close to protected areas (27.3%) (fig. 3).

However, the attack of carnivores was the least mentioned cause of loss of domestic animals; 61% of those surveyed (N = 16) cited floods and droughts as the most frequent cause, 16.7% named theft or loss and, in the same percentage, diseases that affect animals after shortage of resources due to floods and droughts. Only 5.6% ranked carnivore attacks as the first cause of mortality (fig. 4).
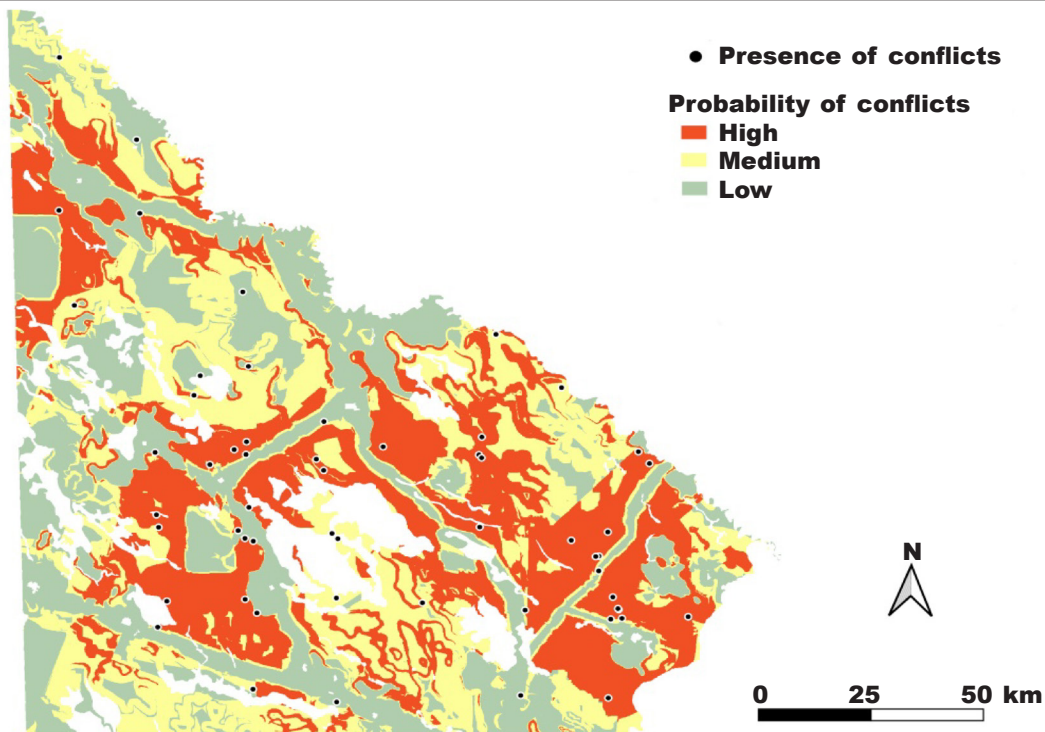
Fig. 5. Distribution of the probability of conflicts with carnivores for the smaller–scale model (846 m radius) in the northeast sector of Chaco province, Argentina.

*Fig. 5. Distribución de la probabilidad de que se produzcan conflictos con carnívoros según el modelo de menor escala (radio de 846 m) en el sector nororiental de la provincia del Chaco, en Argentina.*

## Conflict probability distribution models

A total of 57 sites of presence of conflict with carnivores were obtained from both surveys, 20 of which corresponded to the surveys of 2016 and 37 to those of 2019. In the latter, the majority of respondents indicated more than one site of conflict. For the smaller scale model, the AUC value of the receiver operated characteristic curve (ROC) was of moderate discrimination (0.865) and the standard deviation was low (0.022). The area corresponding to the 'high probability' category covered approximately 5,005 km$^2$, which represents 28.4 % of the total study area (fig. 5).

The variables that most contributed to the distribution model of the probability of conflicts with carnivores were: distance from roads (20.5 %), proportion of anthropized area (18.2 %) and livestock density (17.4 %) (table 2).

The response curves of each variable (fig. 6) showed that the probability of conflicts increased at a greater distance from the roads, but this happened up to 3 km, from when on the probability decreased but increased again after 8 km. On the other hand, the probability of conflicts was higher at proportions between 0.2 and 0.3 of anthropized areas, after which it decreased as the proportion increased. A decrease in the probability of conflicts was also observed with the increase in the livestock density and with the increase in the distance from protected areas.

The larger scale model (radius 2,877 m) also presented moderate discrimination in relation to the AUC of the ROC curve (0.888) and a low standard error (0.012). The area corresponding to the 'high probability' category covered approximately 4,958 km$^2$, which represents 28.2 % of the study area (fig. 7).

The variables that contributed most to this model were livestock density (20.4 %), distance from roads (20.2 %) and proportion of anthropized area (13.9 %) (table 3).

The response curves of each variable indicated that the probability of conflicts decreased with the increase in both the livestock density and the proportion of anthropized area. The variable distance from roads generated the same response as for the previous model (fig. 8).

The predictive maps made it posible to see that the areas with a high probability of conflict were distributed in wide patches and in various sectors of the study area, at the eastern end, around the protected areas, and on the edges of main roads, showing considerable similarity for the two models.

## Discussion

Our study provides novel data on the conflicts between humans and carnivores in the Argentine Humid Chaco. On the one hand, it provides complementary results to those previously obtained in the study area (Soler et al., 2004) on the perceptions and attitudes of rural inhabitants about carnivores and the identification of the most problematic species. On the other hand, it provides the first data on the environmental variables associated with conflicts and their spatial distribution, which arose mainly as a result of the predation of domestic animals whose distribution was associated with anthropogenic variables, such as distance from roads, livestock density and the proportion of anthropized environment.

Characterization of the conflicts

Through the surveys we found that the mountain lion *P. concolor* and foxes *C. thous* and *L. gymnocercus* were considered the most conflictive species due to attacks on small livestock and poultry. Similar results were found in research carried out in other regions of the country, such as the central mountainous area (Pia, 2013), the central east (Caruso et al., 2017), the high Andean area of the northwest (Lucherini et al., 2016), and Patagonia Argentina (Novaro et al., 2017), and also in other areas of South America (Uruguay: Cravino et al., 1999; Bolivia: Pacheco et al., 2004). In contrast to the results obtained by Soler et al. (2004), in the present study the cases of predation by *P. concolor* represented a high proportion. This might be due to a possible increase in the number of pumas in recent years. Recent studies indicate that in nearby regions the species has recolonized areas where it had previously been eliminated, for example in the provinces of Entre Ríos (Bonnot et al., 2011; Muzzachiodi, 2012; Carmarán, 2013), Corrientes (Soler and Cáceres, 2008) and Buenos Aires (Chimento and De Lucca, 2014), as well as in Uruguay (Martínez et al., 2010) and Brazil (Mazzoli, 2012), where it has been possible to detect the

Table 2. Percentage of contribution (P) of each variable to the smaller–scale Maxent model (846 m radius). This model had a mean ± SE area under the curve (AUC) of 0.865 ± 0.022.

*Tabla 2. Porcentaje de la contribución (P) de cada variable al modelo Maxent de menor escala (radio de 846 m). Este modelo tenía un área media ± EE debajo de la curva de 0,865 ± 0,022.*

| Variable | P |
|---|---|
| Distance from roads | 20.5 |
| Proportion of anthropized area | 18.2 |
| Livestock density | 17.4 |
| Distance from protected areas | 13.2 |
| Distance from towns | 12.0 |
| Proportion of arboreal vegetation | 7.5 |
| Population density | 7.1 |
| Proportion of herbaceous vegetation | 4.1 |

species in recent years in areas where it had previously been thought to be extinct. However, Quiroga et al. (2016) found a low density of pumas in the Western Chaco, assuming that this could be mainly due to retaliation by local ranchers in response to goat predation. Therefore, the density of the species should be corroborated with specific studies in the different areas. Pumas can cause considerable economic loss when an attack involves the death of several animals (Pacheco et al., 2004) as is common behavior of the female during the breeding season, according to several respondents. Its impact on the livestock, especially when they are with young, can be very harmful, since a single individual can kill several sheep and goats (Ruth and Murphy, 2009).
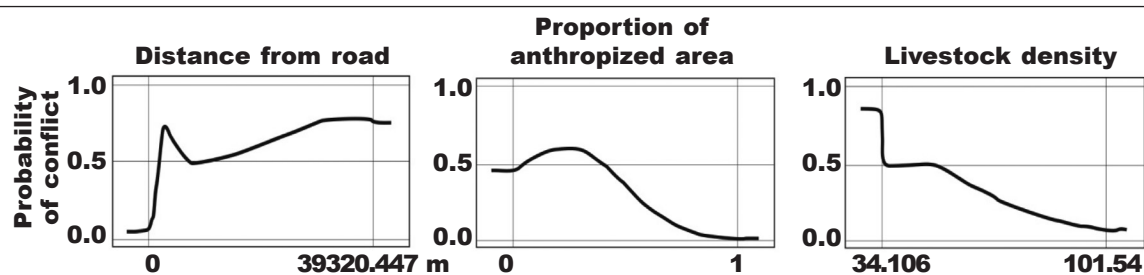


Fig. 6. Response curves of the Maxent model on the smaller scale, showing the relationship between the variables that contribute most to the model and the probability of the presence of conflicts.

*Fig. 6. Curvas de respuesta del modelo de Maxent en menor escala que muestran la relación entre las variables que más contribuyen al modelo y la probabilidad de que se produzcan conflictos.*
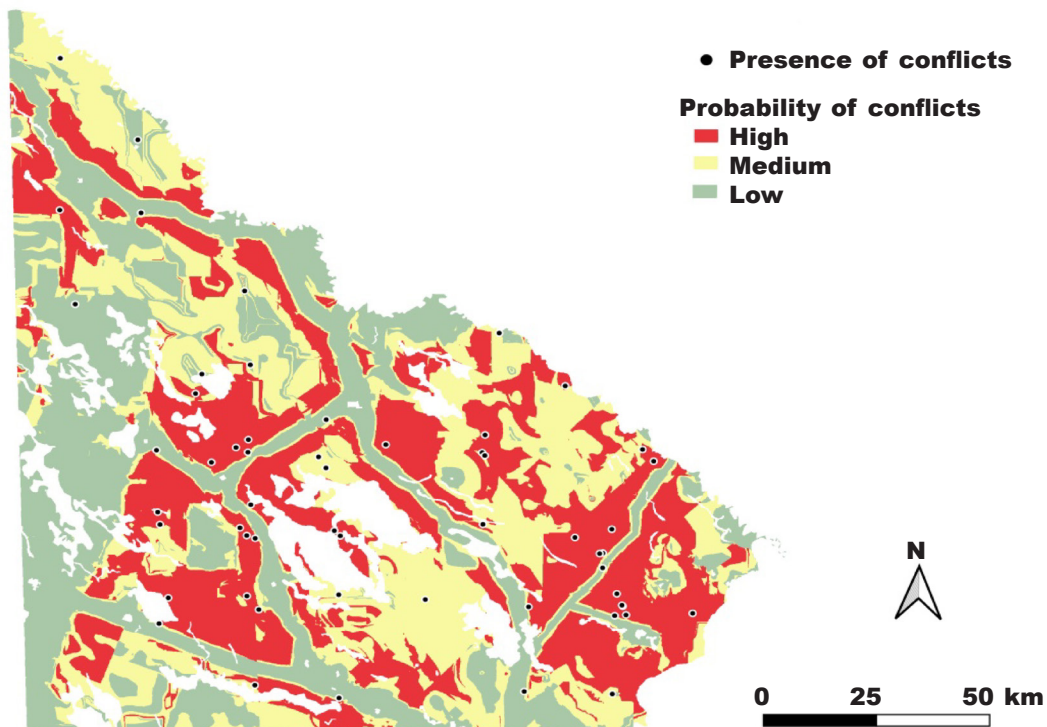
Fig. 7. Distribution of the probability of conflicts with carnivores for the larger–scale model (2,877 m radius) in the northeast sector of Chaco province, Argentina.

*Fig. 7. Distribución de la probabilidad de que se produzcan conflictos con carnívoros según el modelo de mayor escala (radio de 2.877 m) en el sector nororiental de la provincia del Chaco, en Argentina.*

In the case of the other species mentioned as conflictive in this study, and as reported by Soler et al. (2004), foxes are the most problematical predators, followed by *H. yagouaroundi*, *L. geoffroyi*, *C. brachyurus* and C. chinga. Both species of foxes, *L. gymnocercus* in particular, would be the most common carnivores in the study area, in the Dry Chaco (Paulucci, 2018) and in other ecoregions of Argentina such as the Monte and the Pampa (Luengos Vidal et al*.,* 2019). These species are generally considered predators of lambs and poultry, despite the fact that previous studies on their trophic niche, in the same study area, did not report any signs of domestic livestock in their diet (Iaconis, 2015). On the contrary, the most commonly consumed items mentioned were insects, small mammals, and fruit (Iaconis, 2015). Likewise, studies carried out in Brazil (Pradella Dotto, 1997) and in Uruguay (Cravino et al*.,* 1999) did not present sufficient evidence to consider *L. gymnocercus* as an important predator of livestock. Other studies carried out in the Dry or Western Chaco of Argentina showed that fruit predominated in the diet of *L. gymnocercus*, and the predation on domestic cattle was insignificant (Varela et al., 2008). The predation mentioned by respondents would thus appear to be due to a perceived threat rather than

to an actual threat. People's perceptions do not always match the real behavior of carnivores as they can be shaped by social and cultural influences, economic pressure, personal values, and historical events (Bruskotter and Wilson, 2014; Suryawanshi et al., 2013). Moreover, farmers may overestimate the presence of conflictive species (Caruso et al., 2017) and the levels of mortality caused by predation due to confusion with post–mortem mutilation (Cravino et al., 1999). In general, the respondents had not kept track of the number of lost animals, and thiscould also have led them to overestimate losses caused by predators. Besides, predation of poultry by domestic dogs might account for the harm caused by foxes being overestimated.

Our sampling to measure perceptions included diverse perspectives from the people living in the study area. The results showed that the perception of carnivores varied according to the occupation of the respondent, with positive opinions coming from conservation agents and agricultural advisors, probably due to their better understanding of the ecological role of carnivore species and appreciation of nature. Several studies have shown that human perceptions of wildlife are affected not only by educational level (Conforti and de Azevedo, 2003; Røskaft et al.,

2007), but also by economic interests, so it can be expected that people who rear animals may have negative opinions.

The prevalence of causes of mortality of domestic animals that are not related to predation indicates that conflicts with carnivores in the study area are relatively less relevant than in previously mentioned areas such as northern Patagonia (Novaro et al., 2017) and the southwest of Buenos Aires province (Guerisoli et al., 2017) where predation was considered the main cause of livestock loss. In the Humid Chaco the rearing of goats and sheep is lower than in these two regions (INDEC, 2008) and large livestock –that are predominant in our study area– are less vulnerable to attack by carnivores than small livestock, which is a feasible explanation for the low rate of predation. Diseases and cycles of floods and droughts under conditions of scarce adoption of agricultural technology created the greatest losses. Cravino et al. (1999) reported that producers in Uruguay recognized that the mortality of lambs due to climatic causes far exceeded that ascribed to predation even though hunting and the placement of poison and traps for foxes was a common practice.

### Spacial distribution of the conflicts

The results of the spatial risk modeling of the conflicts between humans and carnivores showed that regardless of the scale of analysis, the variables that contributed most to explaining the distribution of the conflicts were the distance from roads, the proportion of anthropized environment, and livestock density. All of these variables are associated with human presence, suggesting that carnivore behavior could be strongly determined by human activities and infrastructure. The distance from the roads showed a maximum probability of conflict within 3 km. This result coincides with that documented by Miller et al. (2015) in India where the risk of attacks on livestock by tigers (*Panthera tigris*) reached its maximum point at 1 km from the roads, a value which could represent a threshold distance, as here livestock can access quality pastures and carnivores can access prey without the inhibition of human

Table 3. Percentage of contribution (P) of each variable to the larger–scale Maxent model (2,877 m radius). This model had a mean ± SE area under the curve (AUC) of 0.888 ± 0.012.

*Tabla 3. Porcentaje de la contribución (P) de cada variable al modelo Maxent de mayor escala (radio de 2.877 m). Este modelo tenía un área media ± EE debajo de la curva de 0,888 ± 0,012.*

| Variable | P |
|---|---|
| Livestock density | 20.4 |
| Distance from roads | 20.2 |
| Proportion of anthropized area | 13.9 |
| Proportion of herbaceous vegetation | 12.8 |
| Distance from protected areas | 9.0 |
| Distance from towns | 8.7 |
| Proportion of arboreal vegetation | 7.7 |
| Population density | 7.3 |

presence. On the other hand, our results might reflect the use of roads by carnivores for their dispersal within their territories, which could be particularly true in areas with dense vegetation, such as in crop fields, grasslands, and scrublands. Local roads may enable permeability through habitat structures (Červinka et al., 2013), resulting in a higher proportion of conflicts. Many large species of predators move on roads with low traffic, as reported found by Forman and Alexander (1998). Wolves, for example, may select roads of low use as travel routes (e.g., Whittington et al., 2005). Research on the use of the roads by carnivores in the area could shed light on this assumption.

In our study area, the livestock density showed a negative relationship with respect to the probability of conflicts, that is, the higher the livestock density, the lower the risk of
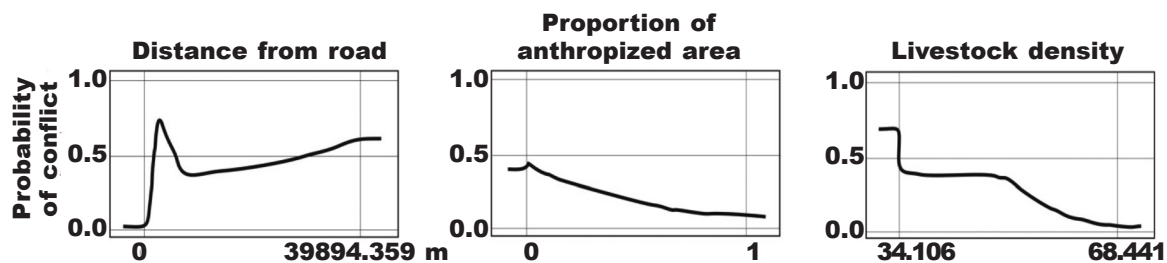


Fig. 8. Response curves of the Maxent model on the larger scale, showing the relationship between the variables with the greatest contribution to the model and the probability of the presence of conflicts.

*Fig. 8. Curvas de respuesta del modelo de Maxent en mayor escala que muestran la relación entre las variables que más contribuyen al modelo y la probabilidad de que se produzcan conflictos.*

predation. This may seem contradictory and contrary to that recorded by Karanth et al. (2013) and Carvalho et al. (2015), who concluded that high livestock densities were related to a higher risk of predation. However Zarco González et al. (2012) showed the existence of a negative relationship for the cases of puma predation, as in our research, which in their case might be due to the fact that the livestock were kept in protected yards and far from wooded areas. On the other hand, we think that these results may also be due to the fact that a higher livestock density is associated with degraded environments and a higher density of human settlements. However, our results could be explained on the basis of the sampling method implemented in 2016, where the surveys were concentrated in the eastern sector of the study area where the livestock density was lower than in the western sector. Uniform sampling would be necessary to define the influence of this variable on the distribution of conflict probabilities. Finally, it is necessary to bear in mind that we are studying a community of carnivores where, in general, mesocarnivores prey preferentially on poultry, whose distribution and density were not analyzed. Future research should consider a more homogeneous sampling design, considering the probabilities of attacks by pumas and mesocarnivores separately and accompanied by a distribution map of the density of poultry.

The lower probability of conflict in highly altered environments could indicate that carnivores avoid degraded areas, which supports our prediction. Although human activities can affect all species of carnivores, this effect varies depending on the ecological and behavioral attributes of each species (Caruso et al., 2016). For example, the puma prefers less degraded sites and is seriously affected by habitat destruction, although it is able to tolerate some degree of fragmentation of natural environments (De Angelo et al., 2011). On the other hand, *L. gymnocercus* and *L. geoffroyi* can inhabit highly modified areas (Pereira et al., 2012; Caruso et al., 2016), demonstrating a degree of ecological plasticity that allows them to tolerate human disturbance, and they survive even in strictly agricultural areas (Pereira et al., 2012). However, it can not be overlooked that the absence, or lower density, of carnivores in anthropized environments may also be due to their elimination by the inhabitants and their dogs, or to a lower abundance of their natural prey (Pereira et al., 2012).

Conclusions

Our analysis of the distribution of conflicts is an estimate of the probability of their presence, and therefore, it is subject to the initial data that we decided to incorporate as predictor variables. In addition, the geographic location of presence data may exhibit spatial autocorrelation, and biases due to sampling.The selection of the options offered by the Maxent software can also affect the results. The location and intensity of data collection in wildlife studies are usually strongly influenced by accessibility to the terrain. Samples are often collected in relatively accessible locations near to roads, urban settlements, and rivers, as was the case

in our study. This potential bias can have an impact on the modeling process and give results that reflect sampling effort rather than the actual distribution of a species or process (Syfert et al., 2013).

On the other hand, it is possible that other factors, such as the abundance of prey, could be important predictors of the distribution of conflicts, despite the fact that they were not taken into account in this study due to the lack of such information. Moreover, our study did not consider any possible differences, in particular, of the predation by each of the species that make up the carnivore guild in this region, so it would be important to take this into account in future studies. The nature of the surveys did not allow the interviewers to verify which species of carnivores were responsible for the attacks and, therefore, we grouped all the data to generate a map of the general risk of conflicts. The environmental variables had almost the same influence in both scales of analysis, so we can assume that the presence of conflicts in our study area does not depend on the scales we used, unlike those found by several studies that analyzed the dependency of the spatial scale on the predation events (Miller et al., 2015; Rostro García et al., 2016; Broekhuis et al., 2017). On the other hand, no significant differences were observed in the distribution of conflicts in the study area, corroborating the importance of the three variables that contributed most to the models.

Although the conflict probability maps showed a wide distribution of the areas with the highest probability, the respondents identified other causes of mortality of domestic animals that produce more losses than predation. Dissemination campaigns that provide information related to improving livestock management practices are thus recommended. Monitoring cases of predation and community workshops should be organized to agree on strategies aimed at preventing predation and promoting coexistence with the native fauna.

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Annex. Survey questionnaire.

*Anexo. Cuestionario de la encuesta.*

Questions asked during interviews with rural inhabitants in 2016.
*Preguntas formuladas durante las entrevistas personales realizadas a los pobladores rurales en 2016:*

1. What species of carnivores have you seen in the area?

2. How frequently have you seen them?

3. Do any of the ones mentioned attack farm animals?

4. Did you shoot them?

5. Do you know anyone who shot or caught them?

6. Why do they kill them?

7. Do you consider that the carnivores mentioned are harmful species?

8. Would you like to make any further comments?

Surveys by electronic forms to producers, INTA extension agents and park rangers in 2019
*Encuestas realizadas por medios electrónicos a productores, agentes de extensión del Instituto Nacional de Tecnología Agropecuaria (INTA) y guardaparques en 2019:*

1. Do you know about any conflicts between carnivores and rural inhabitants living in the Humid Chaco?
    a. Yes
    b. No
    c. Very little

2. Look at the image and mark any grids where you know of cases of conflicts with carnivores. If there are no conflicts in your area, answer: none. If the conflict zone is not marked by the grids, please indicate where the conflict is located.
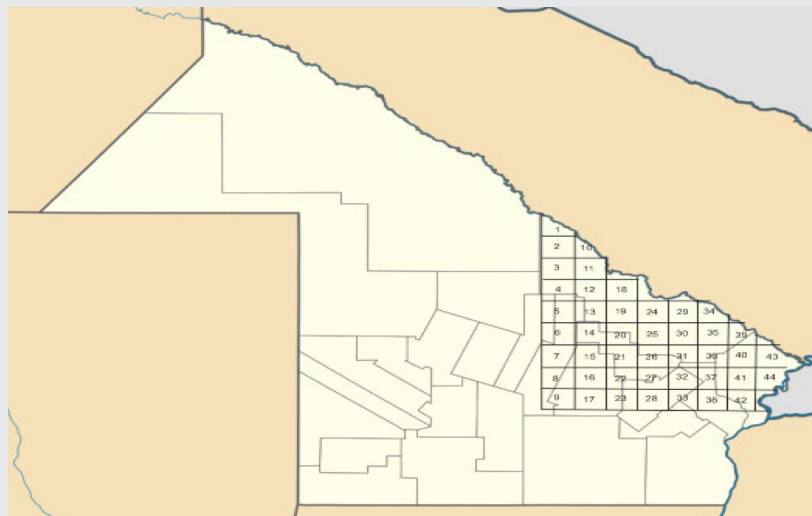
3. What species of wild carnivores do you know that inhabit the area? Which of them are seen most often?

4. Do any of these carnivores attack livestock or other farm animals? If so, which carnivores are they?

5. What animals do rural people keep in your area? (You can mark more than one option)
        a. Poultry
        b. Goats
        c. Pigs
        d. Sheep
        e. Cattle
        f. Horses

6. The following are causes of loss of animals: disease, floods or drought, lost animals, theft, attacks by carnivores. Which of these do you consider causes the most losses and which causes the fewest?

7. How often do carnivores attack domestic animals?
        a. Never
        b. A few times a year
        c. Approximately every month
        d. Approximately every week
        e. Don't know

8. In the case of attacks, which animals are most preyed upon by carnivores?

9. What is the general perception of the community towards carnivores?
        a. They are considered harmful
        b. They are tolerated
        c. Their presence is considered important to the environment
        d. Other

10. What is the attitude of the inhabitants towards carnivores?
        a. Indifference
        b. They chase them away with guns
        c. They chase them with dogs
        d. They try to kill them
        e. Other

11. Do conflicts occur more frequently in a particular type of environment?
        a. Yes
        b. No
        c. Don't know

12. If you answered yes to the previous question, what characteristics do these environments present? For example: near protected areas, away from towns, in areas with a lot of vegetation, etc.

13. Are there policies implemented by the government to solve the problem of human–carnivore conflicts?
        a. Yes
        b. No
        c. If yes, what are they?

14. Do you have any other comments related to this subject that you would like to share?