

Human perceptions of and interactions with wild canids on cattle ranches in central Brazil

STACIE M. BICKLEY, FREDERICO G. LEMOS, MICHAEL P. GILMORE
FERNANDA C. AZEVEDO, ELIZABETH W. FREEMAN and NUCHARIN SONGSASEN

Abstract Local attitudes towards carnivores often reflect the degree of damage they are perceived to cause. Consequently, understanding the interactions between people and these species is essential to conservation efforts. This study investigated local perceptions of three Cerrado canid species and current chicken management practices, to identify the potential damage they cause and how this relates to peoples' attitudes towards these species. Results from structured interviews at 50 ranches in Goiás, Brazil, highlighted that general knowledge about Cerrado canids differed significantly by species, with interviewees unable to correctly answer questions about the hoary fox *Lycalopex vetulus* and crab-eating fox *Cerdocyon thous* in comparison to the maned wolf *Chrysocyon brachyurus*. Chicken coops were identified as the most effective method for preventing predation, yet only 44% of respondents employed this method. Using a perceived predation measure, interviewees reported chicken predation by all three Cerrado canids even though most of these events were stated to occur during the day, outside the species' active periods. Reported predation events were a strong predictor of attitude. Participants who experienced predation events reported they did not like having a Cerrado canid on their property. However, 86% of the respondents agreed that Cerrado canids should nevertheless be protected. Our findings support the need to incorporate the human dimension in canid and broader carnivore conservation issues.

Keywords Attitudes, Brazilian savannah, canid conservation, Cerrado, human–canid interactions, predation

Supplementary material for this article is available at <https://doi.org/10.1017/S0030605318000480>

Introduction

Amongst terrestrial mammals, carnivores are the most threatened group and the most challenging to conserve (Karanth & Chellam, 2009). People tend to see carnivores, particularly large species such as the jaguar *Panthera onca* and lion *Panthera leo*, as a direct threat. These species compete for land and game and sometimes prey upon livestock (Sillero-Zubiri & Laurenson, 2001). Intolerance for carnivores has led to the persecution, decline and local extinction of some species (Treves & Karanth, 2003). Although some carnivore populations are increasing as a result of conservation initiatives (e.g. LaRue et al., 2012), encounters between people and carnivores will probably increase as the human population continues to grow.

Factors such as age, education, and knowledge about carnivores can affect people's attitude and willingness to conserve a species. For example, older respondents hold a more negative view of jaguars than younger individuals (Zimmermann et al., 2005), and ranchers who have completed fewer years of school show stronger negative attitudes towards the species than those with higher education (Cavalcanti et al., 2010). The more knowledge a person has of a species, the more likely they are to protect it or view wildlife positively (Kellert, 1985), although more knowledgeable individuals, such as hunters, may have less favourable attitudes towards carnivores (Ericsson & Heberlein, 2003). Therefore, the knowledge and attitudes of people living with wildlife need to be assessed and integrated into conservation strategies.

Attitudes towards carnivores may also reflect the degree of negative interaction between a person and a species (Kellert, 1985). In South Africa, for example, negative attitudes towards the African wild dog *Lycaon pictus* are related to the economic costs of livestock and wild game predation (Lindsey et al., 2005). Domestic livestock are ideal prey for carnivores as they are often abundant and easy to catch in comparison to other prey (Palmeira et al., 2008). Ranchers troubled by livestock predation have a range of protection techniques available to them (Smith et al., 2000;

STACIE M. BICKLEY*† (Corresponding author) Environmental Science and Policy, George Mason University, Fairfax, Virginia, USA
E-mail stacie.bickley@cincinnatizoo.org

FREDERICO G. LEMOS‡ and FERNANDA C. AZEVEDO Cerrado Mammals Conservation Program, Special Academic Unit of Biotechnology, Federal University of Goiás/Catalão, Goiás, Brazil

MICHAEL P. GILMORE and ELIZABETH W. FREEMAN School of Integrative Studies, George Mason University, Fairfax, Virginia, USA

NUCHARIN SONGSASEN Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal, Virginia, USA

*Current Address: Center for Conservation and Research of Endangered Wildlife, Cincinnati Zoo and Botanical Garden, 3400 Vine St., Cincinnati, Ohio 45220, USA

†Also at: Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal, Virginia, USA

‡Also at: Natural Resources Ecology and Conservation Postgraduate Program, Institute of Biology, Federal University of Uberlândia, Minas Gerais, Brazil

Received 29 June 2017. Revision requested 21 September 2017.
Accepted 26 March 2018. First published online 17 January 2019.

Sillero-Zubiri et al., 2004; Sillero-Zubiri & Switzer, 2004). Some of these strategies are non-invasive (e.g. flags on fencing), whereas others may result in the carnivore's death (e.g. shooting). Managers must appraise the expenditure of money and time, effectiveness, legality and cultural appropriateness of each technique.

Most research on human–carnivore interactions and attitudes towards these species has focused on larger species. Human–canid interactions are well documented for large species such as the grey wolf *Canis lupus* (Treves et al., 2004), Ethiopian wolf *Canis simensis* (Yihune et al., 2008), coyote *Canis latrans* (Draheim, 2012) and maned wolf *Chrysocyon brachyurus* (Emmons, 2012), but less so for small canids other than the red fox *Vulpes vulpes* (Moberly et al., 2004). Of the 36 species of canids, 10 live in South America (Sillero-Zubiri, 2009). Knowledge of interactions with these species is limited to a few studies of the Andean fox *Lycalopex culpaeus* (Travaini et al., 2000), South American grey fox *Lycalopex griseus* (Silva-Rodrigues et al., 2009), hoary and crab-eating foxes *Lycalopex vetulus* and *Cerdocyon thous* (Lemos et al., 2011a) and bush dog *Speothos venaticus* (DeMatteo, 2008).

The maned wolf, crab-eating fox, and hoary fox are sympatric in the Cerrado ecosystem (Juarez & Marinho-Filho, 2002; Jácomo et al., 2004; Lemos, 2016). The Cerrado was once an expansive grassland, but intense agriculture and ranching has severely altered the landscape (Klink & Moreira, 2002; Klink & Machado, 2005). Because of these activities, the hoary fox (endemic to the Cerrado) and the maned wolf are currently categorized as Vulnerable in Brazil (Lemos et al., 2013; Paula et al., 2013), even though these species are categorized as Least Concern (Dalponte & Courtenay, 2008) and Near Threatened (Paula and DeMatteo, 2016), respectively, on the IUCN Red List. The crab-eating fox remains common throughout its range and is categorized as Least Concern both globally (Lucherini, 2015) and in Brazil (Beisiegel et al., 2013).

In such a highly fragmented landscape, native prey species may be uncommon and domestic livestock becomes an accessible alternative prey for carnivores. Abade et al. (2012) reported that in the Cerrado ecosystem the perceived loss of domestic fowl (chickens, ducks, geese and guinea fowl) was an unwelcome interaction between landowners and Cerrado canids. Our study builds on this work, examining the socio-economic factors that may influence peoples' attitudes towards Cerrado canid species. We used structured interviews to examine local knowledge of Cerrado canids and attitudes towards these species. Because Abade et al. (2012) reported that canids in our study area preyed on domestic fowl rather than other domestic species such as calves, we also quantified current chicken management practices and measured the perceived cost and effectiveness of these methods. We hypothesized that (1) interviewees who correctly identified and demonstrated knowledge about Cerrado canids would

have a more positive attitude towards them, (2) the method perceived most effective for preventing predation of domestic animals would be the most frequently implemented, and (3) respondents who experienced predation of chickens would have a more negative attitude towards predators.

Study area

This study was carried out in the Limoeiro region, a farming area within the municipality of Cumari, Goiás state, in central Brazil (Fig. 1) that comprises contiguous private cattle ranches and small-scale agriculture operations (e.g. rubber trees, corn and sugarcane; collectively c. 150 km²). The landscape is dominated by exotic pasture (*Urochloa* spp.; 73%), with the remaining area being a mosaic of natural gallery and seasonal forests (21%) and open Cerrado sensu stricto (4%; Lemos, 2016). The climate is tropical with two well-defined seasons, cold/dry (May–September) and hot/wet (October–April; Alvares et al., 2013), with mean temperatures of 19 and 30 °C, respectively, and a mean annual precipitation of 1,551 mm (CPTEC/INPE, 2015).

Methods

Surveys

Fifty ranches in the Limoeiro region that raised domestic fowl were opportunistically surveyed during June–August 2014. The selected respondent at each ranch was at least 18 years old and was directly responsible for managing the domestic fowl: either the owner (rancher, 44%) or the hired ranch hand (cowboy, 56%). Each respondent was asked to sign a consent form before starting the interview, was assured confidentiality, and could discontinue or withdraw from the interview at any time. All interviews were conducted in Brazilian Portuguese, with the assistance of a native speaker, and recorded.

Questionnaire

We used a structured questionnaire developed to evaluate the interviewees' knowledge, experience, and attitudes towards the maned wolf and crab-eating and hoary foxes, and domestic fowl management practices. The questionnaire was first tested at 15 ranches, refined, and retested at the same 15 ranches. The final questionnaire (Supplementary Material 1) was administered at an additional 35 ranches and comprised 20 questions that combined multiple-choice (nominal data) and open-ended questions (Bernard, 2006). Comments made by interviewees that complemented answers were noted, but were not included in the data analysis.

The questionnaire had sections on demographics, knowledge of carnivores and Cerrado canids, domestic fowl

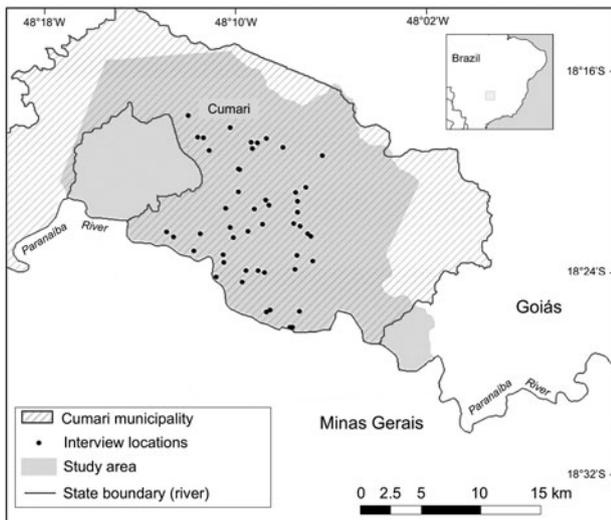


FIG. 1 Locations of ranches in the Limoeiro region, municipality of Cumari, Goiás state, in central Brazil, where interviews were conducted to investigate local perceptions of three Cerrado canid species: the maned wolf *Chrysocyon brachyurus*, the crab-eating fox *Cerdocyon thous* and the hoary fox *Lycalopex vetulus*.

management practices, and attitudes towards Cerrado canids. A canid knowledge score was calculated. Participants were first asked to identify the three species from photographs, and then, for each species, to select its prey from a list, its social structure, and indicate when it is most active. An interviewee was assigned one point for each correct response, for up to a total of four points per species. An overall knowledge score was calculated by summing the three canid knowledge scores (the maximum possible score was 12).

Chicken management practices observed during initial ranch visits were standardized on the questionnaire to nine common methods of preventing predation. Perceptions of the cost and effectiveness of these methods were measured by asking interviewees to identify the most and least expensive, and most and least effective predation prevention practice. Interviewees also answered questions about each perceived chicken predation by Cerrado canids and other species, and the occurrence of these events.

Attitudes towards each Cerrado canid species were measured using a series of suggested statements. Respondents were asked whether they agreed or disagreed with each statement, or they could indicate 'unknown'. Interviews concluded with a tour of the ranches' domestic fowl rearing facilities.

Statistical analyses

Descriptive statistics were derived for all qualitative questions. A *t* test was used to determine if selling chickens (yes, no) influenced the quantity of chickens raised in the past year at each ranch. Canid knowledge scores among

species were compared using a repeated measures ANOVA and Tukey's Honestly Significant Difference post-hoc test. A multiple linear regression model was used to identify which combination of explanatory variables (age, education level, position on the ranch, sale of chickens) contributed to a person's knowledge of Cerrado canids. Relationships with categorical variables (predation prevention method, attitudes towards canid species, action taken in response to domestic fowl predation) were analysed using a χ^2 test. If the expected outcome was < 5 , a Fisher's exact test was used instead (Sokal & Rohlf, 1995). Bivariate analyses were conducted between reported perceived predation and number of chickens, and between predation and number of predation prevention methods employed. A bivariate regression analysis was conducted between attitude (agreement or disagreement with the statement 'I like having this animal on my ranch') and explanatory variables (education level, sale of chickens, experience with predation, knowledge score and age).

All statistical analyses were conducted using R 3.2.3 (R Development Core Team, 2015). Models were fitted by a backwards stepwise process: all variables were initially included in the model (a saturated model) and then the Akaike information criterion (AIC) was used to remove the parameters that least affected the model fit (Burnham & Anderson, 2002).

Results

Demographics

Fifty male respondents participated in structured interviews (men generally oversaw the management of the domestic fowl). The mean age of the study population was $53.62 \pm \text{SE } 2.09$ years and 68% had completed ≤ 8 years of schooling. Ranch size varied (1.21–1,306.80 ha) but the majority (56%) were < 300 ha. The respondents who sold their chickens and/or eggs ($< 20\%$) raised significantly more chickens ($73.89 \pm \text{SE } 8.90$) than those who did not sell them ($44.53 \pm \text{SE } 5.57$; $t_{31} = 2.80$, $P < 0.01$). Respondents sold a dozen eggs for BRL 5–8, and chicks, hens and roosters for BRL 10, 15–20 and 30 each, respectively. Almost all respondents (96%) reported the domestic fowl and their eggs formed part of the family's diet.

Knowledge of Cerrado canids

Respondents' knowledge of canids differed significantly by species ($F_{2,98} = 40.82$, $P < 0.01$). Post-hoc tests indicated that knowledge scores (on a scale of 0–4) were significantly higher for the maned wolf ($3.64 \pm \text{SE } 0.07$) than for the crab-eating fox ($2.84 \pm \text{SE } 0.12$) and hoary foxes ($2.36 \pm \text{SE } 0.13$), and knowledge of the crab-eating fox was greater than that

of the hoary fox ($P < 0.01$). Eighty-eight per cent of the interviewees correctly identified the maned wolf from a photograph, whereas 28% misidentified the two fox species for each other. A multiple regression model did not reveal ($P > 0.05$) any combination of variables (i.e. age, education level, position on the ranch, sell chickens) that could explain overall knowledge of Cerrado canids.

Current chicken management practices

Domestic fowl included chickens, guinea fowl, ducks and geese. All respondents raised chickens and $< 20\%$ raised a small number (≤ 10) of guinea fowl, ducks and/or geese in addition to chickens. As chickens were the predominant domestic fowl species, results hereafter will be presented in the context of management of chickens. However, management practices were consistent across all types of domestic fowl.

On 90% of the ranches chickens were allowed to range freely around the property during the day. Less than half (44%) of the ranches confined their chickens in some form of chicken coop or fenced yard at night. At the other ranches, chickens roosted in trees (48%), in a covered cattle corral (6%) or on roosting ladders (2%) at night. Chicks aged 5–30 days were kept in an enclosed area both day and night at 62% of the ranches. No difference in the use of chicken coops/fenced yards was found between respondents who sold their chickens and/or eggs and those who did not ($\chi^2 = 0.41$, $df = 1$, $P = 0.58$).

Nine additional management practices to prevent chicken predation were identified (Table 1). The most common practice (90%) used by the study population was keeping one or more untrained, outdoor dogs. Lights, noise, flags, poison, electric fencing and scarecrows were used at $\leq 26\%$ of the ranches (Table 1).

Perceptions of common management practices

Respondents perceived chicken coops to be the most expensive (72%) and most effective (38%) management practice to prevent predation (Table 1). Dogs and banners/flags were identified as being among the cheapest methods (30 and 34%, respectively); however, the use of dogs was perceived as being more effective (30%) than banners/flags (26%; Table 1). Interviewees considered the use of scarecrows to be an ineffective management practice, although the few ranches that used them reported not experiencing predation (Table 1).

Perceived chicken predation by Cerrado canids

A total of 32 cases of perceived chicken predation were reported to have occurred among 20 of the 50 ranches in the

year prior to the study. Respondents reported the hoary fox as the culprit in 38% of the predation events, the maned wolf in 35% and the crab-eating fox in 28%. When asked how they knew which animal took the chicken(s), some respondents stated that either they or the ranch hand had seen the canid (hoary fox: 72%, maned wolf: 52%; crab-eating fox: 55%). Birds of prey and the striped hog-nosed skunk *Conepatus semistriatus* were also frequently reported to have taken chicks and eggs, at 18 and 16% of ranches, respectively. A full list of species perceived to be predators of chickens is provided in Supplementary Table 1. Reported predation events were not related to the number of chickens on the ranch ($Z = 0.86$, $P = 0.39$).

Respondents used 0–5 predation prevention methods ($2.42 \pm SE 0.18$); however, there was no relationship between number of predation events and the number of methods employed ($Z = 0.83$, $P = 0.41$). Furthermore, interviewees reported that predation occurred regardless of which prevention method they used, except for scarecrows (Table 1). Poison was particularly ineffective ($P = 0.01$) at preventing predation of chickens (Table 1). Of those who lost chickens to predation, 65% stated that predation events occurred when the chickens were in the yard during the day. Total economic loss as a result of chicken predation could not be calculated because some respondents (39%) were unsure of the number of chickens killed, and others (54%) gave a range rather than a number.

Attitudes towards Cerrado canids

Most respondents (78–86%) agreed that they liked having Cerrado canids on their property even though 92% of the interviewees perceived these species to be a threat to chickens (Table 2). Fewer respondents (8%) perceived them to be a threat to cattle (Table 2). When asked about the ecological benefits of wild canids, 50–64% of respondents remarked that these animals eat the rodents and insects on their ranch, and 78–92% agreed that Cerrado canids were valuable (Table 2).

A logistic regression model indicated that perceived predation was the best variable for explaining the attitudes of interviewees towards Cerrado canids (Tables 3 & 4). Local people who experienced predation of their livestock reported not liking these species. Four interviewees admitted to killing at least one Cerrado canid while living in the area but no one stated they had killed a wild canid in the previous year. One respondent commented that the killing was in response to chicken predation, and two respondents said their dogs had carried out the killing. Attitude was a significant predictor of wanting to protect these species ($Z = 2.18$, $P = 0.03$); those who had a positive attitude towards these species agreed they should be protected. When asked what action participants would take in response to chicken

TABLE 1 A summary of the per cent of 50 ranches in the Limoeiro region, central Brazil (Fig. 1), using common chicken predation prevention techniques in relation to interviewees' views of the perceived cost and effectiveness of each method. Perceived predation events are reported as the percentage of ranches experiencing predation while using the method. A goodness-of-fit test determined the ability of each method to prevent predation.

Method	Ranches using ¹	Cost		Effective		Perceived predation events (%)	Goodness-of-fit test	Result
		Most	Least	Most	Least			
Banner/flags	16	0	34	0	26	12.5	Exact test	P = 0.12
Barbed wire	34	0	0	2	6	52.9	χ^2	$\chi^2 = 0.06$, P = 0.81
Chicken coop	44	72	2	38	0	36.4	χ^2	$\chi^2 = 1.64$, P = 0.20
Dog	90	8	30	36	0	40.0	χ^2	$\chi^2 = 1.80$, P = 0.18
Electric fence	6	0	0	4	0	33.3	Exact test	P = 1.00
Firecrackers	12	2	8	4	6	50.0	Exact test	P = 0.67
Lights	26	12	6	10	16	46.2	χ^2	$\chi^2 = 0.08$, P = 0.78
Noise/radio	12	0	4	0	8	33.3	Exact test	P = 1.00
Poison	10	2	4	2	14	100.0	Exact test	P = 0.01*
Scarecrow	2	0	12	0	18	0.0	Exact test	P = 1.00

*P ≤ 0.05.

¹All interviewees used multiple predation prevention methods.

TABLE 2 The per cent of 50 respondents who agreed with each of the following statements related to attitude, risk, and ecological benefits of the maned wolf *Chrysocyon brachyurus*, and crab-eating fox *Cerdocyon thous* and hoary fox *Lycalopex vetulus*, and the action they would take in response to chicken predation.

Statement	Maned wolf	Crab-eating fox	Hoary fox
Attitude			
I like having this animal on my ranch	78	82	86
This animal needs protection	86	88	86
This animal is valuable	46	78	84
Risk			
This animal attacks chickens	90	92	90
This animal attacks cattle	8	6	0
This animal attacks humans	56	18	14
Ecological benefits			
This animal eats the rodents on my ranch	54	50	64
This animal eats the insects on my ranch	50	60	56
Response to chicken predation			
I would eliminate this animal	8	10	12
I would remove this animal	28	22	20
I would change management	40	46	46
I would do or change nothing	24	22	22

predation by a Cerrado canid, significantly more respondents remarked that they would change their management practices, regardless of their attitudes towards these species (maned wolf: $\chi^2 = 10.48$, P = 0.02; crab-eating fox: $\chi^2 = 13.68$, P = 0.01; hoary fox: $\chi^2 = 12.88$, P = 0.01; Table 2).

Discussion

Knowledge

This was the first study to quantify local community knowledge and attitudes towards the maned wolf, crab-eating fox and hoary fox in relation to interactions with people. Respondents in the Limoeiro region exhibited greater

knowledge about the diet, activity period and social structure of the maned wolf in comparison to the crab-eating and hoary foxes, and frequently confused the two fox species. This is in line with the trend that more is typically known about large, charismatic, flagship species, such as the maned wolf, than mesocarnivores such as small canids (e.g. the dhole *Cuon alpinus*; Jenks et al., 2014).

Our hypothesis that interviewees who correctly identified and demonstrated more knowledge about Cerrado canids would have a more positive attitude towards them was not supported. These results probably reflect that the overall knowledge varied only slightly amongst respondents and that direct experience with Cerrado canids was more important; i.e. among the tested variables, the predation of domestic fowl was the best predictor of attitude in the Limoeiro region.

TABLE 3 Candidate model rankings for predicting attitudes of local residents towards Cerrado canids.

Model	K ¹	AIC _c	ΔAIC _c ²	w _i ³
Predation	3	43.4	0.00	0.48
Predation + Age	4	43.9	0.55	0.37
Sell + Predation + Age	5	46.2	2.86	0.12
Sell + Predation + Knowledge + Age	6	48.7	5.31	0.03
Education + Sell + Predation + Knowledge + Age	7	55.3	11.90	0.00

¹Number of estimable model parameters.

²Difference in value between Akaike's Information Criterion for small sample size (AIC_c) of the current and best model.

³Akaike weight: the probability that the current model is the best model.

TABLE 4 Logistic regression model parameter estimates for predicting attitudes of local residents towards Cerrado canids.

Whole model factors			Odds ratio	Lower 95%	Upper 95%
	Estimate	SE			
Intercept	2.639	0.73	14.00	4.21	86.71
Predation	-1.792	0.88	0.17	0.02	0.83

Cerrado canids and chicken management

Canid species are known to attack poultry (Sillero-Zubiri & Laurenson, 2001), and scat dietary analysis has been used to confirm predation (e.g. Silva-Rodríguez et al., 2009). Poultry remains have been found in the scat of both maned wolves and crab-eating foxes (Juarez & Marinho-Filho, 2002; Courtenay & Maffei, 2004; Jácomo et al., 2004) but never in the scat of hoary foxes (Juarez & Marinho-Filho, 2002; Jácomo et al., 2004; Lemos et al., 2011b; Kotviski, 2017). Ninety per cent of the hoary fox diet comprises insects (Lemos et al., 2011b). Our results indicated that 40% of the ranches sampled perceived that Cerrado canids preyed on their chickens. All three canid species were perceived to be predators of chickens, although the hoary fox was more frequently identified as the culprit. The hoary fox is nocturnal and frequently dens and forages in open cattle pastures (Lemos et al., 2011b; Lemos, 2016). Respondents reported seeing the hoary fox often when working with their cattle in the field, particularly during dawn and dusk. It is possible they considered the hoary fox responsible for killing chickens simply because they saw it more often. Additionally, respondents frequently confused the hoary and crab-eating foxes. Thus, they could also be misidentifying the hoary fox as a chicken predator when the culprit was the crab-eating fox.

Our second hypothesis, that the method perceived as being the most effective at preventing predation would be the most frequently implemented among ranches, was mostly supported. The chicken coop was identified as the most effective practice to prevent chicken predation. Yet in practice, chickens were free-range during the day, and confined at night at only 44% of the ranches; and not all structures were observed to be predator-proof (e.g. there

were broken doors and holes in fencing). Respondents also identified dogs as an effective preventive method, with 90% of interviewees reporting using one or more dogs for this purpose. Chicken coops were identified as the most expensive method of predation control because of the cost of wire and wood, whereas dogs were considered to be one of the cheapest methods (domestic dogs are commonly fed scraps and are rarely vaccinated in the Limoeiro region). The perceived cost of building a chicken coop could be limiting the use and soundness of this type of structure, even though it was deemed the most effective.

Most ranches used multiple predation control methods but none were found to effectively prevent predation, probably because most of the reported predation events occurred during the day, when the chickens were foraging around the house. Confinement of chickens during the day and at night could potentially solve the problem of daytime predation (e.g. Silva-Rodríguez et al., 2009); however, culturally, local people prefer to raise *caipira* (free-ranging) chickens. Respondents commented that *caipira* chickens have a broader diet and taste better than those that are raised in confinement (fed only with corn), and command a higher price in the city. Moreover, the cost of having to feed the chickens in addition to the already perceived high cost of fencing and wood makes permanent confinement an impractical solution. Johnson & Franklin (1994) and Silva-Rodríguez et al. (2009) suggested that night confinement of chickens was potentially a cost-benefit compromise to permanent confinement because it prevents more losses when canid species are most active. However, our results indicated that chickens, when allowed to roam freely during daylight hours, were still at risk of predation by other wildlife (e.g. hawks, tegus and snakes).

Attitudes towards Cerrado canids

In support of our third hypothesis, and consistent with carnivore research elsewhere (e.g. Lindsey et al., 2005; Cavalcanti et al., 2010), the attitudes of respondents in the Limoeiro region were linked with economic loss. Respondents who experienced predation events were more

likely to report they did not like having wild canids on their property. However, most interviewees agreed that Cerrado canids need to be protected and that they are valuable; a response possibly induced by social norms or a product of interviewing bias (Bernard, 2006). It is encouraging that most respondents (46%) stated they would change their management practice in response to predation events rather than eliminate the predator, and 14% of interviewees perceived the use of poison to be an ineffective predator-control method, although some continue to use it (Lemos et al., 2011a,b; Lemos, 2016).

Future directions for Cerrado canid conservation

In the Limoeiro region, perceived predation of domestic fowl by Cerrado canids is the strongest predictor of a negative attitude towards these species. Our study, along with those of Lemos et al. (2011a,b) and Lemos (2016), found that lethal control is sometimes used in retaliation for such events, or as a preventive measure. Improving management practices could potentially reduce chicken predation and the need for lethal control of canids. Physical barriers such as fences and walls are used extensively as a predator control method (Sillero-Zubiri & Switzer, 2004). Respondents in our study and in that of Silva-Rodríguez et al. (2009) commented on the expense of wood and wire for fencing, and food supplements (grain) for a chicken coop. Financial assistance towards building coops from wood and wire or pooling together other natural or unused material to maintain structural soundness could support the use of coops as a regional model for predation management. Domestic dogs used on the ranches are usually untrained, but taking the time to formally train a dog to stay and guard the chickens while they forage in the field during the day could reduce predation risk and the costs associated with supplemental feeding, and the *caipira* status of the chickens.

In summary, this study highlights the importance of incorporating human dimensions in wildlife management and conservation. Changes in behaviours and management practices can often mitigate undesirable interactions with carnivore species. The results of this research are being used to guide outreach efforts that promote the conservation of Cerrado canids by collaboratively working with the ranchers in the Limoeiro region and with other stakeholders of Cumari, such as the municipal environmental secretary.

Acknowledgements We thank the interviewees for their participation and hospitality, the Fulbright Brazil Student Grants, George Mason University, Smithsonian Conservation Biology Institute, Suzanne B. Engel, Jane Smith Turner Foundation, and Maned Wolf Species Survival Plan for financial support, and Ricardo Corassa Arrais for carrying out the interviews and translations.

Author contributions Project design, securing permits, writing and/or revision: SMB, FGL, MPG, FCA, EWF and NS; data collection and analyses: SMB; overall supervision: NS.

Conflicts of interest None.

Ethical standards The research protocol was approved by Universidade Federal de Goiás/Plataforma Brasil (23120213.6.0000.5083) ethics committee, George Mason University Human Subjects Review Board (478275), and the Smithsonian Institution Human Subject Review Board (0005809).

References

- ABADE, L., LEMOS, F.G. & AZEVEDO, F.C. (2012) *Evaluation Report on the Study of Conflicts between Carnivores and Farmers in the Triângulo Mineiro Cerrado and Southeast of Goiás, Brazil*. Unpublished report. Programa de Conservação Mamíferos do Cerrado, Araguari, Brazil.
- ALVARES, C.A., STAPE, J.L., SENTELHAS, P.C., MORAES GONÇALVES, J.L. & SPAROVEK, G. (2013) Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22, 711–728.
- BEISIEGEL, B.M., LEMOS, F.G., AZEVEDO, F.C., QUEIROLO, D. & JORGE, R.S.P. (2013) Avaliação do risco de extinção do cachorro-do-mato *Cerdocyon thous* (Linnaeus, 1766) no Brasil. *Biodiversidade Brasileira*, 3, 138–145.
- BERNARD, H.R. (2006) *Research Methods in Anthropology*. AltaMira, Oxford, UK.
- BURNHAM, K.P. & ANDERSON, D.R. (2002) *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. Springer Science, New York, USA.
- CAVALCANTI, S.M.C., MARCHINI, S., ZIMMERMANN, A., GESE, E. & MACDONALD, D.W. (2010) Jaguars, livestock, and people in Brazil: realities and perceptions behind the conflict. In *The Biology and Conservation of Wild Felids* (eds D. Macdonald & A. Loveridge), pp. 383–402. Oxford University Press, Oxford, UK.
- COURTENAY, O. & MAFFEI, L. (2004) Crab-eating fox *Cerdocyon thous* (Linnaeus, 1776). In *Canids: Foxes, Wolves, Jackals and Dogs* (eds C. Sillero-Zubiri, M. Hoffmann & D.W. Macdonald), pp. 32–38. IUCN/SSC Canid Specialist Group, Gland, Switzerland, and Cambridge, UK.
- CPTEC/INPE (2015) Centre for Weather Forecasting and Climate/National Institute of Space Research. <http://tempo.cptec.inpe.br/> [accessed 15 January 2015].
- DALPONTE, J. & COURTENAY, O. (2008) *Lycalopex vetulus*. The IUCN Red List of Threatened Species 2008: e.T6926A12815527. <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T6926A12815527.en> [accessed 19 September 2018].
- DEMATTEO, K.E. (2008) Using a survey of carnivore conservationists to gain new insight into the ecology and conservation status of the bush dog. *Canid News*, 11, 1–8.
- DRAHEIM, M.M. (2012) *Social conflict and human-coyote interactions in suburban Denver*. PhD thesis. George Mason University, Fairfax, USA.
- EMMONS, L.H. (ed.) (2012) *The Maned Wolves of Noel Kempff Mercado National Park*. Smithsonian Institution Scholarly Press, Washington, DC, USA.
- ERICSSON, G. & HEBERLEIN, T.A. (2003) Attitudes of hunters, locals, and the general public in Sweden now that the wolves are back. *Biological Conservation*, 111, 149–159.
- JÁCOMO, A.T.A., SILVEIRA, L. & DINIZ-FILHO, J.A.F. (2004) Niche separation between the maned wolf (*Chrysocyon brachyurus*), the

- crab-eating fox (*Dusicyon thous*) and the hoary fox (*Dusicyon vetulus*) in central Brazil. *Journal of Zoology*, 262, 99–106.
- JENKS, K.E., SONGSASEN, N., KANCHANASAKA, B., LEIMGRUBER, P. & FULLER, T.K. (2014) Local people's attitudes and perceptions of dholes (*Cuon alpinus*) around protected areas in southeastern Thailand. *Tropical Conservation Science*, 7, 765–780.
- JOHNSON, W.E. & FRANKLIN, W.L. (1994) Conservation implications of the South American gray fox (*Dusicyon griseus*) socioecology in the Patagonia of southern Chile. *Vida Silvestre Neotropical*, 3, 16–23.
- JUAREZ, M.K. & MARINHO-FILHO, J. (2002) Diet, habitat use, and home ranges of sympatric canids in central Brazil. *Journal of Mammalogy*, 83, 925–933.
- KARANTH, K.U. & CHELLAM, R. (2009) Carnivore conservation at the crossroads. *Oryx*, 43, 1–2.
- KELLERT, S.R. (1985) Public perceptions of predators, particularly the wolf and coyote. *Biological Conservation*, 31, 167–189.
- KLINK, C.A. & MACHADO, R.B. (2005) Conservation of the Brazilian Cerrado. *Conservation Biology*, 19, 707–713.
- KLINK, C.A. & MOREIRA, R.B. (2002) Past and current human occupation, and land use. In *The Cerrados of Brazil* (eds P.S. Oliveira & R. L. Marquis), pp. 69–90. Columbia University Press, New York, USA.
- KOTVISKI, B.M. (2017) *Ecologia alimentar de três espécies de canídeos do Cerrado: variações intra e interespecíficas*. MSc thesis. Universidade Federal Uberlândia, Minas Gerais, Brazil.
- LARUE, M.A., NIELSEN, C.K., DOWLING, M., MILLER, K., WILSON, B., SHAW, H. & ANDERSON, C.R. (2012) Cougars are recolonizing the Midwest: analysis of cougar confirmations during 1990–2008. *Journal of Wildlife Management*, 76, 1364–1369.
- LEMOS, F.G. (2016) *Ecologia e conservação da raposa-do-campo (Lycalopex vetulus) e suas interações com canídeos simpátricos em áreas antropizadas de cerrado do Brasil Central*. PhD thesis. Universidade Federal Uberlândia, Minas Gerais, Brazil.
- LEMOS, F.G., AZEVEDO, F.C., BEISIEGEL, B.M., JORGE, R.P.S., PAULA, R.C., RODRIGUES, F.H.C. & RODRIGUES, L.A. (2013) Avaliação do risco de extinção da Raposa-do-campo *Lycalopex vetulus* (Lund, 1842) no Brasil. *Biodiversidade Brasileira*, 3, 160–171.
- LEMOS, F.G., AZEVEDO, F.C., COSTA, H.C.M. & MAY-JUNIOR, J.A. (2011a) Human threats to hoary and crab-eating foxes in central Brazil. *Canid News*, 14, 1–6.
- LEMOS, F.G., FACURE, K.G. & AZEVEDO, F.C. (2011b) A first approach to the comparative ecology of the hoary fox and the crab-eating fox in a fragmented human altered landscape in the Cerrado biome of central Brazil. In *Middle-Sized Carnivores in Agricultural Landscapes* (eds L.M. Rosalino & C. Gheler-Costa), pp. 143–160. Nova Science Publishers, New York, USA.
- LINDSEY, P.A., DU TOIT, J.T. & MILLS, M.G.L. (2005) Attitudes of ranchers towards African wild dogs (*Lycaon pictus*): conservation implications on private land. *Biological Conservation*, 125, 113–121.
- LUCHERINI, M. (2015) *Cerdocyon thous*. *The IUCN Red List of Threatened Species 2015*: e.T4248A81266293. <http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T4248A81266293> [accessed 19 September 2018].
- MOBERLY, R.L., WHITE, P.C.L. & HARRIS, S. (2004) Mortality due to fox predation in free-range poultry flocks in Britain. *Veterinary Record: Journal of the British Veterinary Association*, 155, 48–52.
- PALMEIRA, F.B.L., CRAWSHAW, P.G., HADDAD, C.M., FERRAZ, K. & VERDADE, L.M. (2008) Cattle depredation by puma (*Puma concolor*) and jaguar (*Panthera onca*) in central-western Brazil. *Biological Conservation*, 141, 118–125.
- PAULA, R.C. & DEMATTEO, K. (2016) *Chrysocyon brachyurus*. (errata version published in 2016). *The IUCN Red List of Threatened Species 2015*: e.T4819A88135664. <http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T4819A88135664> [accessed 19 September 2018].
- PAULA, R.C., RODRIGUES, F.H.G., QUEIROLO, D., JORGE, R.P.S., LEMOS, F.G. & RODRIGUES, L.A. (2013) Avaliação do estado de conservação do Lobo-guará *Chrysocyon brachyurus* (Illiger, 1815) no Brasil. *Biodiversidade Brasileira*, 3, 146–159.
- R DEVELOPMENT CORE TEAM (2015) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/> [accessed 20 March 2016].
- SILLERO-ZUBIRI, C. (2009) Family Canidae (dogs). In *Handbook of the Mammals of the World. 1. Carnivores* (eds D.E. Wilson & R.A. Mittermeier), pp. 352–447. Lynx Edicions, Barcelona, Spain.
- SILLERO-ZUBIRI, C. & LAURENSEN, M.K. (2001) Interaction between carnivores and local communities: conflict or co-existence? In *Carnivore Conservation* (eds J. Gittleman, S. Funk, D.W. Macdonald & R. Wayne), pp. 282–312. Cambridge University Press, Cambridge, UK.
- SILLERO-ZUBIRI, C., REYNOLDS, J. & NOVARO, A. J. (2004) Management and control of wild canids alongside people. In *The Biology and Conservation of Wild Canids* (eds D.W. Macdonald & C. Sillero-Zubiri), pp. 107–122. Oxford University Press, Oxford, UK.
- SILLERO-ZUBIRI, C. & SWITZER, D. (2004) Management of wild canids in human-dominated landscapes. In *Canids: Foxes, Wolves, Jackals and Dogs: Status Survey and Conservation Action Plan* (eds C. Sillero-Zubiri, M. Hoffmann & D.W. Macdonald), pp. 257–266. IUCN/SSC Canid Specialist Group, Gland, Switzerland, and Cambridge, UK.
- SILVA-RODRÍGUEZ, E.A., SOTO-GAMBOA, M., ORTEGA-SOLIS, G.R. & JIMÉNEZ, J.E. (2009) Foxes, people and hens: human dimensions of a conflict in a rural area of southern Chile. *Revista Chilena de Historia Natural*, 82, 375–386.
- SMITH, M.E., LINNELL, J.D.C., ODDEN, J. & SWENSON, J. E. (2000) Review of methods to reduce livestock depredation. II. Aversive conditioning, deterrents and repellents. *Acta Agricultura Scandinavica, Section A. Animal Science*, 50, 304–315.
- SOKAL, R.R. & ROHLF, F.J. (1995) *Biometry*. Freeman and Company, New York, USA.
- TRAVAINI, A., ZAPATA, S.C., MARTÍNEZ-PECK, R. & DELIBES, M. (2000) Percepción y actitud humanas hacia la predación de ganado ovino por el zorro colorado (*Pseudalopex culpaeus*) en Santa Cruz, Patagonia Argentina. *Mastozoología Neotropical*, 7, 117–129.
- TREVES, A. & KARANTH, K.U. (2003) Human–carnivore conflicts and perspectives on carnivore management worldwide. *Conservation Biology*, 17, 1491–1499.
- TREVES, A., NAUGHTON-TREVES, L., HARPER, E.K., MLADENOFF, D.J., ROSE, R.A., SICKLEY, T.A. & WYDEVEN, A.P. (2004) Predicting human–carnivore conflict: a spatial model derived from 25 years of data on wolf predation on livestock. *Conservation Biology*, 18, 114–125.
- YIHUNE, M., BEKELE, A. & ASHENAFI, Z.T. (2008) Human–Ethiopian wolf conflict in and around the Simien Mountains National Park, Ethiopia. *International Journal of Ecology and Environmental Science*, 34, 149–155.
- ZIMMERMANN, A., WALPOLE, M.J. & LEADER-WILLIAMS, N. (2005) Cattle ranchers' attitudes to conflicts with jaguar *Panthera onca* in the Pantanal of Brazil. *Oryx*, 39, 406–412.