RESEARCH ARTICLE

Evidence supporting that human-subsidized free-ranging dogs are the main cause of animal losses in small-scale farms in Chile

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Abstract We surveyed professionals from the Chilean Ministry of Agriculture working with small-scale farmers to characterize the attacks of free-ranging dogs across Chile. Nationwide, in a single year, free-ranging dogs attacked 25% of the ca. 8500 farms included in the survey, killing or injuring about 10 000 small ruminants. These dogs were ranked as the main cause of animal losses for small-scale farmers, representing a threat to the livelihoods of this vulnerable group. Further, free-ranging dogs attacking small ruminants were considered as human-subsidized, since they would be recruited by irresponsible ownership and abandonment from urban centers. This is the first national assessment reporting that human-subsidized dogs are a main threat to livestock rearing. Policies to control populations of these animals should target their anthropogenic origin as well as cultural shifts in dog ownership and animal welfare. While these policies may be effective mid- to long-term approaches, short-term actions may also be needed.

Keywords Attacks · Chile · Dogs · Farms · Livestock · Predation

INTRODUCTION

Dogs (*Canis familiaris*) are the most abundant carnivore species on the planet, with an estimated ~ 990 million individuals (Wandeler et al. 1993; Gompper 2014). Between 75 and 80% of these dogs are free-ranging types (Lord et al. 2013). This covers a continuum from full

dependence on human resources and semi-restricted roaming (family dogs) to unrestricted dogs characterized by a high variability of distance to human dwellings, home range size, tolerance toward humans, and the inability to survive independent of human subsidies (stray dogs; Ritchie et al. 2014; Boitani et al. 2016); and to complete independence and unrestricted roaming (feral dogs; Gompper 2014).

Free-ranging dogs (FRDs) face welfare issues (e.g., Beck 1973), but they also cause socioeconomic and environmental problems worldwide. Dogs are an important reservoir of zoonotic diseases (e.g., rabies), and disease vectors, contaminate the environment with feces and urine, and increase human risk to bite wounds and car accidents (reviewed by Macpherson 2013). Moreover, FRDs have become a main threat to biodiversity globally (Doherty et al. 2017) because they regularly prey on wildlife, compete with native predators, and spread virulent pathogens (e.g., Canine distemper virus spilled over lions; reviewed in Hughes and Macdonald [2013], Gompper [2014], Ritchie et al. [2014] and Doherty et al. [2016]). Similarly, dogs impact agriculture because they prey, kill, and injure farm animals, and can also transmit diseases (e.g., *Echinococcus granulosus*; Boitani et al. 2016; Home et al. 2017; Waters 2017; and references in S1). This issue could be especially impactful for small-scale farms (SSFs) that maintain a small number of animals, because dogs could cause relatively significant economic losses and a considerable reduction of assets.

Chile is a distinctive case study because the dog population has grown continuously over the recent decades (Acosta-Jamett et al. 2015). However, no human rabies cases have been reported since 1972 (Favi and Durán 1991), and both the public and the government have shown a high tolerance to FRDs. As a result, these dogs are

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currently widespread in Chile's urban and rural areas (Acosta-Jamett et al. 2010a, b; Silva-Rodríguez and Sieving 2011; Sepúlveda et al. 2015; Villatoro et al. 2016; and references in the supplementary information of Acosta-Jamett et al. 2015).

Research on the social and ecological impacts of FRDs in Chile has increased over the last decade (e.g., Acosta-Jamett et al. 2010a, b, 2011; Tuemmers et al. 2013; Armstrong and Ulloa 2016; and references in S2), including their predation upon the endemic and critically endangered huemul (*Hippocamelus bisulcus*; Corti et al. 2010). With respect to livestock rearing, FRDs have been identified as the main predator of sheep on industrial ranches country-wide (Instituto Nacional de Estadísticas 2015), while isolated reports of FRDs preying on animals of SSFs have been published (Bonacic et al. 2007; Acosta-Jamett et al. 2014), in addition to being documented in news articles (Flores 2017).

In January 2015, Decree Number 65 was officially published. This new regulation modified the hunting legislation to include 'wild/feral dog packs' on the list of invasive species that could be hunted (Ministerio de Agricultura 2015). The Decree was quickly eliminated after pressure from pet-welfare organizations. These groups opposed the regulation because it proposed the use of lethal methods for population control. Even though the decree was quickly dismissed, it revealed the Chilean government's awareness that FRDs are a nuisance for livestock rearing. In general, the media, the public, and government agencies tend to classify FRDs attacking livestock as 'wild' and/or 'feral,' but data supporting such classifications are missing.

As in many developing countries, SSFs are common in Chile. These farms are typically owned by individuals whose main economic activity is farming (Donoso et al. 2010; Boza et al. 2015) and usually maintain few animals (Acosta-Jamett et al. 2014). Therefore, if FRD attacks are extensively damaging farm animals, these carnivores could seriously threaten the livelihood of small-scale farmers. However, the extension of FRD damage to SSFs in terms of farms affected, number of animals attacked, and their importance relative to other causes of livestock losses remains unknown.

Taking into consideration that (a) FRD populations and SSFs are common in rural settings in Chile, (b) FRDs attack and prey on animals of these farms, (c) the loss of just a few animals can impact the economic security of small-scale farmers, and (d) the relevance of FRD attacks among SSFs is unknown, we surveyed professionals from the Ministry of Agriculture to assess FRD attacks on these

farms at a national scale. Furthermore, we explored the role that humans have, according to these professionals, in sustaining populations of FRDs attacking SSFs.

MATERIALS AND METHODS

In Chile, small-scale agriculture producers who work a piece of land no larger than 12 irrigable hectares and whose main income comes from agriculture are supported by the government through the Local Development Program known as PRODESAL (Programa de Desarrollo Local), or by the Indigenous Territorial Development Program known as PDTI (Programa de Desarrollo Territorial Indígena; Ministerio de Agricultura 1990; Ministerio de Agricultura 1993). These governmental programs aim to improve the living conditions and productive systems in SSFs organized in territorial units (hereafter, 'units') by offering technical assistance through veterinarians and agronomists in the field (hereafter, 'professionals').

These professionals work hand in hand with thousands of small-scale farmers across Chile. They assist units of SSFs, are reachable from a centralized source (the Chilean Ministry of Agriculture), and have internet access. Therefore, they represent an accessible direct source of information concerning SSFs across the country. For these reasons, in June 2016, an electronic survey that collected information about FRD attacks on these farms was sent to these professionals through the Chilean Ministry of Agriculture. Although the number of surveys sent was confidential, they covered all the PRODESAL and PDTI units in Chile. Responding to the survey was not mandatory; therefore, it was designed to collect information in the fewest number of questions in order to improve the response rate. To protect the confidentiality of the respondents, the specific unit characterized was not traceable. Before sending the survey, we tested its effectiveness with two professionals from the Chilean Ministry of Agriculture, and appropriate corrections to it were made. Over the next 3 months, we received responses from professionals who had worked in the corresponding territorial unit for at least 1 year by the time of the survey. Professionals who had worked in more than one unit for at least 1 year were asked to complete separate surveys for each unit. We focused on data regarding attacks on sheep and goats, as these animals are commonly farmed and are most often reported as being attacked by FRDs (Bonacic et al. 2007; Acosta-Jamett et al. 2014). The survey is presented in S3, and it contains the following sections.

Fig. 1 The five Zones across Chile used to spatially represent the data collected

Characteristics of PRODESAL and PDTI units

We surveyed the location of the unit, the total number of SSFs in the unit, and the number of SSFs raising sheep, goats, or both. We divided the units into five Zones within Chile's continental territory (North, North-Central, Central, Southern, and Austral) because they are environmentally, economically, and culturally distinctive (Pisano 1966; Fig. 1).

Characteristics of small-scale farms

We assessed the expected size of flocks and the fair market value for a single sheep or goat in each unit. Weighted averages were calculated per Zone. The weights given to the professionals were based on the number of SSFs per unit with respect to the total number of SSFs across all the units in the corresponding Zone. We also examined whether SSFs tended to be insured against unexpected animal losses.

Characterization of the attacks of free-ranging dogs upon small-scale farms

We asked about the number of farms attacked by FRDs and the number of dead and mauled small ruminants per type of

herd (only sheep, only goats, or both small ruminants). We also asked about the number of attacked farms that reported to the authorities.

Methods to identify free-ranging dogs as the attacking species

We assessed the method commonly used in each unit to identify FRDs as the attacking species. The answers to this open-ended question were grouped as 'bite location,' 'direct observation,' 'tracks,' and 'number of small ruminants' affected.

Native carnivores in Chile that may conflict with the identification of FRDs are the mountain lion (*Puma concolor*), the culpeo fox (*Lycalopex culpaeus*), and the south American gray fox (*Lycalopex griseus*; see 'Discussion' for references).

Importance of free-ranging dog attacks as a cause of animal losses

We asked professionals to rank, from 1 to 5, the following causes of small ruminant losses in SSFs in terms of their importance: 'FRD attacks,' 'predation by native carnivores,' 'robbery,' 'diseases,' and 'other causes.' We obtained weighted ranks per Zone as explained previously.

Characteristics of free-ranging dogs attacking and/or preying on farm animals

We asked professionals if, based on their experience, FRDs involved in attacks had an owner or not (Yes/No answer), the perceived origin of FRDs (open statement), and if the definition of 'Wild or Feral Dog Packs' provided in the revoked Decree Number 65 was appropriate for these FRDs (Yes, No, and Do not know answer). The perceived origin of FRDs was classified into three categories: 'abandonment' (dogs that were moved by humans, but not to a household and beyond dogs' known territory), 'irresponsible ownership' (dogs that are owned but are not restricted and/or fed properly) and 'abandonment and irresponsible ownership.' The definition provided in the Decree was 'Wild or feral dogs: wild or feral dogs, that are in packs, out of the urban and urban extension zones or areas, beyond 400 m distant from any town or rural isolated dwelling...' (Ministerio de Agricultura 2015).

About the predation of free-ranging dogs on small farmers' animals

Finally, the survey allowed the professionals to voluntarily provide further information about FRD attacks. Using coding and content analysis (Ryan and Bernard 2000;

Krippendorff 2013), we assigned one or more ‘tags’ to individual responses. The coding and tagging of the open statements combined identifying keywords (e.g., “abandonment” or “responsible ownership law”) or explicit argumentative intention (e.g., “the main problem [or cause] is ...” or “it is important to [do this...]”). These tags were grouped into thematic units and analyzed.

RESULTS

The results presented ‘per Zone’ were as follows: North, North-Central, Central, Southern, and Austral (Fig. 1). We obtained information from 149 units, but 5 were excluded because the answers were based on poultry or because they presented implausible responses (e.g., the number of SSFs attacked by FRDs in the last year was higher than the SSFs assisted during this period). Therefore, general results are based on 144 units, which imply a representation of 34.5% of the total units in the PRODESAL and PDTI programs nationwide (Instituto de Desarrollo Agropecuario 2017, 2018). However, some sections are based on fewer responses because not all the questions had a 100% response rate. We identify those cases appropriately.

Table 1 Number of surveys answered, small-scale farms involved, and general features of these small-scale farms per Zone: average sheep and goat flock size, and expected market value of a single sheep and goat. Two surveys that did not report the number of SSFs rearing only sheep and sheep and goats, and the number of SSF rearing goats and sheep and goats, respectively, were not included in these statistics

	North	North-Central	Central	Southern	Austral
Number of surveys answered	3	11	33	94	3
Number of small-scale farmers assisted	151	867	1141	6434	62
Average flock size, sheep ^{a,b}	23.17	50.08	35.39	15.03	26.67
Average flock size, goats ^{a,b}	35.58	93.30	76.21	16.89	50
Average flock size, both species ^{a,b}	61.14	80.13	57.09	21.08	33.7
Expected sheep sale value ^{a,b,c}	84	77	77	71	70
Expected goat sale value ^{a,b,c}	84	73	52	53	42

^a Weighted average

^b These values correspond to the minimum number because two respondents did not answer this question

^c Dollars. The values were converted taking the average dollar value as of December 2015, equivalent to 711 Chilean pesos

Characteristics of PRODESAL and PDTI units

The results for this section are based on 142 units that assisted 8655 SSFs nationwide the year prior to the survey. As evident from Table 1, the number of units included per Zone was heterogeneous, from 3 in the North and Austral Zones to 94 in the Southern Zone.

Characteristics of small-scale farms

An estimated of 238 425 small ruminants were reported in the same subset of 142 units for the past year. A summary of the characteristics of the SSFs per Zone is presented in Table 1. The Southern Zone was the most represented, but also had the smallest average flock size. The North-Central Zone had the largest average flock size. The North and the Austral Zones were less represented in terms of answered surveys but still represented ~ 200 SSFs.

Only one respondent from the Austral Zone answered that the SSFs in its unit tended to have insurance against animal losses.

Characterization of the attacks of free-ranging dogs upon small-scale farms

Professionals reported that 2331 SSFs were attacked by FRDs during the year prior to the survey, regardless of the small ruminant species attacked. If only the subset of 142 units is considered, the percentage of attacked SSFs per Zone was 13.91, 51.21, 24.01 and 38.71%, respectively. When considering 861 adequate responses with the number of small ruminants killed or mauled by FRDs out of 864 present in the 144 surveys, an estimate of ten thousand small ruminants were killed or mauled during the same time period. The average number of animals damaged per attacked farm in the last year was 4.9 ($n = 137$). Statistics per Zone and herd type are shown in Fig. 2.

When considering the subset of 142 surveys, only 12.14% of the attacks were reported to the authorities.

Methods to identify free-ranging dogs as the attacking species

Nationwide, the most common method to identify FRDs as the attacker was ‘direct observation’ (55.56%) followed by ‘bite location’ (38.89%), ‘number of small ruminants affected’ (4.86%) and ‘tracks left at the scene’ (0.69%).

In each Zone, the most common method to identify FRDs as the attacker was ‘direct observation,’ except in the North where ‘bite location’ and ‘tracks’ were the only methods reported (but $n = 3$, Fig. 3). ‘Tracks’ was only reported in this Zone.

Fig. 2 Left: small farms attacked by free-ranging dogs per Zone. Right: animals damaged per attacked farm in the previous year by Zone and herd type. These values are based on 861 responses out of 864 present in the 144 surveys with respect to small ruminants killed or mauled by FRDs

Fig. 3 Distribution of the most common method used to identify FRDs as the attacker species per Zone

Importance of free-ranging dog attacks as a cause of animal losses

From the 139 professionals that ranked FRDs, 64% of them placed this item as the main cause of animal losses, while ~ 13% ranked this item as second. ‘Predation by native carnivores’ was ranked most often 4 or 5 (~ 22 and ~ 31%, respectively; $n = 139$), with only ~ 10% of respondents ranking this item as 1. ‘Diseases’ were ranked ($n = 139$) between 2 and 4 by ~ 73% of the professionals, while it was ranked 1 by 14% of them. ‘Robbery’ was ranked 2 to 4 ($n = 136$) by ~ 77% of the professionals, and 1 by 12% of them. Finally, ‘other’ was ranked 4 or 5 by ~ 65% of the professionals.

The weighted ranks showed that FRDs were the most important cause of animal losses in SSFs across Zones except in the North, in which ‘robbery’ ranked the highest (Fig. 4). ‘Predation by native carnivores’ was distributed between the second and fifth most important causes across Zones and ranked notably higher in the North-Central Zone. In the three southernmost Zones, ‘predation by native carnivores’ ranked similar to ‘robbery’ (which tended to be ranked 3) and ‘diseases.’ The number of professionals that ranked each item per Zone is provided in S4.

Characteristics of free-ranging dogs attacking and/or preying on farm animals

Nationwide, ~ 58% of the professionals reported that FRDs attacking small ruminants have an owner, while 11.81% did not respond. The perceived origin of FRDs was ~ 34, 17, and 13% for ‘abandonment,’ ‘irresponsible ownership,’ and ‘abandonment and irresponsible ownership,’ respectively. About ~ 37% did not answer. Furthermore, ~ 52% thought the ‘wild/feral dog packs’ definition provided was appropriate and ~ 9% did not know. Most professionals who claimed that the FRDs are owned responded that the ‘wild/feral dog packs’ definition was not appropriate (~ 61%). Within those professionals that claimed FRDs were not owned, 86% responded that the definition was appropriate. Congruence among these answers is not strong at the Zone level (Fig. 5). Within the group that did not respond whether the FRDs were owned or not, ~ 41% said they do not know if the definition is adequate, while ~ 47% answered that it is.

About the predation of free-ranging dogs on small farmers’ animals

A total of 57 professionals used the open statement section. Their comments were organized into 72 tags arranged into 6 main themes (Fig. 6). Theme 1 (34%) addressed dog ownership and origin. Here, professionals portrayed FRD attacks as an anthropogenic issue in terms of abandonment and/or irresponsible ownership. Urban centers were consistently believed to be the source of abandoned dogs, while ownership of too many dogs in conditions of undernutrition was commonly referred to as well.

Theme 2 (33%) addressed the legal dimension. Most statements focused on the importance of a ‘Responsible Ownership Law’ and its enforcement. They also emphasized the lack of effective legal proceedings to either control these dogs or protect affected SSFs, the excessively bureaucratic legal process to report attacks, and/or the lack

Fig. 4 Weighted rank for causes of small ruminant losses in SSF per Zone in Chile. Darker red indicates weighted ranks closer to 1

Fig. 5 Left: Percentage of professionals who responded that FRDs attacking small ruminants do have an owner, do not have an owner, or did not respond, per Zone. Right: Percentage of professionals who answered that the definition of wild/feral dogs provided in Decree Number 65 is appropriate for FRDs attacking small ruminants, is not appropriate, or do not know, per Zone

Fig. 6 Main themes and tags from open-ended statements ($n = 57$) using text content analysis

of action thereafter. The conflict between animal rights and the need to control FRDs in Chile was also mentioned.

Theme 3 (8%) included suggestions on other public policy instruments such as sterilization campaigns and FRD eradication, the expansion of resources for infrastructure and insurance for the farms. Theme 4 (5%) had comments on actions already taken at the SSFs, and the importance of infrastructure (e.g., fences and corrals) to protect animals. Theme 5 (14%) contained comments on how FRDs also affect other species such as poultry and South American camelids (North-Central Zone).

DISCUSSION

We surveyed PRODESAL and PDTI professionals to assess the importance of free-ranging dog predation as a cause of animal losses in small-scale farms in Chile. Our results, representing ~ 8500 farms across Chile, show that dogs are considered the most important cause of animal losses. This finding is consistent with the level of predation of dogs upon sheep in Chilean large-scale farming (Instituto Nacional de Estadísticas 2015) and supports previous suggestions that dogs are underrated as livestock predators in specific areas of Chile (Bonacic et al. 2007; Acosta-Jamett et al. 2014). Similar results have been reported in specific regions of India (Suryawanshi et al. 2013; Home et al. 2017) and Italy (Boitani et al. 2016).

During the year prior to the survey, ~ 25% of the farms represented in the survey were attacked by dogs that killed or injured approximately ten thousand small ruminants (sheep and goats). Dog attacks cost at least US\$420 000 (using the lowest weighted average value per Zone for goats or sheep), and the number of expected small ruminants damaged in 1 year in affected farms was between 4 and 11, depending on the Zone and the type of herd. This is equivalent to half of the average flock size (Southern Zone), which is in agreement with a recent study in the Austral Zone (Schüttler et al. 2018). Although dogs can be economically catastrophic, farmers tended to have no insurance for their livestock.

These results contribute to a better understanding of the social dimension of FRDs and, in particular, they show to what extent they can threaten the livelihoods of a vulnerable group such as small-scale farmers. They also offer compelling evidence in support of the development of future policy instruments; however, this human dimension might have been hidden until now from the policy arena by at least three factors. First, although global scientific attention to the impact of FRDs has increased in recent years (see the references section and the electronic supplementary material S1–S6), their potential threat to the subsistence of local communities or farmers has received

less attention compared to FRD-associated public health or biodiversity concerns. Second, local media usually presents the FRD problem as an animal welfare issue. Finally, farmers do not report the attacks (only 12% of the attacked farms in our case). According to the respondents, farmers do not report attacks because of the difficulties in the reporting process and the perceived lack of results. Policy frameworks and the scientific community require a better understanding of the multiple social dimensions of FRDs, and the former must include effective mechanisms for farmers to report attacks and to generate results afterward.

Responses about the origin and ownership of FRDs preying on small ruminants suggest that the inappropriate tenancy of dogs, including inadequate nutrition, and their abandonment, likely from urban areas, are the main drivers of FRDs attacking small-scale farms. These results are consistent with past research. Family dogs (semi-restricted and human-subsidized) are commonly found in Chilean rural areas, but, as in other developing countries, they are rarely restricted (Acosta-Jamett et al. 2010a, b; Silva-Rodríguez and Sieving 2011; Gompper 2014; Sepúlveda et al. 2014; Schüttler et al. 2018). These animals can be underfed (Silva-Rodríguez and Sieving 2011; Sepúlveda et al. 2014), triggering predation on wild vertebrates (Silva-Rodríguez and Sieving 2011), while predation of sheep by owned dogs also occurs (Silva-Rodríguez and Sieving 2011; Sepúlveda et al. 2014). Furthermore, the abandonment of dogs from urban centers has been previously reported in rural areas in the North-Central and Southern Zones (Acosta-Jamett et al. 2011; Villatoro et al. 2016), and it may be a strong component of dog population growth (Acosta-Jamett et al. 2010a, b). Abandoned dogs may be adopted (Acosta-Jamett et al. 2010a, b; Villatoro et al. 2016), remain as stray dogs (not restricted and intentionally or unintentionally human-subsidized), or become feral (not restricted and independent of human subsidies). Adopted individuals may still add to the set of dogs attacking small farms if they are undernourished. A certain fraction of these stray dogs would add to the set of small-ruminant predators in order to satisfy their energetic requirements. Finally, some abandoned dogs may become totally independent of human-derived resources, although these populations do not seem to be able to sustain themselves (Boitani et al. 2016), and strict wild/feral dog populations are globally rare (with Australia as an exception [Gompper 2014]). Indeed, feral dogs have not been reported in the Southern Zone of Chile (Silva-Rodríguez and Sieving 2011; Sepúlveda et al. 2014), although Schüttler et al. (2018) recently proposed the presence of such dogs in the Austral Zone. Furthermore, when feral dogs are present, they do not necessarily add to the set of livestock predators (Scott and Causey 1973; Boitani et al. 2016).

In this context, policy frameworks should target the anthropogenic origin of these dogs, such as legally punishing their abandonment and enforcing responsible ownership, including restrictions on roaming and stipulations for adequate health. Policies such as Decree Number 65 did not consider the anthropogenic sources of FRDs, and only proposed hunting of the animals, which prompted the opposition of pet welfare organizations and the general public because of the use of lethal mechanisms (Rivas 2015). Moreover, the definition of “wild/feral dog packs” in this Decree was based on the distance of dogs to human settlements. Under this terminology, stray and family dogs would have been hunted because of the extended foray distances that some FRDs exhibit (Sepúlveda et al. 2015; Boitani et al. 2016). Indeed, the proportion of professionals claiming that dogs attacking small ruminants were owned did not parallel the proportion claiming that the definition in the Decree was not appropriate, which confirms that the text was misleading. Conversely, in August 2017, a “pet responsible ownership” law was approved by the Chilean Congress which targets the restriction of dogs within the owner’s property, punishes inappropriate ownership and the abandonment of animals, and requires the removal of stray dogs to no-kill shelters (Ministerio de Salud 2017). The strategies in this new regulation may produce medium- to long-term results (Amaku et al. 2010; Yoak et al. 2016) if they are applied at a relevant spatial scale (Villatoro et al. 2016). They may also be more accepted socially, and could be more economically efficient over time than the permanent use of lethal mechanisms alone. However, despite being a necessary initial effort, this legal framework seems to be biased toward urban settings, and it likely needs to expand on strategies that foster a cultural shift on dog ownership and animal welfare. Furthermore, small-scale farmers and other groups severely affected by FRDs may not be willing to accept strategies targeting medium- to long-term results, and preventing FRD predation on endangered wild species is urgent. Therefore, realistic strategies that aim to reduce the number of FRDs in the short term may also be required, at least at local scales.

Free-ranging dogs should be regarded as a pressing environmental justice concern in the arena of public debates and policy-making processes. Environmental justice scholars and activists have shown how ecological change (anthropogenic or not) unequally affects vulnerable communities and underrepresented groups at many levels, including globally (Mohai et al. 2009; Walker 2012). Consistently, FRDs are human-subsidized carnivores introduced from urban centers that cause severe socioeconomic effects among small-scale farmers and indigenous communities. Reframing FRDs as an environmental justice issue can offer a novel and shared argument for a community of stakeholders with diverse, and sometimes

conflicting, interests and concerns, such as farmers, pet-welfare organizations, and environmental conservation groups. By doing so, decision-making processes might be able to integrate the experiences of a vulnerable group but also contribute to generating the necessary agreements to develop the needed policy and behavioral change.

We chose to survey professionals from the Ministry of Agriculture because small-scale farmers in Chile have consistently reported native carnivores as one of their main problems (e.g., Bonacic et al. 2007; Cattán et al. 2010; Acosta-Jamett et al. 2014); however, studies on the diet of native carnivores such as *P. concolor*, *L. culpaeus*, and *L. griseus* have consistently found a very low proportion of farm animal remains in feces (e.g., Bonacic et al. 2007; Rubio et al. 2013; Zúñiga and Muñoz-Pedrerros 2014; and references in S5), while cattle remains have been found in over 50% of FRD fecal samples (Bonacic et al. 2007; Schüttler et al. 2018). Although native carnivores have been found to be the main predators in certain areas of Chile (Acosta-Jamett et al. 2016), these past results could be influenced by farmers’ bias toward assuming predation by wild carnivores. This bias could originate in cultural attitudes, either because they tend to miss the actual predator species or they observe the scavenging of already dead animals. For example, small-scale farmers have reported the Andean condor (*Vultur gryphus*), a scavenger vulture, as a goat predator (Bonacic et al. 2007). Chile offers no compensation program for livestock losses due to wild carnivore predation, so economic incentive would not drive this misidentification. Conversely, surveying professionals resulted in the first dataset, to our knowledge, supporting that human-subsidized dogs can be the main threat to small-scale livestock rearing at a country scale. Based on the results of this study, past research in Chile, and previous results in regions of India, Italy, and England (Suryawanshi et al. 2013; Boitani et al. 2016; Home et al. 2017; Waters 2017), we propose that future assessments of the carnivore–livestock conflict in regions where FRDs are common must include these animals. The misidentification of the species claimed to be preying on livestock, or failing to identify the most relevant predators, can lead to dramatically different (and likely counterproductive) outcomes when deciding on strategies to mitigate the carnivore–livestock conflict.

Finally, to assess the quality of our results, we evaluated the capacity of these professionals to properly respond to the questions by asking them to self-report their ability to differentiate the attacks of different carnivore species (results not shown). Even though ~ 40% of them claimed not to have this skill, the most common method used to identify dogs as the attacking species in the units was ‘direct observation’ (~ 56%). Under this specific method, dogs tended to be ranked as the main cause of animal losses. In

the case of professionals reporting ‘bite location,’ the second most common method, 68% of professionals reported that they had the skills to differentiate carnivores. Under this method of identification, dogs also tended to be ranked as the main cause of animal losses (see S6). Therefore, professionals can be a valid source of information in studying FRD attacks in small-scale farms. Field professionals have valuable knowledge on the social and ecological effects of FRDs attacks. Public policy practitioners and scholars should include both this knowledge and actors into the arena of data collection and decision-making. Nevertheless, longitudinal assessments of dog predation on small ruminants including all units are needed in order to properly represent all the Zones, and avoid self-selection bias.

CONCLUSIONS

This survey offers evidence that FRDs are a major cause of animal losses in SSFs across Chile and that they represent a threat to the livelihood of this vulnerable group. Free-ranging dogs preying on small ruminants in SSFs are likely human-subsidized (family dogs and stray dogs), driven by abandonment and inadequate ownership of these animals. Consequently, FRDs present a dual human dimension as humans actively participate in the genesis of these animals, and are also impacted by them.

These results offer significant support for the development of policy instruments targeting the anthropogenic origin of these dogs. Furthermore, they advocate a need to expand on strategies that foster a cultural shift on dog ownership and animal welfare. However, such instruments may only produce medium-to-long-term results, and strategies that aim to reduce FRDs in the short term may also be required.

Free-ranging dogs’ attacks and their effects on economically vulnerable communities can be reframed as an environmental justice concern. This can offer a novel and shared argument to a diverse community of stakeholders in order to develop effective and participatory decision-making processes to manage the dog population in the future.

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REFERENCES

- Acosta-Jamett, G., W.S.K. Chalmers, A.A. Cunningham, S. Cleaveland, I.G. Handel, and B.M.D. Bronsvoort. 2011. Urban domestic dog populations as a source of canine distemper virus for wild carnivores in the Coquimbo Region of Chile. *Veterinary Microbiology* 152: 247–257.
- Acosta-Jamett, G., S. Cleaveland, B.M. Dec Bronsvoort, A.A. Cunningham, H. Bradshaw, and P.S. Craig. 2010a. *Echinococcus granulosus* infection in domestic dogs in urban and rural areas of the Coquimbo region, north-central Chile. *Veterinary Parasitology* 169: 117–122.
- Acosta-Jamett, G., S. Cleaveland, A.A. Cunningham, and B.M.D. Bronsvoort. 2010b. Demography of domestic dogs in rural and urban areas of the Coquimbo Region of Chile and implications for disease transmission. *Preventive Veterinary Medicine* 94: 272–281.
- Acosta-Jamett, G., P. Corti, A. Aleuy, A. Espinoza, and P. Quevedo. 2014. *Study of perception of farming-predator conflicts Arica y Parinacota, Coquimbo, Araucanía and Aysén Districts*, 26–27. Valdivia: Univ. Austral Chile.
- Acosta-Jamett, G., et al. 2015. Increased dog population and potential for bat-borne rabies spillover in Chile in response to “Dog management, abundance and potential for bat-borne rabies spillover in Chile” by Astorga et al. *Preventive Veterinary Medicine* 120: 246–247.
- Acosta-Jamett, G., J.R. Gutiérrez, D.A. Kelt, P.L. Meserve, and M.A. Previtali. 2016. El Niño Southern Oscillation drives conflict between wild carnivores and livestock farmers in a semiarid area in Chile. *Journal of Arid Environments* 126: 76–80.
- Amaku, M., R.A. Dias, and F. Ferreira. 2010. Dynamics and control of stray dog populations. *Mathematical Population Studies* 17: 69–78.
- Armstrong, W., and G. Ulloa. 2016. Epidemiological features of canine bites during the year 2011 in Temuco City, Chile. *Sustainability, Agri, Food Environmental Research* 4: 41–49. (In Spanish. Summary in English).
- Beck, A.M. 1973. *The ecology of stray dogs: A study of free-ranging Urban animals*. Baltimore: York Press.
- Boitani, L., F. Francisci, P. Ciucci, and G. Andreoli. 2016. The ecology and behavior of feral dogs: A case study from central Italy. In *The domestic dog: Its evolution, behaviour, and interactions with people*, ed. J. Serpell, 342–368. Cambridge: Cambridge University Press.
- Bonacic, C., T. Ibarra, M.F. Amar, D. Sanhueza, N. Guarda, N. Gálvez, and T. Murphy. 2007. Assessment of the conflict between wild carnivores and livestock. 612-461-LE07. Laboratorio de Vida Silvestre Fauna Australis Facultad de Agronomía e Ingeniería Forestal Pontificia Universidad Católica de Chile. Santiago (In Spanish).
- Boza, S., M. Cortés, and F. Guzmán. 2015. Characterization of small-scale agriculture producers benefited by the Programa of Local Development in the Metropolitan District, Chile. *IDESIA* 33: 135–142 (In Spanish. Summary in English).
- Cattan, P., G. Acosta-Jamett, G. Cundill, P. Correa, G. Cortes, and G. Rojo. 2010. Assessment of the interaction between puma (*Puma concolor*) and livestock in Choapa Province, Coquimbo District. 612-370-LE09. Centro de Estudios de Vida Silvestre Facultad de Ciencias Veterinarias y Pecuarias Universidad de Chile. Santiago (In Spanish).
- Corti, P., H.U. Wittmer, and M. Festa-Bianchet. 2010. Dynamics of a small population of endangered huemul deer (*Hippocamelus bisulcus*) in Chilean Patagonia. *Journal of Mammalogy* 91: 690–697.

- Doherty, T.S., C.R. Dickman, A.S. Glen, T.M. Newsome, D.G. Nimmo, E.G. Ritchie, A.T. Vanak, and A.J. Wirsing. 2017. The global impacts of domestic dogs on threatened vertebrates. *Biological Conservation* 210: 56–59.
- Doherty, T.S., A.S. Glen, D.G. Nimmo, E.G. Ritchie, and C.R. Dickman. 2016. Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences of the United States of America* 113: 11261–11265.
- Donoso, G., O. Melo, and E. Negrete. 2010. Participation determinants and impact assessment of the Institute of Agricultural Development (INDAP) credit program. *Ciencia e Investigación Agraria* 37: 87–99.
- Favi, M.C., and J.C. Durán. 1991. Rabies epidemiology in Chile (1929–1988) and perspectives in wild mammals. *Avances en Ciencias Veterinarias*. <https://doi.org/10.5354/acv.v6i1.4623>. (In Spanish).
- Flores, J. 2017. Pack of wild dogs costs millions in lost after attacking sheep in Porvenir. Radio Biobío. Retrieved 20 March 2017 from <https://www.biobiochile.cl/noticias/nacional/region-demagallanes/2017/03/20/jauria-deperros-silvestres-deja-millonariasperdidas-tras-atacar-ovej-as-enporvenir.shtml>. (In Spanish).
- Gompper, M.E. 2014. Introduction: Outlining the ecological influences of a subsidized, domesticated predator. In *Free-ranging Dogs and Wildlife Conservation*, ed. M.E. Gompper, 1–7. Oxford: Oxford University Press.
- Home, C., R. Pal, R.K. Sharma, K.R. Suryawanshi, Y.V. Bhatnagar, and A.T. Vanak. 2017. Commensal in conflict: Livestock depredation patterns by free-ranging domestic dogs in the upper Spiti landscape. *Ambio*. <https://doi.org/10.1007/s13280-016-0858-6>.
- Hughes, J., and D.W. Macdonald. 2013. A review of the interactions between free-roaming domestic dogs and wildlife. *Biological Conservation* 157: 341–351.
- Instituto de Desarrollo Agropecuario. 2017. *State of the Institution 2016* (In Spanish).
- Instituto de Desarrollo Agropecuario. 2018. The improvement process of the indigenous territorial development program. Jofré Godoy, M.; Huenchumil (In Spanish).
- Instituto Nacional de Estadísticas. 2015. Survey of sheep flocks. *Estadísticas Pecuarias/Ganadería Ovina* (In Spanish).
- Krippendorff, K. 2013. *Content analysis: An introduction to its methodology*. Thousand Oaks: Sage.
- Lord, K., M. Feinstein, B. Smith, and R. Coppinger. 2013. Variation in reproductive traits of members of the genus *Canis* with special attention to the domestic dog (*Canis familiaris*). *Behavioral Processes* 92: 131–142.
- Macpherson, C.N.L. 2013. *Dogs, zoonoses and public health*. Boston: CAB International.
- Ministerio de Agricultura. 1990. Replaces the act of the Instituto de Desarrollo Agropecuario. *Biblioteca del Congreso Nacional de Chile*. February 3 (In Spanish).
- Ministerio de Agricultura. 1993. Amendment to the Act of the Instituto de Desarrollo Agropecuario. *Biblioteca del Congreso Nacional de Chile*. Mayo 5 (In Spanish).
- Ministerio de Agricultura. 2015. Modification of hunting law enforcement, approved by Decree No 5, 1998. *Biblioteca del Congreso Nacional de Chile*. January 31 (In Spanish).
- Ministerio de Salud. 2017. Law number 21020 about responsible pet and company animals' ownership. *Biblioteca del Congreso Nacional de Chile*. August 2 (In Spanish).
- Mohai, P., D. Pellow, and J.T. Roberts. 2009. Environmental justice. *Annual Review of Environment and Resources* 34: 405–430.
- Pisano, E. 1966. *Biogeographic zones. Economical geography of Chile*. Santiago: Corporación de Fomento de la Producción. (In Spanish).
- Ritchie, E.G., C.R. Dickman, M. Letnic, A.T. Vanak, and M. Gompper. 2014. Dogs as predators and trophic regulators. In *Free-ranging Dogs and Wildlife Conservation*, ed. M. E. Gompper: 55–68. Oxford: Oxford University Press.
- Rivas, F. 2015. Campaign against the hunting of wild dogs goes viral. *Radio Biobío*. Retrieved 15 February 2018 from <https://www.biobiochile.cl/noticias/2015/02/05/campana-contra-lacaza-de-perros-salvajes-se-tomaredes-sociales.shtml>. (In Spanish).
- Rubio, A.V., R. Alvarado, and C. Bonacic. 2013. Introduced European rabbit as main prey of the native carnivore culpeo fox (*Lycalopex culpaeus*) in disturbed ecosystems of central Chile. *Studies on Neotropical Fauna and Environment* 48: 89–94.
- Ryan, G.W., and H.R. Bernard. 2000. Data management and analysis methods. In *Handbook of qualitative research*, ed. N.K. Denzin and Y.S. Lincoln, 769–802. Thousand Oaks: SAGE.
- Schüttler, E., L. Saavedra-Aracena, and J.E. Jiménez. 2018. Domestic carnivore interactions with wildlife in the Cape Horn Biosphere Reserve, Chile: husbandry and perceptions of impact from a community perspective. *PeerJ* 6: e4124. [peerj.com](https://doi.org/10.7554/peerj.4124).
- Scott, M.D., and K. Causey. 1973. Ecology of feral dogs in Alabama. *The Journal of Wildlife Management* 37: 253–265.
- Sepúlveda, M.A., R.S. Singer, E. Silva-Rodríguez, P. Stowhas, and K. Pelican. 2014. Domestic dogs in rural communities around protected areas: Conservation problem or conflict solution? *PLoS ONE* 9: e86152. [dx.plos.org](https://doi.org/10.1371/journal.pone.0086152).
- Sepúlveda, M., K. Pelican, P. Cross, A. Eguren, and R. Singer. 2015. Fine-scale movements of rural free-ranging dogs in conservation areas in the temperate rainforest of the coastal range of southern Chile. *Mammalian Biology* 80: 290–297.
- Silva-Rodríguez, E.A., and K.E. Sieving. 2011. Influence of care of domestic carnivores on their predation on vertebrates. *Conservation Biology* 25: 808–815.
- Suryawanshi, K.R., Y.V. Bhatnagar, S. Redpath, and C. Mishra. 2013. People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. *The Journal of Applied Ecology* 50: 550–560.
- Tuëmmers, C., C. Lueders, C. Rojas, M. Serri, C. Castillo, and R. Espinoza. 2013. Detection of *Brucella canis* by immunochromatography method in stray dogs captured in Temuco city, Chile, 2011. *Revista Chilena de Infectología* 30: 395–401.
- Villatoro, F.J., M.A. Sepúlveda, P. Stowhas, and E.A. Silva-Rodríguez. 2016. Urban dogs in rural areas: Human-mediated movement defines dog populations in southern Chile. *Preventive Veterinary Medicine* 135: 59–66.
- Walker, G. 2012. *Environmental justice: Concepts, evidence and politics*. Abingdon: Routledge.
- Wandeler, A.I., H.C. Matter, A. Kappeler, and A. Budde. 1993. The ecology of dogs and canine rabies: A selective review. *Revue Scientifique et Technique* 12: 51–71.
- Waters, A. 2017. Helping prevent sheep attacks. *The Veterinary Record* 180: 314.
- Yoak, A.J., J.F. Reece, S.D. Gehrt, and I.M. Hamilton. 2016. Optimizing free-roaming dog control programs using agent-based models. *Ecological Modelling* 341: 53–61.
- Zúñiga, A.H., and A. Muñoz-Pedreros. 2014. Feeding habits of *Puma concolor* (Carnivora, *Felidae*) in fragmented forests in the south of Chile. *Mastozoología Neotropical* 21: 157–161. (In Spanish. Summary in English).

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