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Carnivore–livestock conflicts in Chile: evidence and methods for mitigation

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Abstract: Human population growth and habitat loss have exacerbated human–wildlife conflicts worldwide. We explored trends in human–wildlife conflicts (HWCs) in Chile using scientific and official reports to identify areas and species with higher risk of conflicts and tools available for their prevention and mitigation. The puma (*Puma concolor*) was considered the most frequent predator; however, fox (*Lycalopex* spp.) and free-ranging or feral dog (*Canis lupus familiaris*) attacks were also common. Our results suggest that the magnitude of puma conflicts may be overestimated. Domestic sheep (*Ovis* spp.) and poultry (Galliformes) were the most common species predated. Livestock losses were widespread across Chile but were highest in San Jose de Maipo, located in central Chile, and Cochrane, La Unión, and Lago Verde in south Chile municipalities. Livestock guardian dogs and the livestock insurance, as a part of the Agriculture Insurance of Chile, were identified as the most promising tools to mitigate HWCs, short- and mid-term, respectively. However, longer-term strategies should focus on improving livestock management through extension (i.e., farmer education) programs for local communities. In Chile, HWCs negatively impact small farmers and wild carnivore populations. An interinstitutional and interdisciplinary strategy integrating input from government and nongovernmental organizations, farmers, and academia is needed to achieve effective carnivore conservation in the long-term.

Key words: compensation, human–wildlife conflict, insurance, livestock, predation, puma, *Puma concolor*

Conflicts between humans and wildlife are often due to increasing human populations and encroachment in natural habitats (Messmer 2000). Human–wildlife conflicts (HWCs) include crop damage, livestock predation, and transmission of diseases affecting humans or domestic animals (Sillero-Zubiri et al. 2006, Messmer 2009). Examples of livestock depredation by wildlife occur worldwide (Conover 2002). For instance, in Asia, livestock are killed by leopards (*Panthera pardus*), tigers (*P. tigris*), Asian black bears (*Ursus thibetanus*), snow leopards (*Uncia uncia*), and other meso-predators (Madhusudan 2003, Mishra et al. 2003, Wang and Macdonald 2006). In Europe, wolves (*Canis lupus*; Blanco 2003), grizzly bears (*Ursus arctos*), lynx (*Lynx lynx*), and wolverines (*Gulo gulo*; Linnell and Broseth 2003) have been implicated as major predators of livestock. In South America, jaguars (*Panthera onca*), pumas (*Puma concolor*; Michalski et al. 2006, Gallardo et al. 2009), crab-eating foxes (*Cerdocyon thous*), and pampas foxes (*Lycalopex gymnocercus*; Soler et al. 2008) are considered important livestock predators.

In Chile, most depredations occur when livestock graze close to natural reserves (Bonacic et al. 2007). Increased depredations have also been associated with a reduction in wild prey abundance due to hunting, free-roaming dogs (*C. lupus familiaris*), and habitat loss (Gittleman et al. 2001). The increased frequency of livestock attacks has exacerbated HWCs and impeded the conservation of rare species. In Chile, local authorities recognized the potential for increased HWCs despite the limited data available documenting livestock losses. Reports suggested that small farmers

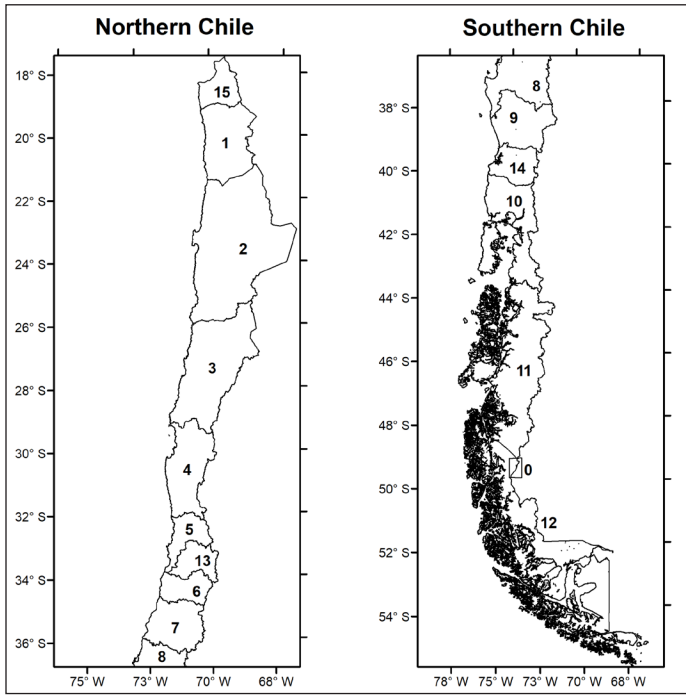

Figure 1. Map of Chile denoting its regions. Region 0 denotes the area of conflict between Chile and Agentina.

are most affected (Amar 2008). Livestock losses on small farms represent a high impact to livelihood, considering that the depredation of a single animal may result in considerable income loss for a family (Gittleman et al. 2001, Amar 2008).

The wildlife most commonly involved in livestock losses in Chile include puma, foxes (*Lycalopex griseus*, *L. culpaeus*, and *L. fulvipes*; Silva-Rodríguez et al. 2009*a*), and the lesser grison (*Galictis cuja*). However, few researchers have attempted to quantify and characterize HWCs in Chile (Cattan et al. 2010). As such, there are information gaps for geographic areas and species. This information could be used to develop more effective management plans and to evaluate economic, social, and legal aspects to reduce negative HWCs.

To address this gap, in 2017 we conducted a descriptive study of HWCs across Chile. We reviewed scientific and official reports to identify areas and species with higher risk as well as the tools available for prevention and mitigation. The objectives of this study were to assess: (1) the amount and location of reported livestock losses, involving both wild and domestic species and identify areas with highest risk; (2) potential legal and administrative tools for the prevention and mitigation of these conflicts; and (3) possible solutions to prevent wildlife-associated damage, which could be incorporated into a manual designed to better inform livestock producers and managers.

Study area

Chile is located along the southwest of the Americas and has an estimated 17.37 million people, mostly living in urban areas (87%; Instituto Nacional de Estadísticas [INE] 2017*a*). Chile's national territory is divided into regions for the purpose of government administration; these in turn are divided into provinces and communes or municipalities (local authorities) (Oficina de Estudios y Políticas Agrarias [ODEPA] 2017). Chile presents 4 marked seasons, which also differ according to the latitude. The country has a long and narrow shape (4,200 km in length); the broadest area is 375 km wide, and the narrowest area is 90 km wide (Figure 1). The country is bordered on the west by the Pacific Ocean, and its central valley is flanked by the Andes Mountain Range, which separates Chile from Argentina (ODEPA 2017). The country displays a singular biogeography: the northern area (neighboring Bolivia and Peru) presents mostly arid zones (<1 mm of rainfall per year) where the Atacama Desert is located, the driest desert of the world (ODEPA 2017). The central area is mostly Mediterranean, and the south is characterized by cold and rain, humid forest, lakes, and rivers, ending in the Antarctic. This great diversity of climates and landscapes provides the basis for the country's diversity (ODEPA 2017).

Livestock are mostly concentrated in the central and southern regions of the country. Farmlands, crops, livestock, and forestry are located in the southern Regions 7, 8, and 9 (54%; Figure 1), and only 8.4% farms are located between in the extreme north of the country and Region 4 (INE 2017*b*, ODEPA 2017). However, sheep (*Ovis* spp.) farms are

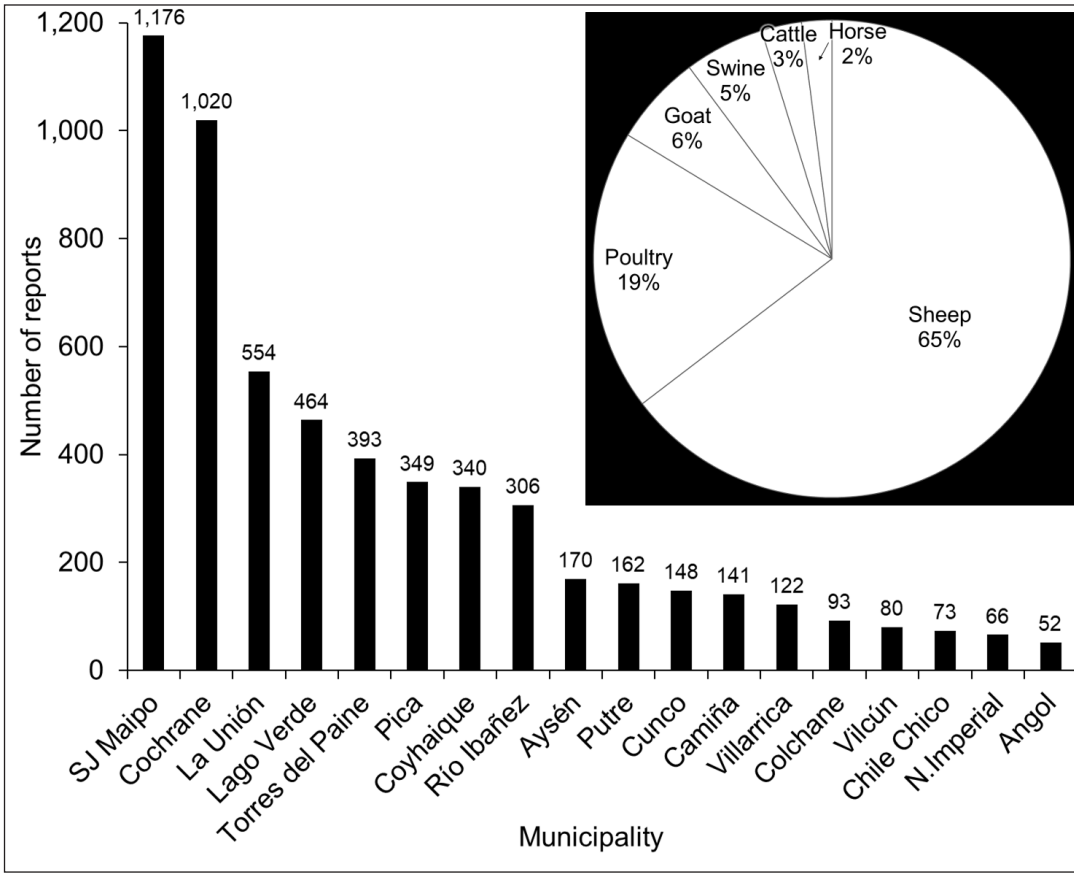

Figure 2. Livestock (sheep [*Ovis* spp.], poultry [Galliformes], goats [*Capra* spp.], swine [*Sus* spp.], cattle [*Bos* spp.], horses [*Equus* spp.]) depredation across Chile between 2006 and 2012. Most reports (91%; 5,709), occurred in 18 municipalities (bars). Insert shows depredation by type of species affected. SJ Maipo = San José de Maipo; N. Imperial = Nueva Imperial. Bars include only municipalities with >50 reports (Bonacic et al. 2007; Amar 2008; Cattan et al. 2010; Arévalo et al. 2011; Instituto Nacional de Estadísticas 2011; Iriarte et al. 2011; SAG 2011*a*, *b*; SAG 2012*a*, *b*; SAG-Tarapacá 2012; Soto 2012).

concentrated (75.4%) in the Patagonian areas of Region 12 (Figure 1), the southernmost area from the country (INE 2017*b*). Small livestock farms have relatively low income, poor management, and are vulnerable to attacks by predators (Rojas 2012, Montecino-Latorre and San Martín 2019). However, attacks are also reported in large livestock farms (Montecino-Latorre and San Martín 2019).

Methods

In 2017, we collected data from scientific literature (Amar 2008), official reports (Bonacic et al. 2007, Cattan et al. 2010, Arévalo et al. 2011, Instituto Nacional de Estadística [INE] 2011, Iriarte et al. 2011, Servicio Agrícola y Ganadero-Tarapacá [SAG-Tarapacá] 2012, Soto 2012), and from government datasets (Servicio Agrícola y Ganadero [SAG] 2011*a*, *b*; SAG 2012*a*, *b*) on wildlife damage in Chile between 2006 and 2012. For this period, the Chilean government developed a systematized data collection regarding HWCs. We obtained official records from the Sub-Departamento de Vida Silvestre of the SAG, División de Protección de los Recursos Naturales. Additional records were obtained from the scientific literature and the Chilean census summarizing nationwide surveys of HWCs (INE 2011).

The inclusion criteria we used for the collection of literature included scientific data generated via empirical research (fieldwork), publications, research conducted in Chile or collected by the Chilean government, manuscript and reports of HWCs in any type of livestock (sheep, poultry [Galliformes], goats [*Capra* spp.], swine [*Sus* spp.], cattle [*Bos* spp.], horses [*Equus* spp.]) and caused by any type

of predator (wild felid, canids, mustelids, and dogs). Aquaculture and raptors were excluded from the search due to the lack of reports about this type of HWC. We searched the literature using the keywords wildlife + livestock + Chile in Google Scholar during the period 2006–2012 in Spanish and English. Complementary information was provided by the SAG, the state agency in charge of wildlife management and conservation in Chile.

For reports that contained information regarding specific site or locations where damage or losses occurred, we categorized them based on the level of geographic detail available. The first scale used geographic coordinates as units and included fine resolution information of the damaged or loss site location (i.e., latitude and longitude). Reports without geographic coordinates but with detailed information of the location (i.e., Chilean region, municipality, city, street name, and street number) were geolocated using an online geo-referencing tool (Aus-emaps 2017). The second spatial scale we used was at the level of the municipality. This spatial unit was used to geolocate sites where livestock damage was reported. Additionally, information regarding the predator species and numbers of livestock depredated was collected when available.

Municipality data were used to generate risk maps based on the frequency of the reports of damage or losses to highlight areas with high, intermediate, and low amount of reports. Specifically, the Jenks Natural Breaks method was used to group values into 3 categories defined by minimizing the standard deviation in each category and maximizing the deviation among categories (de Smith et al. 2018). Municipalities clustered in the lower, intermediate, and high categories, in terms of frequency of reports, were defined as areas of low, mid, and high risk of HWC due to livestock depredation. Spatial analyses were conducted using ArcGIS 10.4 (ESRI, Redlands, California, USA).

Because our second objective was to explore potential legal and administrative tools for the prevention and mitigation HWCs in Chile, we reviewed the current legal status and the role of state agencies regarding the species involved in HWCs in Chile. We evaluated the legal framework defining wildlife, conservation status, and the role of government agencies in wildlife management. To do this, we reviewed current laws in Chile to identify the specific regulations that described the role of the government in terms of: (1) livestock production; (2) farmers' economic development; (3) agriculture management and improvement; and (4) wildlife management and conservation, with special emphasis on wild carnivores such as pumas and foxes.

Our third objective was to assess potential solutions to mitigate HWCs in Chile. We summarized these solutions in the form of a farmers' manual focused on tools to prevent and manage livestock depredation by wildlife. For a tool to be included in the manual, we reviewed the scientific literature published in English and Spanish to document evidence to support the successful reduction in the frequency of livestock damage by wildlife. In this review, we included a description of the livestock insurance program as a potential way to compensate for livestock loss. We discussed each tool and retained those that could be applicable to Chile in terms of the cultural, legal, and economic contexts.

Results

Amount and location of livestock losses

Geographic areas affected. Livestock depredation data from official reports and the scientific literature were obtained for 55 municipalities (see Appendix 1, supplementary material 1), with 6,295 total complaints (Bonacic et al. 2007; Amar 2008; Cattan et al. 2010; INE 2011; Iriarte et al. 2011; SAG 2011*a*, *b*; SAG 2012*a*, *b*; SAG-Tarapacá 2012; Soto 2012). Sheep (65%) was the most depredated species, followed by poultry (19%).

Detailed information of the attack, allowing geolocation, was available for 161 reports (Appendix 1, supplementary material 2). Attack reports were clustered around a few municipalities in central and southern Chile (Figure 2). For example, San José de Maipo (Region 13), Cochrane (Region 11), La Unión (Region 14), and Lago Verde (Region 11) municipalities accounted for most (>51%) of the livestock depredation reports (Figure 2).

However, data for several municipalities were not available (Figure 3). Livestock depredation reports showed high frequency of attacks in

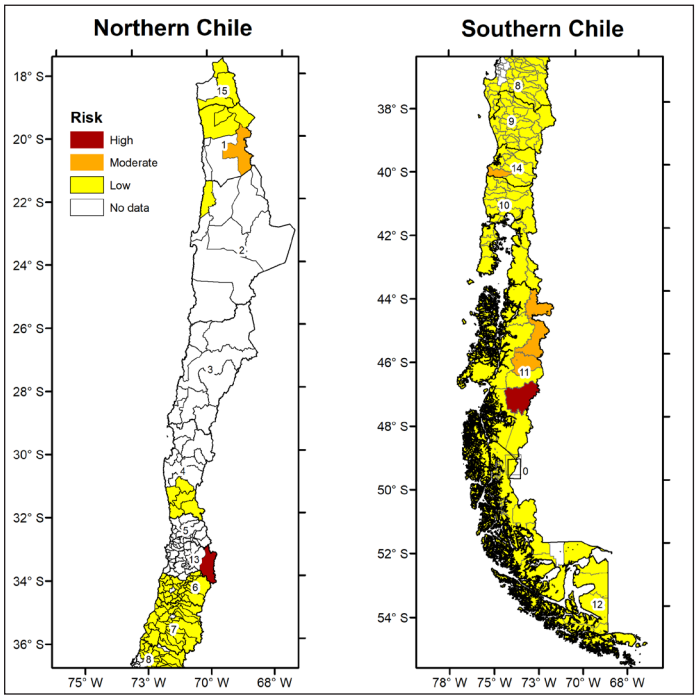

Figure 3. Livestock (sheep [*Ovis* spp.], poultry [Galliformes], goats [*Capra* spp.], swine [*Sus* spp.], cattle [*Bos* spp.], horses [*Equus* spp.]) attacks reported by municipality in Chile between 2006 and 2012. High (maroon), moderate (orange), and low risk (yellow) estimated in terms of the overall number of complaints of livestock depredated based on the Jenks Natural Breaks method. White denotes areas without data (dashed; Instituto Nacional de Estadísticas 2011). Inset numbers denote the administrative region of Chile.

municipalities in Regions 15 and 11. Data gaps were found in north-central Chile, including some reports in south-central Chile, which lacked number of domestic animals lost (INE 2011; Figure 3). These data gaps in north-central Chile could reflect a lack of reporting instead of a real lack of wildlife attacks, considering that data gaps occurred near municipalities with livestock depredation (Figure 3).

Across the diverse livestock production systems in Chile, we detected similar patterns in wildlife livestock depredations. Most of the wildlife attacks on livestock were associated with specific factors (i.e., they did not seem to occur at random; Figures 2 and 3). According to the literature, wildlife attacks were reported with more frequency in central and southern Chile, mainly in rural areas with production of sheep, close to national parks, and in small-farm livestock production. The most vulnerable settlements were those with livestock (i.e., cattle, sheep, horses, calves, and poultry) grazing freely, unprotected and unsupervised for long periods, from hours to weeks (Bonacic et al. 2007, Cattan et al. 2010).

The quality of livestock housing also varied with the geographic area. In general, pens were built to restrict livestock movement, but not to protect livestock from attacks. Hence, even livestock in pens were vulnerable to depredation (Cattan et al. 2010, Iriarte et al. 2011). Additionally, pens may not be a feasible, cost-effective solution across Chile, and other alternatives may be more suitable. Other factors associated with livestock depredation included local weather and habitat. For example, there was more predation in the years with a drought in central and northern Chile along with the areas that had ongoing habitat loss (e.g., wild fires in south-central Chile).

Species involved. The puma was the wildlife species most frequently implicated as a livestock predator in Regions 3 and 15 (Figure 4). In Tarapacá, northern Chile, livestock attacks from pumas overlapped with reports associated with foxes. In the rest of the country (i.e., central and southern Chile), livestock depredation involved pumas, foxes, domestic dogs, and American mink (*Neovison vison*) as the potential predators. Strikingly, reports of dogs and American mink attacks, 2 non-native invasive species in Chile, came from villages in southern Chile at sites near large protected areas. Consequently, these attacks likely occurred by non-native predators in natural areas with high biodiversity.

Historically, pumas have been blamed for livestock losses, and this species has been hunted in retaliation to reduce livestock attacks. However, our analysis indicated that depredation, attributed to pumas in southern Chile, could have been caused by dogs and American mink (Figure 4). Indeed, according to agricultural extension education professionals, human-subsidized free-ranging dogs, instead of wildlife, are the main cause of losses in small

livestock farms in rural Chile (Montecino-Latorre and San Martín 2019).

Legal and administrative framework

According to the Chilean law, puma and foxes are cataloged as native wildlife (Ministerio de Agricultura de Chile [MINAGRI] 1996). By law, pumas are considered to provide ecosystem services by regulating populations of herbivores and potentials pests (MINAGRI 1998). In Chile, the puma is also considered a species at risk of extinction in the north (i.e. Regions 1 and 2) and central areas (Regions 4 and 7), while in southern (Regions 8 and 10) and austral area (Regions 11 and 12), it is a vulnerable species (MINAGRI 1998). Consequently, hunting and capturing pumas is forbidden in Chile (MINAGRI 1996).

The 3 fox species that occur in Chile are also considered beneficial to ecosystems and are legally protected from hunting and capturing (MINAGRI 1996, 1998). The Darwin's fox (*L. fulvipes*) is classified in 3 wildlife protection categories of Chilean law: beneficial to the ecosystem, beneficial to the agriculture, and a species of low population density (MINAGRI 1998).

As a general rule, hunting or capturing native wild carnivores is forbidden in Chile. However, the law has some exceptions. First, hunting and capturing wild carnivores is allowed for scientific purposes, control of problem animals, for the establishment of wildlife reproduction centers, and for sustainable use of the species (MINAGRI 1996). People or institutions intending to hunt or capture a puma must obtain a SAG authorization, based solely on presenting a request (MINAGRI 1998). This permitting framework is used to authorize the legal hunting and capturing of puma and other wild carnivores suspected of livestock depredation.

Additionally, livestock attacks and depredation are often blamed on any wild carnivore roaming near the site of the report, even when several livestock attacks in Chile were likely caused by domestic dogs (Silva-Rodríguez et al. 2009*a*, Sepúlveda et al. 2014). From 1999 to 2012, 94 pumas were captured and relocated in the Araucania (Region 9), representing data for just 1 of the 15 regions in Chile (Iriarte et al. 2012). The SAG officers in Los Lagos (Region 10) also relocate puma, in collaboration with farmers, to mitigate the HWC without killing puma individuals (SAG 2012*b*). We found no information regarding the details of the translocation (e.g., final destination, health status of translocated animal, date). The second exception to the hunting and capture prohibition refers to the chilla foxes (*L. chilla*) in Tierra del Fuego (i.e., Patagonia in southern Chile), as this species is a non-native invasive on the island (MINAGRI 1998).

Potential solutions

Potential solutions for HWCs include improvements in the management of livestock, additional protection of livestock, and compensation of losses. While livestock management varies according to the domestic species involved, several practices are applicable to all the species (e.g., improved sanitary status, reduction of predator's access to the herd, and reduced free-ranging unsupervised grazing). We summarized potential tools to prevent HWCs in the manual for farmers: *Manual de Educación Ambiental y Prevención de Ataques* (Appendix 1, supplementary material 3).

Livestock guardian dogs. Additional tools to prevent livestock depredation included the use of livestock guardian dogs (LGDs), which are considered a cost-effective, humane tool promoting wildlife coexistence (Gehring et al. 2010*a*). This approach was traditionally used in Europe and Asia (Gehring et al. 2010*b*). Different from herding dogs, LGDs do not guide the herd (Marker et al. 2014) but instead protect livestock from wild predators such as pumas and foxes (González et al. 2012). The overall performance of LGDs suggests that they reduce livestock attacks by wild carnivores in Chile (Herrera 2017) by protecting herds both day and night, and inside-outside pens. In addition, LGDs develop a bond with the livestock herd, but this bond must be promoted at an early age though training (González et al. 2012). In Chile, some initiatives have explored using LGDs to reduce livestock depredation with promising results (Herrera 2017).

Livestock insurance. Among the tools to mitigate HWCs in Chile, Livestock Insurance, a branch of the Chilean Agricultural Insurance, was implemented by MINAGRI through Agroseguros—previously Comité del Seguro

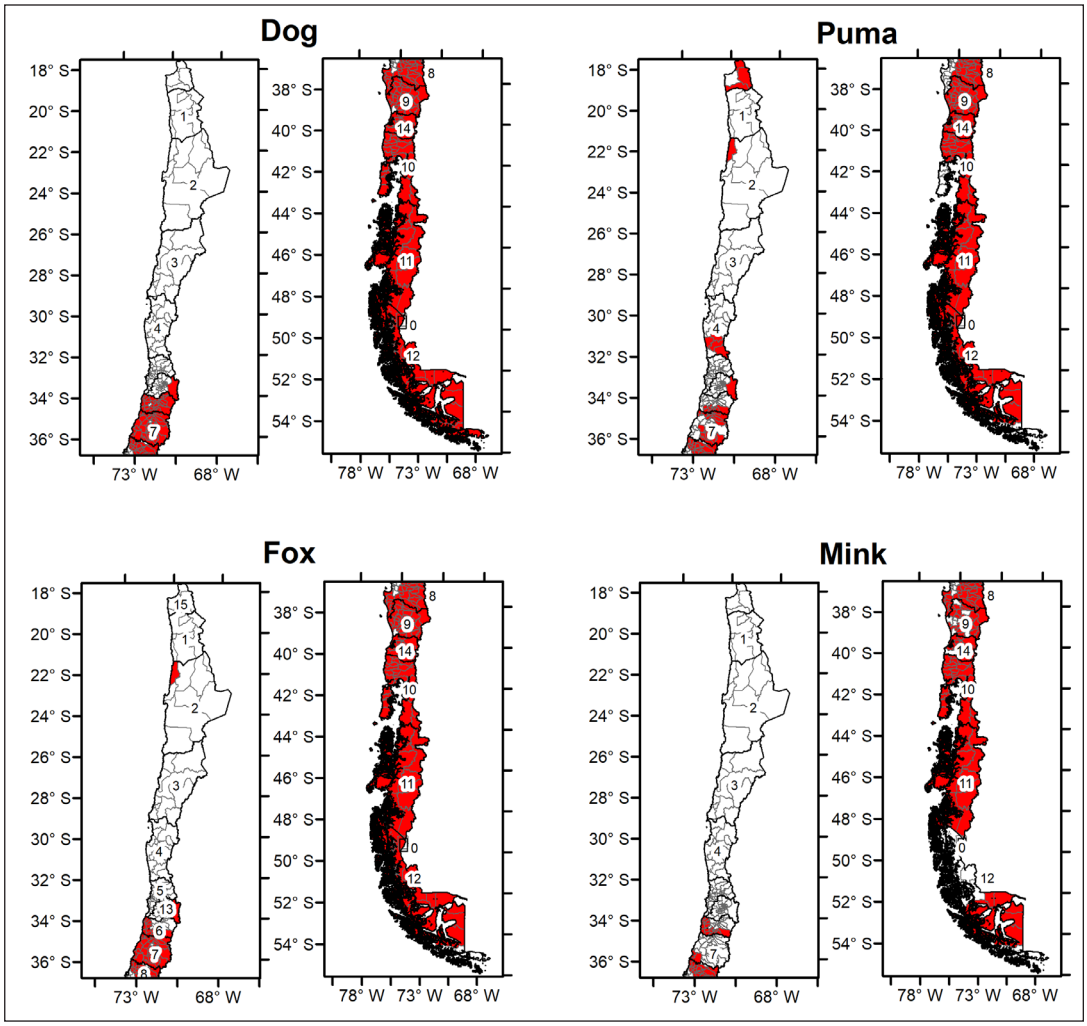

Figure 4. Geographic areas with reports of wildlife (dog [*Canis lupus familiaris*], puma [*Puma concolor*], fox [*Lycalopex* spp.], American mink [*Neovision vision*]) attacks in northern Chile (leftmost image in each set) and southern Chile between 2006 and 2012. Municipalities with at least 1 report (red) contrast with areas without reports of depredation (white) according to the species of depredator reported (i.e., dog, puma, fox, and American mink).

Agrícola ([COMSA] 2012, Corporación de Fomento de la Producción [CORFO] 2014). This agency is responsible for developing, promoting, and administrating tools to manage risks in forestry, agriculture, and food-animal production. Agroseguros also manages subsidies that the government provides to small farmers to help pay for the insurance (Ministerio de Economía, Fomento y Turismo/Corporación de Fomento de la Producción [MEFT/CFP] 2016). Thus, if it has continued administrative and economic support to operate, livestock insurance is a potential long-term tool to manage HWCs. Livestock insurance is administrated in Chile by CORFO through Agroseguros as part of MINAGRI and is available to the farmers from private insurance companies (MEFT/CFP 2016). Granting administration of livestock insurance to private companies may promote transparency and effective management of the process. Livestock insurance has been recently implemented, but its performance has not been assessed. We argue that future research is indispensable across Chile to quantify the effects of the economic compensation on both wild carnivore populations and farmer perceptions of wildlife conflicts in areas with and without implementation of livestock insurance to better understand its effectiveness.

Initially, the livestock insurance was promoted

by the Instituto Nacional de Desarrollo Agropecuario (INDAP) to support cattle producers. The original goal of this insurance program was to transfer economic losses from producers to the insurance companies. Economic losses in livestock production also include mortality due to adverse weather conditions or infectious diseases (COMSA 2012). We suggest that this system and administrative infrastructure may be extended to mitigate the livestock predation and losses. The SAG is the agency primarily responsible for developing agriculture and protecting and managing natural resources of Chile (MINAGRI 1989). These 2 responsibilities make SAG the ideal agency to develop and implement tools to mitigate HWCs while supporting farmers.

Discussion

We found that information regarding HWCs involving wildlife depredation of livestock in Chile was limited, dispersed, and not standardized. Bonacic et al. (2007) previously reported similar observations prior to 2006. Although SAG has initiated efforts to improve the data collection system across different rural offices, reports were difficult to access from countryside SAG agencies. We were able to detect similar patterns in depredations across the diverse livestock production systems in Chile. Attacks were reported with more frequency in central and southern Chile, mainly in unsupervised sheep herds close to national parks (Bonacic et al. 2007, Cattan et al. 2010).

Historically, the response of farmers to livestock depredation has been retaliatory, and farmers have killed the wild predators blamed for the attack (Treves et al. 2009*a*). However, preventive alternatives have proven to be more effective for reducing HWCs worldwide while conserving endangered carnivore species (Treves et al. 2009*a*, *b*). More efforts are necessary to improve the sustainability of livestock farming, including improvements in livestock management.

We recommend increased use of HWC mitigation strategies contained in the manual for farmers (i.e., *Manual de Educación Ambiental y Prevención de Ataques*; Appendix 1, supplementary material 3). This manual provides information for agricultural extension professionals to assist small farmers and improve their livestock management. This information may help reduce losses in areas with recurrent livestock depredation (Treves et al. 2009*a*, *b*).

Our research indicates that most of the livestock attacks occur on unattended and unsupervised herds. Strategies for livestock management include the use of fences and deterrents. The manual also includes other specific livestock management tactics such as sanitary measures and individual identification of livestock. The manual can be used by farmers and insurance companies, along with a previous manual describing the forensic verification of livestock attacks (Guarda et al. 2010). Both manuals are complementary and provide updated, science-based instructions to evaluate and prevent livestock depredation in Chile. Federal officials may also use these materials for environmental education and training for biodiversity conservation (Ministerio Secretaria General de la Presidencia 1994, Ministerio de Relaciones Exteriores [MINREL] 1995).

The use of LGDs was found to be an innovative potential solution for HWCs in Chile. The Pyrenean Shepherd breed was employed by the municipality of Cajón del Maipo in central Chile during a project supported by the Fundación para la Innovación Agraria, and Great Pyrenees dogs were used by Conservación Patagonica in Chacabuco Valley, southern Chile (Herrera 2017). To our knowledge, there are no robust quantitative evaluations to assess the cost-effectiveness of guardian dogs across Chile, although the literature suggests that this method has reduced the losses caused by wild carnivores (González et al. 2012). Farmers in Chile lack basic training for managing LGDs, which may result in free-ranging dogs. In Chilean culture, free-ranging dogs and stray dogs are broadly accepted and tolerated (Silva-Rodríguez and Sieving 2012, Sepúlveda et al. 2015), which could negatively impact wildlife or LGDs by direct attacks, parasite transmission, and competition for prey species (Silva-Rodríguez et al. 2009*b*; Silva-Rodríguez and Sieving 2012; Knobel et al. 2014; Sepúlveda et al. 2014, 2015; Poo-Muñoz et al. 2016). In general, LGDs are perceived positively by farmers (van Bommel and Johnson 2012, Marker et al. 2014). We argue that the use of LGDs may be a potential tool to implement

in areas where livestock pens are not feasible; pens may not be feasible in extensive farming in southern Chile (Herrera 2017). Future research to quantify effectiveness of guardian dogs under different scenarios is warranted, including the development of literature and videos for instructive and corrective training aiming effective livestock protection (Marker et al. 2014).

Elimination of all livestock losses caused by wild carnivores is not attainable in areas with extensive livestock production near natural reserves with habitat suitable for wild carnivores. Due to poor administration and the controversy associated with hunting wild carnivores, economic compensation via livestock insurance, along with farmer education to improve livestock management, could mitigate HWCs in the short- and long-term. In Chile, several challenges limit application of these tools. For example, implementation plans should consider the ecological and social heterogeneity across a broad latitudinal gradient. Indigenous communities, climate, and livestock species vary across the southern and northern regions. In northern Chile, pumas predate domestic camelids (i.e., alpacas [*Vicugna pacos*] and llamas [*Lama glama*]), while in the south, pumas kill sheep.

The process to provide a permit as a hunting license for pumas has no official protocol. The decision is not based on scientific evidence or the estimates of the abundance of pumas in the wild. Local SAG officials take subjective decisions on the number of hunting licenses and who receives them. Under these unregulated procedures, Chilean law does not protect native wildlife that coexist with humans. The livestock insurance is a useful short- and mid-term tool to assist farmers. However, limitations of this program include low farmer awareness of this insurance, and the species covered (i.e., only cattle were considered as livestock in the insurance program prior to 2012). We propose to include other livestock species produced in Chile (i.e., sheep, goats, poultry, and llamas), as they are the main species killed by predators (Figure 2). Additionally, agencies managing agriculture extension and biodiversity conservation in remote areas are crucial for raising awareness about the existence and use of livestock insurance. We recommend that under this scenario, the central government should provide the infrastructure and resources necessary for the effective performance of SAG. Additionally, INDAP is another agency responsible for supporting small farmers (MINAGRI 1990), and thus would be an ideal agency to bring livestock insurance to farmers.

Management implications

We found that better quantification of HWCs in Chile is needed, including reporting of events, the species involved, and economic losses. It is critical to create a database of livestock depredation. This was proposed in 2014 by SAG as a website platform (e.g., Sistema Informático para el Monitoreo de Ataques de Carnívoros—SIMAC), but to our knowledge, this method has not been implemented, nor its feasibility assessed. Thus, no system currently exists to collect, store, and analyze wildlife conflict data in Chile. Finally, livestock losses in Chile occur in a complex combination of landscape, social, climatic, and cultural factors. To achieve an effective plan for prevention and mitigation of HWCs, an interinstitutional and interdisciplinary approach must be adopted to assess the ecological and social dimensions of the problem and identify context-specific solutions to mitigate these conflicts.

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Appendix 1. Permanent digital locations of supplementary materials referenced, VTechData, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA. Access to all supplementary materials can be found at https://data.lib.vt.edu/collections/tm70mv30s.

Material	File name	Location
Supplementary material 1	Source of information of wildlife and domestic species implicated in the human–wildlife conflict across Chile	https://data.lib.vt.edu/files/cc08hf71g
Supplementary material 2	Locations of livestock depredation	https://data.lib.vt.edu/files/bc386j392
Supplementary material 3	Manual de Educación Ambiental y Prevención de Ataques	https://data.lib.vt.edu/files/6d56zw776

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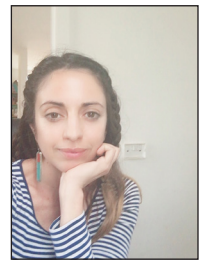

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