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Mass poisonings of the Vulnerable Andean condor prompt national strategy against the use of toxic baits in Argentina

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ABSTRACT

Massive deaths of Andean condors (*Vultur gryphus*) prompted a National Strategy Against the Use of Toxic Baits in Argentina, based on 6 lines of action: 1) delivery of kits and unified intervention protocols in cases of wildlife poisoning, 2) community education programs, 3) surveys of rural people, 4) training courses and participatory construction workshops, 5) toxicology studies, and 6) an academic-scientific committee made up of specialists in toxicology. The strategy was developed in the 14 provinces of the country where the Andean condor is distributed. 554 people from 166 institutions have participated in the trainings and workshops, reporting 200 poisoning events involving more than 21000 individuals from 61 species. Birds and mammals were the groups most affected, and further, human victims show the impact on public health. 19 toxic substances were identified, mainly insecticides. This study proved that carbofuran is the toxic most used. Analysis of bait types suggests a significant conflict with carnivores. 195 surveys revealed that almost half of the farmers know people who use toxic baits and that the negative perception towards some species could determine their use. The strategy began to address the problem of the use of toxic baits in Argentina in a strategic, participatory and regional way, through the management of public policies and scientific research. We propose actions to work on the causes that lead to the application of this dangerous practice. Given its extensive use, we believe that this strategy can be adapted and applied in other countries in the region.

Keywords: Pesticides, wildlife poisoning, conservation, massive mortalities, Andean condor, South America.

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SIGNIFICANCE STATEMENT

Poisoning due to the use of toxic baits threatens wildlife, the environment and human health. The massive death of condors in Argentina, an emblematic species threatened with extinction, motivated the launching of a National Strategy against the use of Toxic Baits [Estrategia Nacional contra el uso de Cebos Tóxicos (ENCT)]. Here we present its six lines of action, analyze the results obtained and propose future guidelines to address this complex problem. Valuable scientific information, based on the reports of hundreds of poisoning cases, surveys and toxicological studies, allowed us to uncover and evaluate, for the first time, the toxicants being used, the types of baits used, the areas of greatest conflict, and the species and number of specimens that are victims, directly or indirectly, of this dangerous practice. Considering this problem at a global level, ENCT can be a strategic model of action that can be adapted and applied to other countries.

INTRODUCTION

The use of toxic baits to kill species considered conflict is happening worldwide (Cowan y Blakley 2015; Henriques et al. 2020; De la Bodega et al. 2020). This practice is nonspecific because by poisoning a food source, many species that use it are exposed to toxic effects. This has concerned the international scientific and conservation community due to the serious consequences it has on species populations and ecosystems (Henriques et al. 2020). Given their gregarious feeding habits, vultures are one of the groups most affected by the use of toxic baits (Márquez et al. 2012), and some species populations are even declining due to this threat (Buechley y Şekercioğlu 2016). Mass mortalities of vultures due to the use of toxic baits have been reported worldwide, especially in Europe and Africa, while information about this in Latin America is still scarce (Plaza et al. 2019).

The Andean condor (*Vultur gryphus*) is the world's largest scavenger and is endemic to South America. Globally, the species is considered as "vulnerable to extinction" and its populations are declining due to anthropogenic causes (BirdLife International 2021). In Argentina, the Andean condor is threatened (MAyDS and AA 2017) and currently its main conservation problem is the use of toxic baits used as a livestock practice (Estrada Pacheco et al. 2020a). In recent years, massive deaths of this species have been recorded in the country due to the consumption of poisoned baits used by ranchers, mainly to kill cougars (*Puma concolor*), foxes (*Lycalopex* sp.) and dogs (*Canis familiaris*) (Estrada Pacheco et al. 2020b).

For more than three decades, the Andean Condor Conservation Program [Programa de Conservación Cóndor Andino (PCCA)], intervened in the rescue and rehabilitation of more than 370 wild condors from the 14 provinces where the species is distributed en Argentina (Jacome y Astore 2016). Studies performed by the PCCA demonstrated the use of carbofuran and parathion in the toxic baits that caused the massive deaths of condors in the country (Estrada Pacheco et al. 2020a). Similar poisoning events are occurring at a worrying scale and frequency in other countries in the region, which could drive the species to extinction (Méndez et al. 2021b). However, these cases represent only the tip of an iceberg, since the discovery and intervention in poisoning events is not always possible because people do not report them or they may occur in inaccessible places. Other times, there is no adequate training or the necessary equipment to intervene in them, which undermines sampling, research and even puts the lives of those who must operate in cases of wildlife poisoning at risk (Ogada 2014).

Due to the massive condor deaths in Argentina, the Ministerio de Ambiente y Desarrollo Sostenible de la Nación (MAyDS), as the enforcement authority of Law No. 22,421 on the protection and conservation of wildlife from the Dirección Nacional de Educación y Participación Ciudadana, together with the Fundación Bioandina Argentina (FBA), agreed to carry out management and research actions within the framework of the PCCA to address the problem of use of toxic baits (CONVE-2019-14377560-APN-SGAYDS # SGP). To this end, human, technical and financial resources were made available to establish a working network with provincial authorities and national and international institutions to create a National Strategy against the use of Toxic Baits [Estrategia Nacional contra el uso de Cebos Tóxicos (ENCT)]. ENCT addresses the cases of condor poisoning in Argentina and aims to uncover which other species are affected by the use of toxic baits, researching the types of baits, the substances used and their incidence in the different regions of the country to propose unified protocols for action.

ENCT has the support of Secretaria de Ambiente y Ordenamiento Territorial de Mendoza, Secretaría de Estado de Ambiente y Desarrollo Sustentable de San Juan, Ministerio de Ambiente de Jujuy, Secretaría de Ambiente y Desarrollo Sustentable de Salta, Secretaría de Ambiente y Cambio Climático de Córdoba, Secretaría de Medio Ambiente de San Luis, Secretaría de Estado de Ambiente de Santa Cruz, Secretaría de Ambiente, Desarrollo Sostenible y Cam-

bio Climático de Tierra del Fuego, Antártida e Islas del Atlántico Sur, Secretaría de Ambiente, Desarrollo Sustentable y Cambio Climático de Río Negro, Secretaría de Desarrollo Territorial y Ambiente de Neuquén, Ministerio de Desarrollo Productivo del Gobierno de Tucumán, Secretaría de Medio Ambiente de Catamarca, Dirección de Fauna y Flora Silvestre de Chubut and Secretaría de Medio Ambiente de La Rioja. ENCT was declared of federal environmental interest by Consejo Federal de Medio Ambiente (COFEMA), through Resolution 390 / June 2019.

After two years in office, we describe ENCT's lines of action, as a strategic model that can be replicated in other countries in the region, we analyze its results and propose future development actions.

MATERIAL AND METHODS

Study area

Our study area encompassed the 14 argentine provinces where the Andean condor is distributed, covering more than 3500 km of mountain range from Jujuy to Tierra del Fuego, with peaks that reaches altitudes of 6961 m, and the central sierras of Córdoba and San Luis. These provinces represent 61% of the national territory and cover more than 1.69 million km^2 (Northern Region 333,834 km^2, Central Region 570,216 km2 and Southern Region 786,983 km^2).

In this large area, the main productive activity is cattle ranching and, to a lesser extent, agriculture (Nanni et al. 2020). Cattle ranching is an important activity in northwestern and central Argentina, with about 4.4 million cows per region (Rearte 2007). Patagonia, on the other hand, is the region with the fewest cattle, with about 1.5 million cows. In the northwestern, central and Patagonian regions, there is extensive cattle raising by small producers where cows feed on natural pastures. On the other hand, sheep farming is an important productive activity in the Patagonian region where there are both small farms with few animals and large farms that manage a large number of sheep (SENASA 2018). In the rest of the country sheep farming is usually framed in mixed production systems (agricultural-livestock, sheep-goat) (Mueller 2013). As for the production of goats for meat and milk, Mendoza, Neuquén and the entire northwestern are the main producers, where the activity is mainly associated with small producers who raise livestock for family and local consumption (Planet Finance 2011). Finally, llamas are also farmed in the Puna, and their meat and wool are consumed and sold locally (Rigalt 2012). In our study area, agriculture is practically not developed in the southern region, while it occupies eastern sectors of the central and northern regions (Nanni et al. 2020; SAGyN 2022).

ENCT lines of action

In order to address the use of toxic baits in Argentina, the ENCT developed 6 lines of action.

1. EMERGENCY KITS. It is essential for the environmental authority of each province to have basic equipment and an action protocol for emergency intervention in cases of wildlife poisoning. Therefore, within the framework of the ENCT, a kit was provided with biosecurity elements, materials, instruments and a protocol with procedural norms (Estrada Pacheco et al. 2021). This equipment has the necessary elements for sampling, data collection, sanitation, as well as biosafety elements to minimize the risks for the technical personnel who must intervene in the field.

2. COMMUNITY EDUCATION. Since it is necessary to reach the community with a clear message about the danger posed by the use of toxic baits, the ENCT includes an educational program, based on the scientific, cultural and educational exhibitions developed by the PCCA. The exhibitions highlights the risks of this serious threat, as well as the efforts being made to address a solution. It consists of a display of more than 70 pictures (1 m x 0.7 m) and material and videos that support the educational talks. The exhibitions were presented in cultural centers in the provinces with the highest number of poisoning cases due to the use of toxic baits (Estrada Pacheco et al. 2020a), representing the northern, central and southern regions of the country. The month-long exhibitions, with free admission, were open to the general public and were coordinated by the provincial environmental authorities, MAyDS and FBA.

3. SURVEYS OF RURAL PEOPLE. Surveys were conducted in different localities, in provinces where the Andean condor is distributed. The surveys were aimed at people with some degree of association with livestock (they currently have livestock or have had livestock in the past). To locate these individuals, key informants in the area (police, teachers, park rangers, etc.) were contacted, and they indicated which people met these conditions and their locations. To maximize the number of people surveyed, this information was complemented with snowball sampling (Goodman 1961). The surveys were

anonymous to protect the respondent's identity. Semi-structured forms were used, complementing the information with interviews and informal conversations. The locality of the livestock establishment, the perception (harmful vs. non-harmful) of 12 species of wildlife (using photographs for correct identification), and the knowledge and eventual use of toxic baits as a livestock practice were recorded.

4. TRAINING COURSES (TC) AND PARTICIPATORY CONSTRUCTION WORKSHOPS (PCW). In each province, environmental, productive, educational, health, safety, research, NGOs and other social activists involved with mitigating the poisoning problems were summoned to a one day meeting which began with a press conference announcing the provincial support of the ENCT. The meetings were the ideal framework for the delivery of emergency intervention kits to the environmental authorities.

   The TC began with an anonymous survey to assess the participants' knowledge of the problem of the use of toxic baits. The training included presentations by local specialists and ENCT professionals who presented the impacts of poisoning on the conservation of the Andean condor and other wildlife, the environment and human health. Training was also provided on the ENCT action protocol in cases of wildlife poisoning.

   In the PCW, heterogeneous groups were formed so that all the stakeholders involved were as well represented as possible and the participants assigned a reference person to take notes.

   Each group reported the cases of poisoning they knew of, where and when they occurred, the species and number of individuals involved, and the type of baits and poisons used. When participants did not remember the number of individuals involved in an event, the number was considered equal to one for that species. In the analysis of the poisoning events recorded, duplicate data were eliminated, that is, those in which the place, date and species involved coincided. Finally, the participants presented their results, and the different presentations were recorded as testimonial records.

5. SOS CONDOR: TOXICOLOGICAL STUDIES. ENCT, within the framework of the PCCA, developed a program called SOS Condor which, together with the provincial environmental authorities and security forces, implements emergency action in cases of wildlife poisoning to guarantee that taking of samples, the chain of custody, toxicology studies and the sanitation of the affected site is completed according to an established protocol (Estrada Pacheco et al. 2021). It is essential to scientifically study the cases of wildlife poisoning in order to be able to reliably determine the type of poison used and the severity of its impact. The diversity of poisons is enormous, and their effects can be different, so gas chromatography and mass spectrometry were used to detect and differentiate them. Alternatively, enzymatic activity of acetylcholinesterase in blood was measured to determine toxicant category. Toxicology studies were performed on crop contents and blood samples. We considered poisoning when it was found that the bird had been in contact with poison or when carcasses of these birds were found in a typical scene of poisoning due to the use of toxic bait (dead condors found near a bait in the same area). We define possible poisoning, when at the time of rescue the bird was found with symptoms compatible with a picture of poisoning (jaundice, salivation, regurgitation, loss of stability and flight capacity) and subsequent studies showed no other results.

6. SCIENTIFIC ACADEMIC COMMITTEE. Within the framework of ENCT, coordinated by the Dirección Nacional de Sustancias y Productos Químicos of MAyDS, specialists in toxicology, representatives of prestigious study centers of the country were summoned to form an academic-scientific working group to contribute to the scope of the strategy. The committee oversees review ENCT protocols and proposing measures to combat this serious problem.

Statistical analysis

We analyzed the results of ENCT from its beginning on June 12, 2019 to March 2021. The poisoning events were grouped according to the region of the country where they occurred: Northern Region (Jujuy, Salta, Tucumán and Catamarca provinces), Central Region (San Juan, Córdoba, Mendoza, San Luis and La Rioja provinces) and Southern Region (Neuquén, Río Negro, Chubut, Santa Cruz and Tierra del Fuego provinces). We analyzed the relative frequency of poisoning by applying the chi-square test, where the expected values were the same for the three regions (total of events / 3). We made maps with the emerging information from the PCW using QGIS software version 2.18.28 (QGIS Development Team 2022).

In the analysis of the rural population surveys, we evaluated the use of poison as a lethal method to combat wildlife. For this purpose, we constructed

generalized linear models (GLMs), with binomial distribution, where the response variable was whether they ever used/use poison to kill wildlife considered harmful (1) or never used it (0). The variables included in the models were province, sex, and perception of the species, depending on whether they are considered harmful or not for livestock.

Model selection was made using Akaike's Information Criterion for Small Samples (AICc), choosing the model with the lowest index. Differences in the Akaike value greater than 2 were considered different models (Burnham y Anderson 2002). All analyses were performed using R software version 3.6.0 (R Core Team 2020) and we considered statistical significance when $p < 0.05$.

RESULTS

ENCT was officially launched on June 12, 2019 and covered 14 provinces within the distribution area of the Andean condor in Argentina. With the cooperation of the environmental authorities, ENCT was developed in the provinces of Jujuy, Salta, Tucumán, Catamarca, San Juan, Córdoba, Mendoza, San Luis, La Rioja, Neuquén, Río Negro, Chubut, Santa Cruz and Tierra del Fuego.

Emergency intervention kit

During the training sessions, the emergency intervention kits and protocols for action in cases of wildlife poisoning were delivered to the environmental authorities of the 14 provinces (one kit for province). Both the contents of the kit and the action protocol have been updated during the ENCT course, making these resources available to the provinces.

Training courses (TC) and participatory construction workshops (PCW)

In all the provinces mentioned above, the TC and PCW were established, where 554 people participated (167 individuals in northern region, 247 in central region and 140 in southern region), representing 166 institutions.

Surveys conducted at the beginning of the TC indicated that 69% of the participants were aware of the use of toxic baits and 21% indicated that they knew people who use or have used toxic baits. 44% of the participants were aware of strychnine and carbofuran, and to a lesser extent parathion (29%), as substances used in the preparation of baits. On the other hand, 78% considered the practice ineffective for its intended purpose, and a danger to human health (93%) and the environment (93%).

In the PCW, 200 poisoning events between 1982 and 2020 were reported. A total of 191 cases were located in the 14 provinces studied, 6 in other provinces (La Pampa, Buenos Aires, Entre Ríos and Corrientes) and 3 in Chile (Figure 1). A total of 21,816 victims of poisoning ($mean = 109.08$, $SD = 1,413.76$) from 61 species were reported. Birds ($n = 28$ species) and mammals ($n = 25$) were the most frequently reported groups. Other groups reported included fish, insects and reptiles ($n = 8$).

Events occurring within the study area were more frequent in the central region ($n = 82$) than in the southern ($n = 56$) and in the northern ($n = 53$) regions ($X^2 = 7.98$, $g.l. = 2$, $p = 0.018$, $n = 191$). In terms of the number of individuals, the central and southern regions were more affected than the northern region ($X^2 = 337$, $g.l. = 2$, $p < 0.001$) (Figure 1).

The events involving birds within the study area were distributed with the same frequency in the three regions of the country ($X^2 = 2.31$, $g.l. = 2$, $p = 0.31$, $n = 115$). In terms of the number of victims, the central region was the most affected, followed by the southern region and, to a lesser degree, the northern region ($X^2 = 67.75$, $g.l. = 2$, $p < 0.001$, $n = 512$). Outside the study area, two events were recorded. The antecedent of 20000 dead individuals of Swainson's hawk (*Buteo sawinsoni*) in the province La Pampa, due to the use of monocrotophos, an organophosphate insecticide (Sarasola et al. 2007) and one case of 5 ducks, in the province Entre Ríos (Figure 2).

Within the study area, the Andean condor was the most affected species, with 177 individuals reported. In addition to condors, other vultures were recorded (n=78), highlighting that scavenger birds are especially affected by this problem (Figure 3).

Mammals, in terms of the number of species, were the second most affected taxonomic group by toxic baits in the country. Within the study area, 1106 individuals, including wildlife, domestic species and humans, were affected in 120 events.

Dogs were the most frequent victims, with 890 individuals in 75 poisoning events. The number of events varied among regions of the country ($X^2 = 13.13$, $g.l. = 2$, $p = 0.001$), as they were more numerous in the center ($n = 36$) and south ($n = 29$), relative to the northern region ($n = 10$), and the same was found for the number of affected individuals ($X^2 = 303$, $g.l. = 2$, $p < 0.001$, $n = 890$) (Figure 4). Guanacos (*Lama guanicoe*), cats, foxes and deer have also been among the main victims, and even 11 humans were affected by toxic baits (Figure 5).

In relation to events involving wild mammals within the study area, we found similar frequencies in the three regions of the country ($X^2 = 3.45$, $g.l. = 2$,

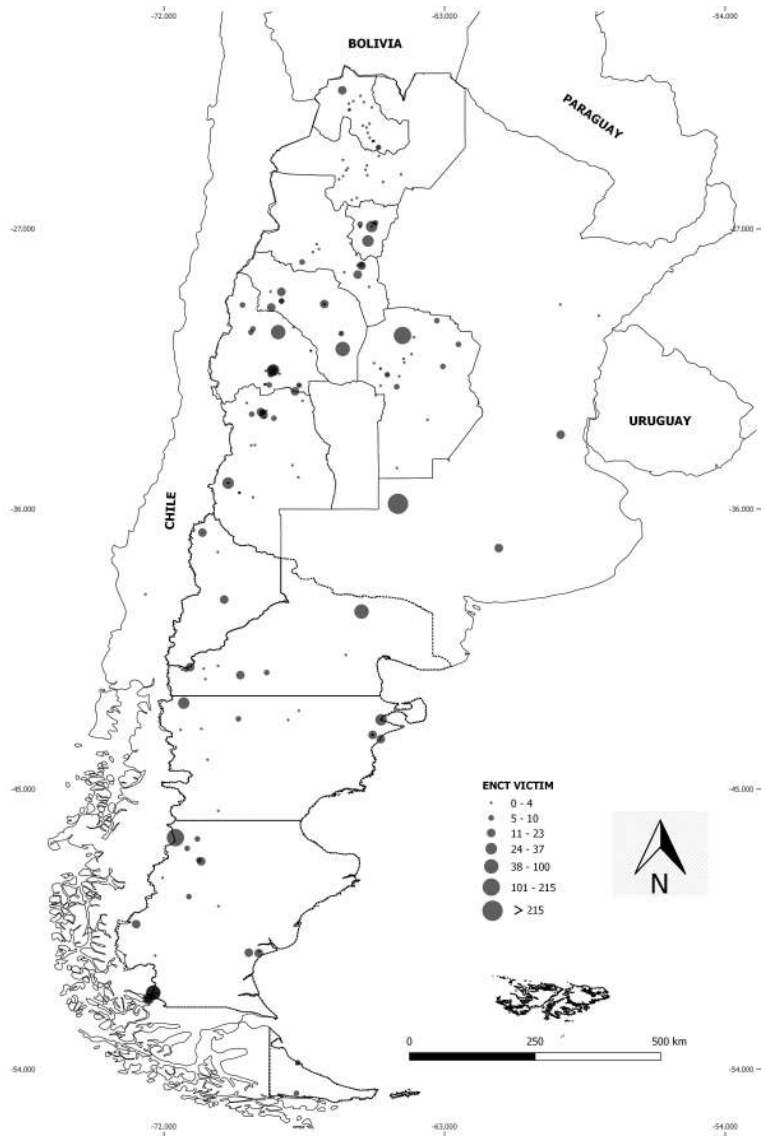

Figure 1. Poisoning events due to the use of toxic baits reported by the PCW. 200 events involving 61 species are shown. The size of the circles corresponds to the number of victims. The political boundaries of the 14 argentine provinces included in the study area are shown.

$p = 0.18$, $n = 44$). However, the number of individuals involved was higher in the southern and central region ($X^2 = 12.90$, $g.l. = 2$, $p = 0.002$, $n = 108$). Outside the study area, 8 events involving 72 individuals were reported in Corrientes, Entre Ríos, Buenos Aires and Chile, affecting one Maned Wolf (*Chrysocyon brachyurus*), 3 foxes, 66 dogs, 1 cat and even 1 human.

In relation to the type of poison used, the PCW allowed the identification of at least 19 toxic substances, used in 74 poisoning events, observed with the same frequency in the three regions of the country ($X^2 = 2.27$, $g.l. = 2$, $p = 0.32$).

The most used toxicants were insecticides (78%), among them carbamates, such as carbofuran and methomyl, which were used in most of the poisoning events (74%). The use of carbamates was associated with the southern ($n = 18$) and northern ($n = 14$) regions, and to a lesser extent with the central region of the country ($n = 5$) ($X^2 = 7.19$, $g.l. = 2$, $p = 0.027$). The use of organophosphates such as parathion, monocrotophos and chlorpyrifos (17%), organochlorines such as endrin (4%), pyrethroids (2%), among other insecticides (3%) was also reported (Figure 6).

Rodenticides, such as warfarin and strychnine (12%), herbicides (3%) and other substances, such as antifreeze, metaldehyde, sulfur, aluminum sulfate and

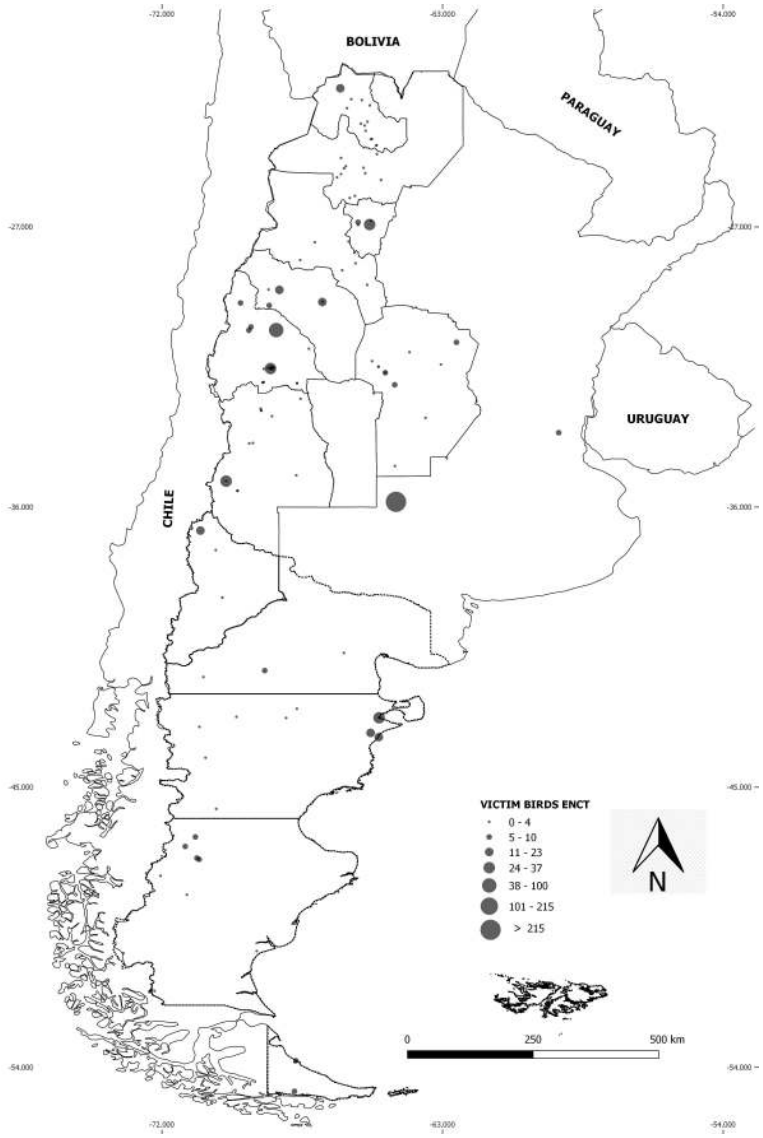

Figure 2. Bird poisoning events due to the use of toxic baits reported in the PCW. The size of the circles corresponds to the number of individuals involved. The political boundaries of the 14 argentine provinces included in the study area are shown.

carbide pills (7%) were also reported in the preparation of poisoned baits.

From the PCW it becomes apparent that toxicants were applied in different types of baits. Animal products (pieces of meat, fat, eggs) were used in 38% of the events, domestic animals (sheep, cows, goats, donkeys, chickens, dogs) in 33%, wild animals (guanacos, pumas) in 11%, vegetables (mandarins, corn) in 11%, water in 4% and processed foods (noodles, bread) in 3% (Figure 7).

Both products of animal origin ($n = 28$ events), domestic animals ($n = 24$ events) and wild animals ($n = 8$) were used as bait with the same frequency in the three regions of the country ($X^2 = 4.59$, $g.l. = 2$, $p = 0.10$). Vegetables, on the other hand, were used almost exclusively in the provinces of the northern region. Water was used in very few events occurring in the provinces of Mendoza and Santa Cruz. Processed food was used in 2 events in the provinces of La Rioja and Río Negro (Figure 8).

Of the 200 poisoning events recorded in the PCW, in 132 (66%) information was obtained about the year in which they occurred. Of these, 54% of the cases were recorded between the years 2018 to 2020, and the oldest event corresponds to the year 1982, in Arroyito, Córdoba, where even one person died after poisoning fat with Endrin in an attempt to kill psittacines (Figure 9).

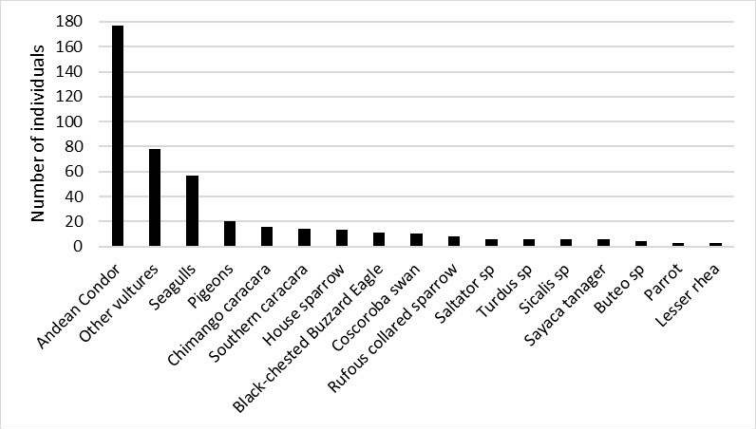

Figure 3. Birds most affected by the use of toxic baits in Argentina within the study area reported by PCW.

SOS Condor: toxicological studies

Within the framework of ENCT's SOS Condor program, we intervened to study and clean up the environment in 13 events involving 26 condors. In 7 cases, poisoning was confirmed, and 20 condors were poisoned in the provinces of Salta (Paraje San Luis), Tucumán (Tafí del Valle), San Juan (Bauchaceta), Mendoza (Poti Malal), Córdoba (El Volcán), Río Negro (Arroyo Tembrao) and Santa Cruz (Perito Moreno). Six occurrences of possible condor poisoning involving 6 condors were recorded in the provinces of Jujuy (Tilcara), Mendoza (Las Loicas), Córdoba (Punilla), Río Negro (La Fragua), Neuquén (Bajada del Agrio) and Santa Cruz (28 de Noviembre).

It is worth noting that the events in Tafí del Valle and Perito Moreno were massive, each involving at least 6 poisoned condors. In Tafí del Valle it was possible to prove the use of organophosphates or carbamates, by means of enzymatic activity of acetylcholinesterase in blood. The presence of Puma meat as a vehicle for the poison could be confirmed in the crop of one the condors which died. The other 5 individuals were rehabilitated and released. In Perito Moreno, 6 dead condors and a sheep used as bait were found. Toxicology studies determined the use of carbofuran. In the events in Paraje San Luis and El Volcán, it was also possible to confirm the use of carbofuran.

All the cases were reported by FBA, within the framework of the PCCA, to the provincial and national environmental authorities, to the Unidad Fiscal para la Investigación de delitos contra el Medio Ambiente, to the Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA) and to COFEMA.

Community education programs

Four educational campaigns presenting the scientific, cultural and educational exhibitions developed by the PCCA were carried out in the provinces of Jujuy (Facultad de Humanidades y Ciencias Sociales de la Universidad Nacional de Jujuy), Mendoza (Museo de Educación), Río Negro (Residencia del Gobernador) and Santa Cruz (Complejo Cultural de Río Gallegos), thus covering the northern, central and southern regions of the country.

Press releases in the mass media, as well as the production of videos and educational spots, made it possible to extend the reach of ENCT's educational campaigns in the community.

Surveys of rural people

Surveys were conducted in 7 Argentine provinces within the Andean condor distribution (Jujuy, Salta, San Juan, Córdoba, Mendoza, Río Negro and Chubut). The total number of surveys was 195 (63 in the northern region, 80 in the central region and 52 in the southern region). Most respondents were male (77%, binomial test $p < 0.001$) and age ranged from 15 to 84 years ($mean = 52$, $SD = 14$ years). All respondents were involved in livestock activity, 48% were engaged in the activity exclusively, 42% complemented it with other work and 10% were engaged in the past.

Perceptions of wildlife species varied, with the Puma (80%), Grey fox (61%), Culpeo fox (60%), Andean condor (32%) and, to a lesser extent, other species, being considered the most detrimental to livestock farming. Fifteen percent of the respondents indicated that they use or have used toxic baits to combat wildlife that they considered harmful. There was a association with this practice in the southern region ($X^2 = 13.65$, $g.l. = 2$, $p = 0.001$). The perception of

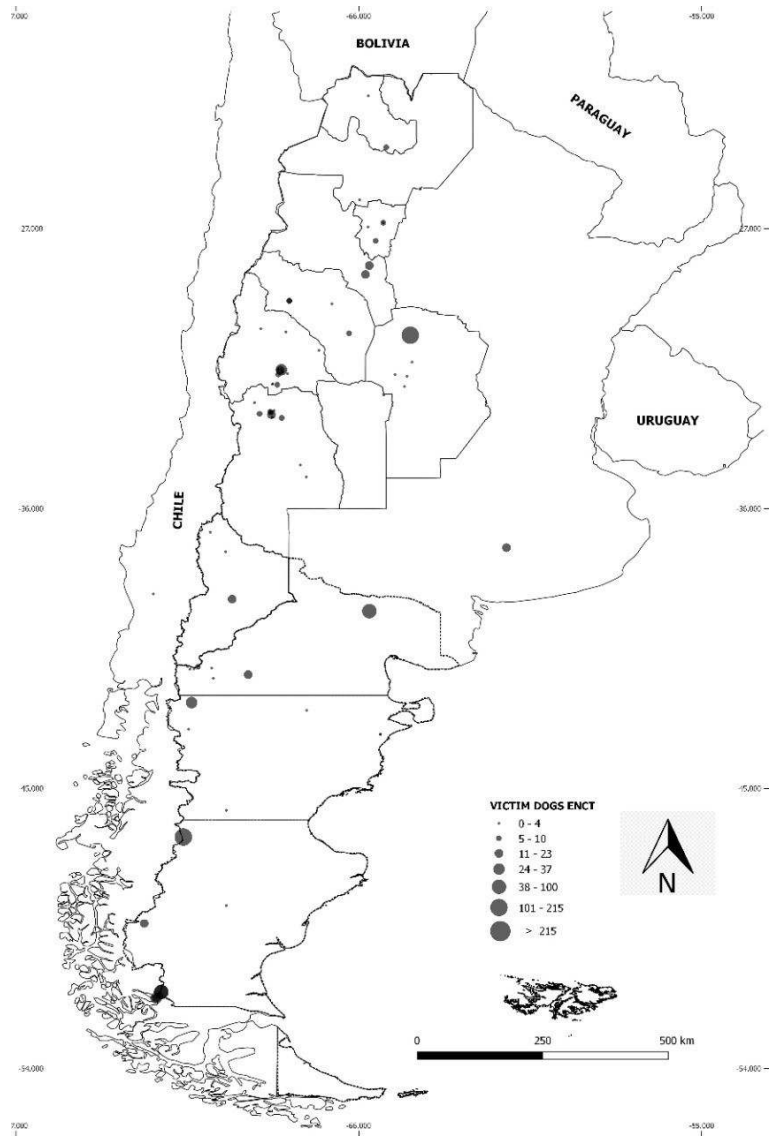

Figure 4. Dog poisoning events by use of toxic baits reported by PCW. The size of the circles corresponds to the number of individuals involved. The political boundaries of the 14 argentine provinces included in the study area are shown.

Puma, Grey Fox and Andean condor was not associated with the use of toxic baits (Puma: $X^2 = 0.14$, $g.l. = 1$, $p = 0.7$; Grey fox: $X^2 = 0.27$, $g.l. = 1$, $p = 0.6$; Andean condor: $X^2 = 0.18$, $g.l. = 1$, $p = 0.67$), while the perception of the Culpeo fox was associated ($X^2 = 6.16$, $g.l. = 1$, $p = 0.01$).

Regarding the target species to which the toxic bait was directed, 8.7% of the respondents reported that it was directed toward Culpeo fox, 6% toward Puma and 5.6% toward Grey fox. Only one person in the town of Liviara, province of Jujuy, in addition to applying toxic bait against Grey fox and Puma, reported using this practice against Andean condor (0.5%). Around 45.5% of respondents indicated that other villagers in the area use toxic baits. These responses varied between regions ($X^2 = 38.7$, $g.l. = 2$, $p < 0.001$), with most respondents from the southern region reporting that their neighbors use toxic baits to combat species considered harmful (77%), almost half of the respondents from the northern region indicating the same, and only 20% of respondents from the central region accepting their use.

With no differences between regions, 60% considered the use of toxic baits to be an effective method for the objective pursued ($X^2 = 3.48$, $g.l. = 2$, $p = 0.17$), 80% indicated that it was dangerous for human health (Fisher Test, $p = 0.21$) and 93% that it was dangerous for wildlife (other non-conflict species)

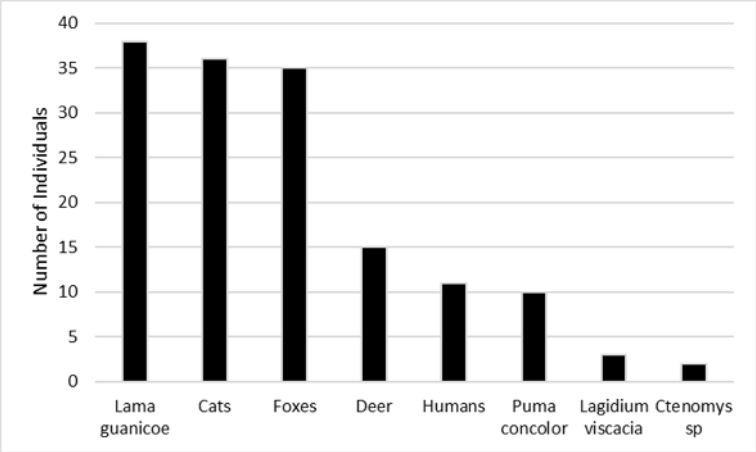

Figure 5. Mammals most affected by the use of toxic baits in Argentina reported by PCW. Dogs are not included for better visualization.

(Fisher Test, $p = 0.41$). Three equivalent models were obtained, which explain the use of toxic baits by farmers, where the provinces in which they are applied and the perception of the Culpeo fox turned out to be the most important variables (Model 1 = province, $AIC = 136.29$, $\Delta AIC = 0.0$; Model 2 = province and perception of the Culpeo fox, $AIC = 136.51$, $\Delta AIC = 0.22$; Model 3 = perception of the Culpeo fox, $AIC = 137.3$, $\Delta AIC = 1.00$).

Academic-scientific committee

More than 35 specialists in toxicology formed the academic-scientific committee of the ENCT. They reviewed and updated the protocol developed by the FBA with the collaboration of national and international professionals. The committee improved the functioning of the chain of custody to make more effective the taking of samples for toxicological studies in order to have a unified document to attend wildlife poisoning events.

DISCUSSION

ENCT made it possible to equip, train and provide an action protocol to the environmental authorities of each province, so that their technicians can operate under biosafety standards in a unified and effective way in cases of wildlife poisoning. These resources are essential for an adequate sampling, which allows for the scientific study of each case and provides solid evidence as grounds for criminal cases.

The ENCT protocol, whenever possible, was implemented for each new poisoning event that occurred. Due to the vastness of the national territory and the distances that need to be covered to deal with these cases, it became evident that a single kit per environmental authority is a very limited resource. Therefore, we recommend providing additional kits to the provinces, including national security forces (Gendarmeria Nacional Argentina), provincial security forces (environmental and rural police), Administración de Parques Nacionales, among others. According to our results, the majority of people consider that the use of toxic baits is a danger to human health, wildlife and the environment. However, their use is widespread in the 14 provinces where the ENCT was carried out, so we recommend applying the strategy, as a federal policy, in the rest of the country. TC participants and farmers respondents are aware of this practice, and some even stated that they use it. It is worrisome that almost half of the farmers said they know producers who currently use this practice. It is urgent to implement legal, educational and management measures to avoid its use.

We recorded a higher number of events and individuals affected by toxic baits in the central and southern region during PCW. The higher number of participants could explain our results in the central region. However, the southern region, which had the lowest number of participants, was very prominent in the results, suggesting that the number of participants in the PCW might not limit the number of events and victims recorded.

In the southern region, livestock producers admitted using or having used toxic baits to combat wildlife and even that their neighbors use them more frequently than in the other regions. Previous studies conducted in Patagonia demonstrate the appreciation that ranchers have for this practice (Gáspero et al. 2017; Travaini et al. 2000). The livestock production system, the negative perception towards

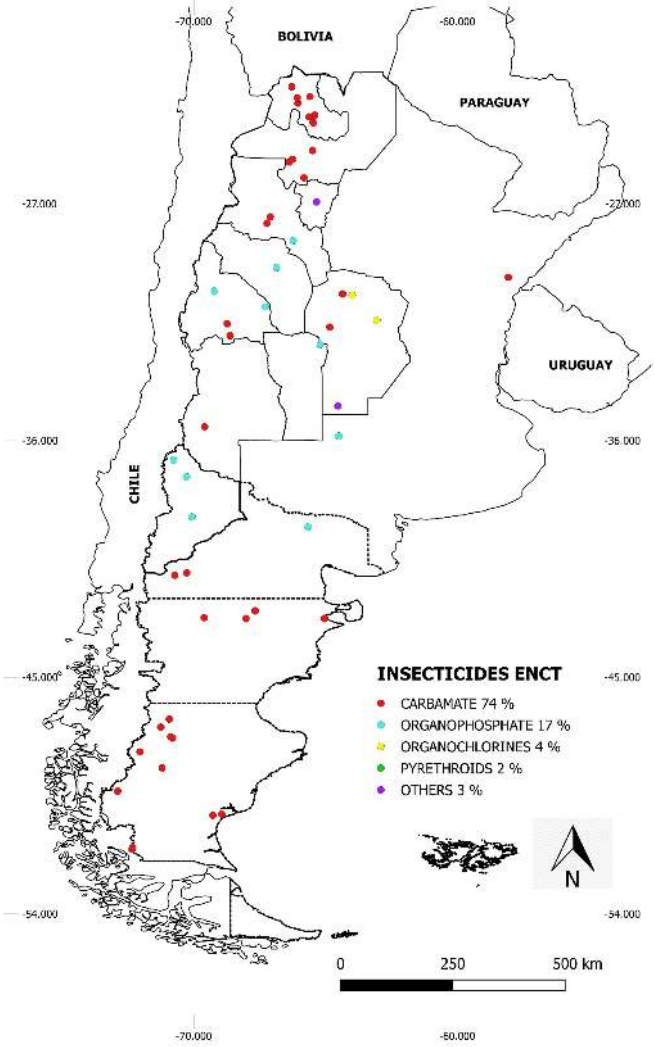

Figure 6. Insecticides used in poisoning events due to the use of toxic baits reported by the PCW and their percentages of occurrence. The political boundaries of the 14 argentine provinces included in the study area are shown.

wild carnivores and the legal regulations in some of these provinces that endorse and even grant economic compensation for the killing of pumas and foxes (García Brea et al. 2010; Llanos et al. 2014) perpetuate strong livestock-wildlife conflict in the region, that could explain an higher use of toxic baits.

As has been recorded in other countries, the use of poison-baits in Argentina affects many species, including humans. In addition, the enormous number of individuals involved could seriously impact natural populations of many of these species (De la Bodega et al. 2020).

Our results suggest that birds are one of the group most affected by this practice and poisoning events occur in all the regions studied. We reported the poisoning of the Swainson's hawk occurred in mid-1990. This was one of the paradigmatic cases of the negative effects of pesticide use in Argentina. Spatial aggregation, habitat selection and feeding habits, together with environmental conditions that favored demographic explosions of insects considered harmful to crops in the Pampean Region, were decisive in the massive deaths of this species (Sarasola et al. 2007). Vultures were particularly affected by toxic baits and the Andean condor were the main victims. Their gregarious habits and hierarchical feeding behavior making them vulnerable to suffer massive deaths in poisoning events (Méndez et al. 2021a). The high mortality of adult individuals and consequent loss of future offspring, are devastating for natural populations, especially for threatened species such as the Andean condor (Estrada Pacheco et al. 2020a; Mén-

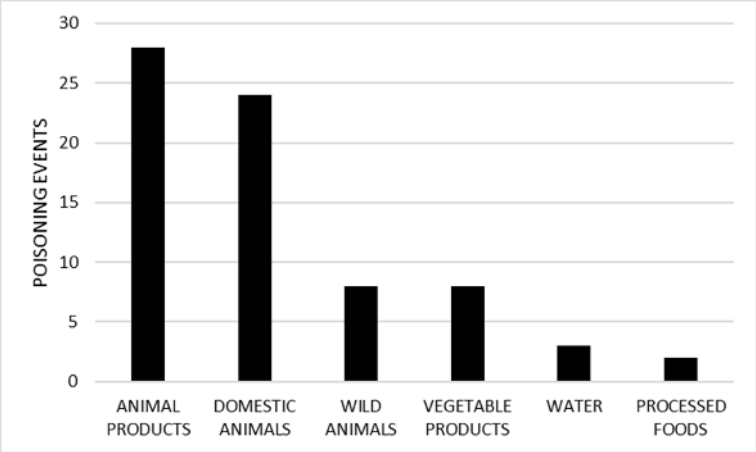

Figure 7. Types of baits used in the poisoning events reported in Argentina by the PCW.

dez et al. 2021a). The loss of scavenger birds results in a decrease in their environmental services, and the carrion that are not eliminated can become foci of infection, generating the spread of unwanted species and disease transmission (Baruzzi et al. 2018; Ogada et al. 2012). Within the study area, mammals were the most affected group by the use of toxic baits in terms of number of events and individuals, with dogs being the most frequent victims. Their deaths are associated with the vicinity of large urban centers and the conflict between feral dogs and livestock. One of the most important cases occurred in the city of Deán Funes, province of Córdoba, where at least 215 dogs were killed. This case was brought to justice in the 12th Criminal Court of the city of Córdoba (Ámbito 2013). The massive death of dogs has caused the declaration of environmental and sanitary alarm in important cities of the country on several occasions (Ámbito 2013; Norte 2019). Hundreds of poisoned dogs, mainly associated with the central and southern regions of the country, expose the lack of responsible pet ownership and proper sanitary management programs. Conflict with dogs is a problem, as documented in Argentina and other countries, with great impact on wildlife conservation (Montecino-Latorre y San Martín 2018; Zamora-Nasca et al. 2021). Reptiles, fish and insects were also victims of poisoning, demonstrating that the use of toxic baits targeted at certain species may affect various forms of life. The number of individuals involved in these events could not be precisely determined and was considered equal to one. Therefore, the total number of poison-bait victims reported by the PCW is underestimated. Identification of substances involved in poisoning events is often difficult due to the lack of appropriate material and training for sample collection (Plaza et al. 2019). Nevertheless, through our strategy we were able to identify at least 19 toxics that could be being used in the production of poison baits. Our results suggest that most of the poisons used are cholinesterase inhibitor insecticides (carbamates and to a lesser extent organophosphates) used in agriculture. Of these, carbofuran is the most widely used, especially in the north and south of the country where it was reported in the initial surveys of the TC, as well as in the PCW and toxicological studies of the SOS Condor program. The massive cases of condor poisoning that we investigated and denounced from the PCCA in 2017 in Rinconada (Jujuy) and in 2018 in Los Molles (Mendoza), Perito Moreno (Santa Cruz), and Manzano Amargo (Neuquén) shocked the public and occupied the main mass media (Estrada Pacheco et al. 2020a). As a result of these events, society began to become more aware of the danger posed by poisoned baits, which could explain the greater number of events reported in the PCW in the last three years (Figure 9). These cases influenced SENASA to ban the use of carbofuran in Argentina (Resolution 263/2018). This is a very important measure, although not enough, given that substances such as parathion and strychnine, despite being banned decades ago in all their formulations and uses (Resolution 606/93, Resolution 976/93), are still used in the production of toxic baits (Estrada Pacheco et al. 2020a; García Brea et al. 2010; Travaini et al. 2000). Unfortunately, these substances are also used in other countries around the world for the same purpose (Botha et al. 2015; Hernández y Margalida 2008; De la Bodega et al. 2020; Otieno et al. 2011). Regarding the type of bait, although we found that vegetables are used in some agricultural production areas, our data showed that domestic animals, animal products and wild animals are the most commonly used as baits (82%). These baits target species that

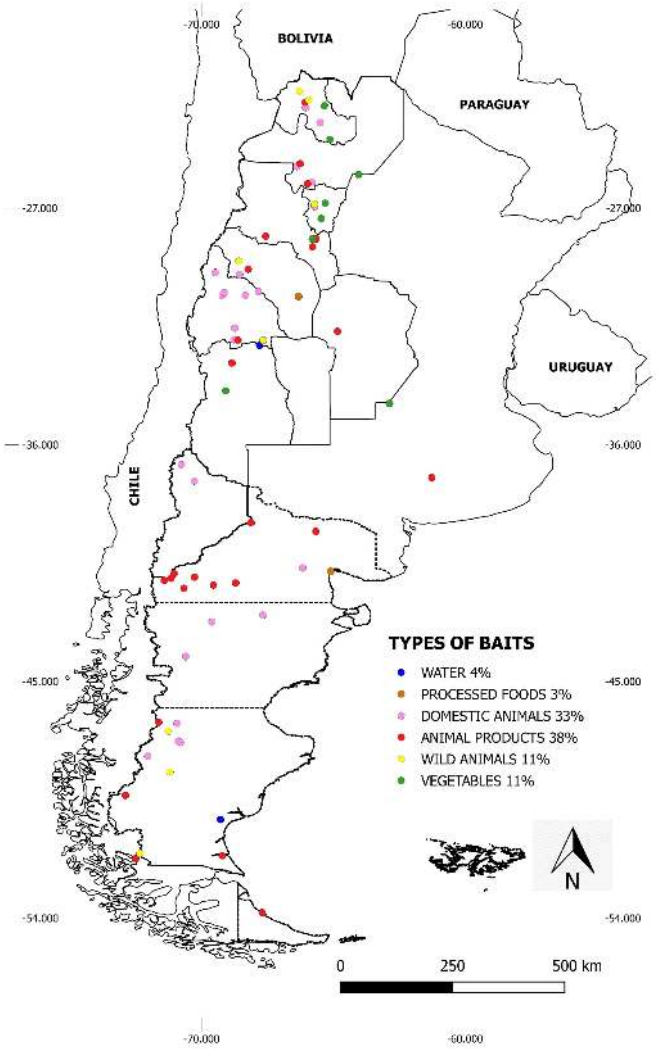

Figure 8. Types of bait used in the poisoning events recorded by PCW and their percentages. The political boundaries of the 14 argentine provinces included in the study area are shown.

consume these resources and are considered harmful in livestock farming, which highlights the need to address livestock-wildlife conflicts in depth, as mentioned by other studies in the country (Ballejo et al. 2019; Cailly Arnulphi et al. 2017). Therefore, we recommend promoting permanent educational actions, public policies that encourage livestock alternatives and responsible practices among producers, such as tax compensation systems for producers who demonstrate good management practices, improvements in the design and condition of corrals, sound and light alarms, protection dogs, and economic compensation for losses to those who develop good practices. Some of these alternatives have already been implemented locally and have demonstrated their effectiveness in reducing livestock predation (Garramuño et al. 2017; González et al. 2012; Ohrens et al. 2019). Increasing these efforts would address conflicts with wildlife through appropriate management measures that help to reduce the use of toxic baits. We recorded cases of poisoning throughout the 14 provinces studied. Some of them occurred in isolated areas, with few inhabitants and far from the main cities. Even the use of pesticides associated with agricultural production was recorded in areas of livestock production, suggesting that there is easy access to toxic substances, anywhere in the country, to be used for a variety of purposes. We recorded the abuse of permitted (metomil Resolution 1563/01 and piretroides Resolution 466/1) and prohibited substances (endrin, Resolution 2121/90; monocrotofos, Resolution 182/99; carbofuran, Resolution 263/18; clorpirifos, Resolution 414/21). Access to the last ones is evidence of an active illegal market and/or the consequences of

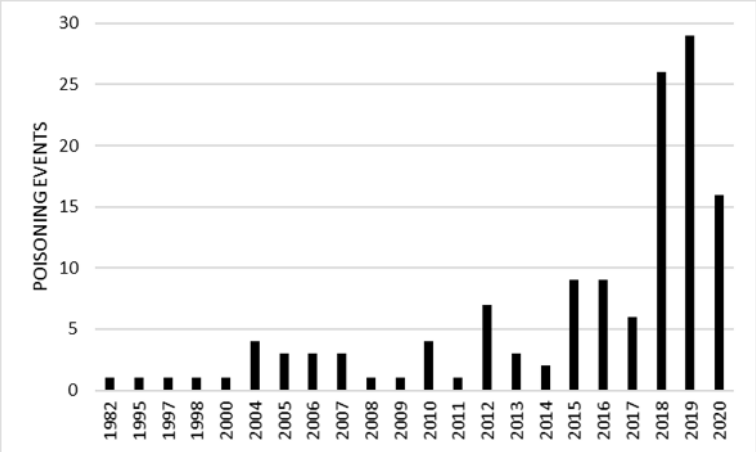

Figure 9. Poisoning events that occurred between 1982 and 2020, reported in Argentina, in the PCW.

remaining stocks.

ENCT provides scientific evidence that unequivocally demonstrates the occurrence of cases of poisoning in the country and its consequent impact for several species. This information makes it possible to go deeper into the problem of the use of toxic baits and provides results which can support future lines of investigation and the initiation of legal cases in search of sanctions for environmental remediation (La República Digital 2021). In addition, the detection of the specific type of poison used makes it possible to identify sales channels and tighten controls on their commercialization and use. Environmental education is a continuous pedagogical process which contributes to a critical reflection of humans' relationship with the environment. It is a fundamental line of action of the ENCT. In order to generate a substantial change in society and stop the use of toxic baits, we consider it a priority to continue with training courses and participatory construction workshops and to extend educational campaigns and dissemination actions to the entire national territory. In formal education, although it is a big challenge, it is necessary to include this problem and its consequences as a curricular proposal at all levels: initial, primary, secondary and higher education. In the non-formal sphere, it is essential to carry out direct awareness talks to farmers and stallholders on the risks and damages, direct and indirect, of the use of toxic baits. We recommend the creation of a register of producers, importers, traders, users, storage and final disposal of agrochemicals. Agree with producers and importers on annual quotas, supervising and reducing the number of outlets. We suggest ensure the professional service of agronomists to small producers. Further, we recommend border controls are intensified and seizures and fines for the illegal possession of prohibited products are implemented. It is urgent to have a National Law on traceability and prescription of agrochemicals in Argentina that will make it possible to control the sale and distribution of these dangerous substances. It is worth noting that, to date, of all the cases reported by ENCT very few have led to the initiation of judicial or criminal proceedings or the arrest of individuals. It is urgent to reform the penal code so that these crimes against the environment and human health are duly punished.

CONCLUSION

The massive death of Andean condors in Argentina prompted the launching of a National Strategy against the use of Toxic Baits (ENCT). This generated valuable scientific information, based on reports of hundreds of poisoning cases, surveys and toxicological studies that allowed us to know and evaluate the toxicants and types of baits used, the areas of greatest conflict, and the species and number of individuals that are victims, directly or indirectly, of this dangerous practice. The development of this work and the knowledge generated allowed us to propose actions to work on the causes that lead to the application of this activity.

ENCT began to address the issue of the use of toxic baits in Argentina in a strategic, participatory and regional manner, through public policy management and scientific research. Considering this problem at a global level, we believe that ENCT can be a strategic model of action that can be adapted and applied in other countries of the region. Unfortunately, the impacts of the use of toxic baits extend to other Latin American countries. In February 2021, ENCT assisted the technical team of the Centro de Custodia de Fauna Silvestre del Bioparque Urbano in the city

of Tarija, Bolivia that intervened in a case of massive condor deaths where at least 34 condors died as a consequence of the use of toxic baits (Méndez et al. 2021b). Other cases have been reported in Chile, Colombia, Ecuador and Peru (CAS 2021; Pavez y Estades 2016; Trome 2017; El Universo 2019). Therefore, we hope that ENCT will be used as a model for strategic action in the fight against the use of toxic baits in the region.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: NLJ.
Carried out the experiment: NLJ, REP, GA, and VA.
Carried out the data analysis: NLJ, REP.
Wrote the first draft of the manuscript: NLJ, REP.
Review and final write of the manuscript: VA, GA, NLJ, and REP.
Supervision: NLJ, VA, GA and REP.

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