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LETTER

Testing a conservation compromise: No evidence that public wolf hunting in Slovakia reduced livestock losses

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Abstract

Variation in the legal status and management of wolves (*Canis lupus*) across EU Member States provides a good opportunity to test the effectiveness of different practices to reduce livestock losses. This opportunity for testing is particularly useful for lethal interventions, as they are among the most controversial actions within the large carnivore management toolbox. We aimed to test a conservation compromise adopted in Slovakia, based on a public wolf-hunting scheme and annual hunting quotas between 2014 and 2019, and partially justified to reduce livestock losses. We assessed whether this hunting scheme influenced livestock depredation levels (at the district level). Wolves in the area fed mainly on wild ungulates (98.9% of consumed biomass). While domestic sheep comprised only 0.5% of the diet, they were dominant among the reported livestock killed by wolves (91.1%). Using two different approaches, we did not observe a relationship between the number of killed wolves and livestock losses. Alternatively, a negative relationship between wild prey biomass and livestock losses was found. Since 2021, public wolf hunting has not been conducted in Slovakia, and there is no merit in the previous justification for this conservation compromise to reduce livestock losses.

KEYWORDS

Canis lupus, evidence-informed conservation, large carnivores, livestock depredation, wolf hunting, wolf management

1 | INTRODUCTION

Large carnivore conservation is challenging in human-dominated landscapes, where the compatibility of their presence with livestock farming (particularly extensive practices) represents one of the oldest conflict drivers in the conservation of these species (Lute et al., 2018). From the perspective of either wildlife management or livestock welfare (López-Bao & Mateo-Tomás, 2022), a range of different nonlethal and lethal interventions have been proposed, and used, to minimize the risk of livestock depredations (e.g., Eklund et al., 2017; Lorand et al., 2022; van Eeden et al., 2018). Balancing between large carnivore conservation and farming or hunting interests is politically

desirable, which often results in controversial conservation compromises.

Lethal interventions are among the most controversial issues when dealing with large carnivores (Lute et al., 2018) and currently receive less public support (Lute & Attari, 2017) and increased attention due to several ethical concerns (Vucetich & Nelson, 2014). Furthermore, four independent reviews published between 2016 and 2018 (van Eeden et al., 2018) agreed on the need to improve standards of evidence used in evaluating interventions against carnivore attacks and highlighted how these standards have thus far been much lower for lethal compared to nonlethal interventions (see also Lorand et al., 2022; Treves et al., 2019), although there are also relatively few robust studies evaluating the latter (see Eklund et al., 2017).

Variation in the wolf's legal status and management measures implemented among EU Member States, states of the United States or Canadian provinces provides useful opportunities to test the impact of different wolf management approaches (e.g., Treves et al., 2021) on conflict mitigation and wolf conservation. Wolf public hunting schemes are frequently justified as a tool to reduce livestock depredations and facilitate safe coexistence with humans (e.g., Vucetich et al., 2017). Apart from the diverse legal, ethical, and ecological considerations, lethal interventions in this case should only be considered an effective tool if there is an observable reduction in livestock losses after their implementation that does not come at the cost of threatening the viability of wolf populations.

Interestingly, the relationship between wolf public hunting schemes and the dynamics of livestock losses has received less research attention than expected considering the remarkable public interest around this topic (e.g., Delibes-Mateos, 2020). Standards for available studies vary considerably, but excluding studies with flawed design still shows weak or uncertain effects of lethal control (Treves et al., 2016). Previous studies that have explored the relationship between lethal control (mainly carried out by agency authorities; i.e., culling) and livestock depredation have offered contrasting results (e.g., Bradley et al., 2015; DeCesare et al., 2018; Santiago-Avila et al., 2018), even when using the same dataset (Kompaniyets & Evans, 2017; Poudyal et al., 2016; Wielgus & Peebles, 2014) and being complex to synthesize a general and unique effect (Grente, 2021).

In Europe, the Bern Convention of 1979 and the Habitats Directive of 1992 are the fundamental legal frameworks for wolf conservation. Wolves are listed in Annex IV of the Directive (species of community interest in need of strict protection) in most EU Member States, with some populations (entire or partial) being listed in Annex V (species of community interest whose taking in the wild and exploitation may be subject to management measures, including regulated hunting). Under either of these annexes, Member States are required to ensure that wolf populations reach or maintain a "*favorable conservation status*" (Epstein et al., 2016). Several Member States with a historical tradition of public wolf hunting have banned this practice even with the species listed in Annex V. Poland passed the full protection of wolves into national law in 1998 (Nowak & Mysłajek, 2016). Public hunting of wolves has been banned in Romania since 2016 (Popescu et al., 2019), in Slovenia since 2018 (Ferraro & Bombieri, 2022), and Spain since 2021 (Instruction No. TED/980/2021 of the Ministry for the Ecological Transition). In Slovakia, the wolf protection status has changed substantially after 2013, following an infringement procedure at the EU level. The number of killed wolves dropped by 65% (Kutal et al., 2016 and this study), and the species was protected year-round in a strictly defined area along the borders with the Czech Republic, Poland and Hungary. This partial protection was a conservation compromise among the interests of diverse stakeholders. The Ministry of the Environment of the Slovak Republic listed the wolf as a fully protected species under the implementation of the Decree no. 170/2021.

Although public wolf hunting continues in other *Annex V*, or even *Annex IV*, countries (e.g., Sweden; Epstein et al., 2019), there is limited knowledge on how public wolf-hunting schemes influence livestock depredations in Europe (Krofel et al., 2011) (see DeCesare et al., 2018 for North America). Such evidence is of paramount importance as the recent recovery of wolves across EU Member States, excluding islands (Boitani et al., 2022; Chapron et al., 2014) has intensified the debate on the liberalization of strict wolf protection due to the social conflicts arising from livestock depredation (e.g., Kiffner et al., 2019). Compared to North America, domestic ungulates are a more common food source for wolves in Europe (Newsome et al., 2016; Singer et al., 2023).

Here, we aimed to test the influence of this conservation compromise, the limited public wolf-hunting scheme used in the Slovak Republic between 2014 and 2019 (i.e., a regulated hunting of nonspecific individuals by private citizens, based on annual hunting quotas), on livestock depredation levels at the Slovakian district level. Wolves have long been hunted in the area without a robust evaluation of the impact of this practice on wolf population dynamics or livestock losses (Kutal & Dula, 2020). Each year, public wolf hunting was allowed from November 1 until January 15, the next year. Quotas were set prior to November each year on a national or regional level by a special working group, based on suggestions from district hunting administrations and from several sources of information such as official livestock depredation data and results of wolf monitoring (Antal et al., 2016). However, no methodology has been developed on the use of livestock depredation data for

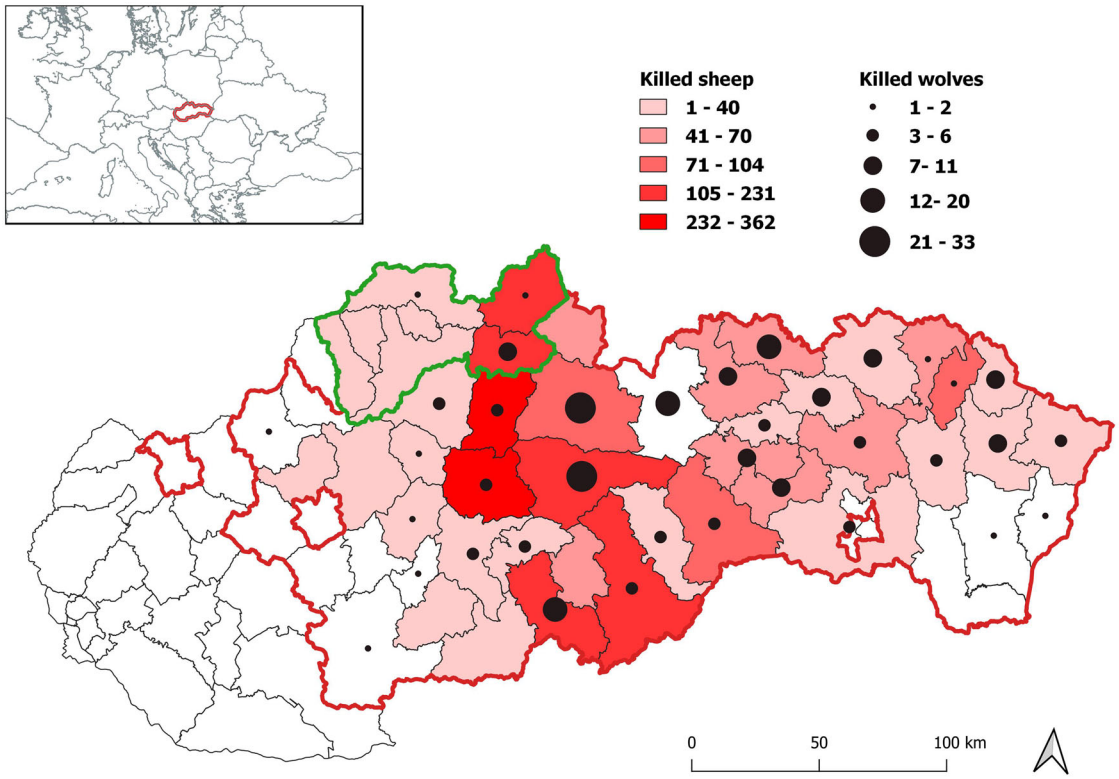

FIGURE 1 Study area for analysis of wolf livestock depredation in Slovakia (54 districts with reported wolf presence, 2014–2019, red line) and model area for detailed analysis of species feeding ecology (7 districts, green line). Area-specific data showing the number of sheep killed by wolves (shades of red) and the number of wolves killed the previous winter in Slovakia (circles).

quota setting, and quotes were set only at the regional level rather than the district level.

2 | METHODS

2.1 | Data collection

We used information at the level of Slovakian districts on livestock damages, number of wolves hunted, and wolf diet. We selected 54 districts (37,752 km^2; 77% of total Slovak area) where wolf presence was reported by hunters during the study period to study the effect of public wolf hunting on patterns of livestock damage, and 7 districts (3680 km^2; 9.75% of area with reported presence of wolves) in north-western Slovakia to study wolf diet (Figure 1). This region has permanent wolf occurrence and breeding (Kutal et al., 2016) and unlike other areas in Slovakia it has not yet been studied regarding wolf feeding habits (e.g., Guimarães et al., 2022). The district level was the smallest administrative unit available across all data sources (average of 711 ± 328 km^2; 85–1552 km^2) and was on average larger than the size of wolf territories in Slovakia or neighboring Poland (Finďo & Chovancová, 2004; Jędrzejewski et al., 2007).

Overall, sheep is the most common livestock species in all selected districts (318,366 heads; 50.8% of total farmed animals), followed by cattle (295,977; 47.2%) and goats (12,610; 2%; Central Evidence of Livestock, https://www.cehz.sk/index.jsp). According to the National Forest Centre database "Polovstat" (https://gis.nlcsk.org/ibulh/PolovStat/PolovStat), the assemblage of wild ungulates here consists of wild boar (*Sus scrofa*, 45.1% of hunted ungulates), red deer (*Cervus elaphus*, 31.2%), roe deer (*Capreolus capreolus*, 14.8%), fallow deer (*Dama dama*, 6.6%), and mouflon (*Ovis aries*, 2.3%). Slovakian authorities reported 302–610 wolves for the entire country in 2018 to the European Commission, according to Article 17 reporting of the Habitats Directive (Černecký et al., 2020; Eionet Portal, 2022). In 2020, around 600 wolves were estimated in the country, including transboundary animals (Boitani et al., 2022).

For the period 2014–2019, we obtained yearly data on livestock heads killed by wolves (2838 heads in total), estimated the total number of wolves, counted the number of wolves killed by district in the previous season

(246 wolves were hunted during the study period; annual average 41 ± 9.6), estimated the number of wild ungulates, and obtained the number of farmed livestock (State Nature Conservancy of the Slovak Republic, National Forest Centre, and Central Evidence of Livestock, respectively). Sheep was the most common livestock type killed by wolves (91.1% of livestock heads). Goats and cattle were reported rather rarely (reaching 3.0% and 5.6% of livestock killed by wolves, respectively). These figures account for 0.78% of sheep, 0.67% of goats, and 0.06% of cattle of the livestock census. Data on livestock damages older than 2014 were not available at the district level. We estimated the available biomass of wild ungulates based on a reverse calculation method, following Kutal et al. (2016). We also analyzed 260 wolf scats collected between 2013 and 2019 in north-western Slovakia. Details on scat collection, determination and analysis are described in Appendix S1.1.

2.2 | The relationship between public hunting and livestock depredations

We adopted two different approaches to explore the effect of public wolf hunting on livestock depredation levels. First, we built generalized mixed models using a negative binomial distribution for the response variable: number of livestock killed by wolves at the district level. We tested whether the number of livestock killed in a given year and district was influenced by the number of wolves shot in the previous hunting season (i.e., from November 1 of the previous year until January 15 of that year). We used two proxies for measuring the impact of public wolf hunting: (i) absolute number of wolves hunted and (ii) the proportion of wolves hunted from the total estimated number of wolves at the district level. We considered two additional competing models in our analyses: (iii) considering the number of farmed livestock and (iv) considering the estimated biomass of wild ungulates. See Appendix S1.2 for details of the statistical analysis performed. Second, we retrospectively selected a subset of pairs of consecutive years (i.e., cases) to run a 2 × 2 before-after control-impact design (BACI design; Appendix S1.3). We compared the number of livestock depredations one year before and after wintertime, the period of wolf-hunting season (November 1 to January 15), in a number of treatment and control cases with and without killed wolves (treatment = 25 cases, control = 44 cases). See Appendix S1.3 for the criteria used to select cases for the BACI design, and the statistical analysis performed.

3 | RESULTS

3.1 | The influence of public wolf hunting on livestock losses

There were no changes over time in the number of livestock losses ($r_S = -0.486$, $p = 0.356$), number of wolves killed in the previous season ($r_S = -0.09$, $p = 0.919$), or number of districts with reported wolves during the study period (i.e., wolf range; $r_S = 0.764$, $p = 0.084$). However, the estimated biomass density of wild ungulates increased significantly over time ($r_S = 0.04$, $p = 0.017$). Livestock losses in a given year did not correlate with the number of wolves hunted in the immediate previous hunting season (Appendix S2), either in absolute (posterior parameter estimate: 0.16 ± 0.18, 95% BCI: −0.21/0.51) or relative terms (posterior parameter estimate: −0.19 ± 0.20, 95% BCI: −0.60/0.21). Our 2 × 2 BACI design approach complemented this finding as we did not detect differences in the number of livestock losses at the district level between treatment and control groups (Appendix S1.3).

3.2 | Other factors affecting livestock losses

Wild ungulates dominated the wolf diet (97.7% of consumed biomass), and cervids were consumed far more than wild boars (84% deer vs. 14.8% wild boar). According to hunting bags in north-western Slovakia, the communities of wild ungulates were dominated by wild boar, followed by red deer and roe deer. We observed a high selection for roe deer ($D = 0.83$), a high avoidance of wild boar ($D = -0.81$), and predation on red deer according to its availability ($D = -0.09$; Figure 2). Sheep was estimated to account for 0.55 % of consumed biomass, and no other domestic animal was detected in this dataset (Table 1). In this context, the model including the estimated biomass density of wild ungulates was the most parsimonious model explaining livestock losses in this area, with a negative influence on the magnitude of losses (Appendix S2).

4 | DISCUSSION

Based on the two different approaches used in this study, public wolf-hunting schemes did not correlate with livestock depredation levels at the Slovak district level. Although livestock damages in the previous two years

TABLE 1 Diet composition of wolves in the study area of north-western Slovakia (2013–2019). Subtotals and totals are marked in bold.

Prey item	Frequency of occurrence (%)	Biomass consumed (%)	Biomass consumed (g)
Undetermined cervids	33.07	21.92	79,789
Roe deer *Capreolus capreolus*	21.15	31.57	114,907
Red deer *Cervus elaphus*	27.69	30.53	111,110
Wild boar *Sus scrofa*	27.69	14.83	53,986
Wild ungulates total	**97.69**	**98.86**	**359,792**
Brown hare *Lepus europaeus*	0.38	0.52	1898
Medium mammals total	**0.38**	**0.52**	**1898**
Bank vole *Myodes glareolus*	0.38	≤0.05	45
Undetermined weasel *Mustela* spp.	0.38	≤0.05	1
Undetermined Soricidae	0.38	≤0.05	3
Undetermined small mammal	0.38	≤0.05	187
Small mammals total	**1.53**	**0.07**	**237**
Sheep	2.69	0.55	2015
Livestock total	2.69	**0.55**	**2015**
Plant material	**7.3**	—	—
Number of scats	**260**		

were used to set the baseline for establishing hunting quotas, according to the Slovak wolf management plan (Antal et al., 2016), the quota system was set on national and regional scales yearly and could not target specific hotspots with increased damages. The absence of uniform procedures for using livestock depredation data throughout Slovakia to prioritize conflict areas was likely one of the significant shortcomings of quota setting. The observed failure in reducing livestock losses is expected if predators are nonselectively removed (Lennox et al., 2018). Bradley et al. (2015) found that even partial removal of a wolf pack was not effective in reducing livestock depredations if conducted more than 14 days after the depredation event, and only a marginally significant difference between partial pack removal and no action was observed if conducted after 7 days from the depredation (but see Santiago-Avila et al., 2018). The assessed public hunting scheme did not fulfill the criteria for this short-term targeted removal. Two other studies performed in Montana, USA and Slovenia found no evidence that removing wolves through public harvest affected the year-to-year presence or absence of livestock losses by wolves (DeCesare et al., 2018; Krofel et al., 2011). A small effect (5.7 fewer depredation events year) was found only within the subset of districts with conflicts, where public harvest of a greater proportion of the known wolves in a district reduced the number of depredations (DeCesare et al., 2018). Additionally, previous research has demonstrated that removing wolves from a particular site did not reduce future risk of recurrence in wolf depredations in neighboring areas (Santiago-Avila et al., 2018). The before-after control-impact design used in this study does not provide the strongest inference about the effects of predator control and the use of higher standards is recommended to address this question more thoroughly (Treves et al., 2019). For example, some finer effects of wolf culling could also be hidden by the relatively coarse scale of our study at the district level (Santiago-Avila et al., 2018).

The overall results of diet analysis closely resemble observations of the dietary preference of wolves in Central Europe, where wild ungulates were by far the dominant prey item and livestock was marginally represented (e.g., Guimarães et al., 2022; Nowak et al., 2011). The lack of exact data on the abundance of prey communities, which were not studied by robust methods in most of referred studies on wolf diet, could cause a possible bias in prey selection.

The lack of a relationship between wolves hunted and livestock killed by wolves could also be caused by negligible representation of livestock in the diet of Slovakian wolves found in north-western Slovakia within the same period (this study) or in central and eastern Slovakia in 2015–2017 (Guimarães et al., 2022). In addition to the correct implementation of effective livestock damage prevention measures (to reduce the vulnerability of livestock to wolf attacks), the availability of wild ungulates is an important factor shaping wolf diet patterns in human-dominated landscapes (e.g., Mayer et al., 2022). Our analysis indicated that abundant wild prey may actually avert wolf predation on livestock, but these conclusions should be interpreted with caution—a large area with permanent wolf presence has lower biomass density due to higher altitudes and overall lower productivity of mountain habitats and the

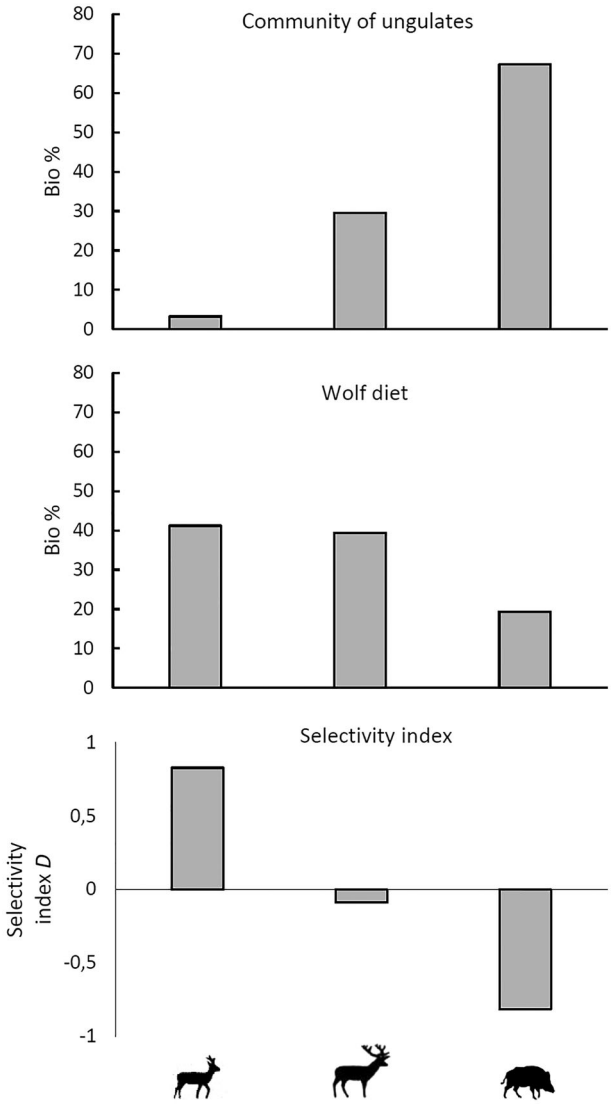

FIGURE 2 Composition of wild ungulate communities based on hunting bag, wolf prey, and preference/avoidance of wolves based on Ivlev's electivity index in study area of north-western Slovakia (2013–2019).

densities of ungulate populations cannot be augmented due to generally high damages from deer browsing in the forest (Find'o et al., 2011). Data on other important factors which drive livestock vulnerability, such as presence and effectiveness of damage prevention measures, are missing for each reported case in official statistics. We also acknowledge that reported damages on livestock may not be complete, since some minor losses may not be discovered or reported due to bureaucratic reasons. However, considering the average annual number of damages was 473 livestock heads and depredations were one of basis for setting hunting quotas, we expect that the proportion of missing head was low. We used the only available official data and believe they are not significantly underestimated due to the opportunity for financial compensation.

Low levels of livestock predation by wolves in our study and in other studies from Central Europe indicate that wolves in this area do not rely on livestock for their persistence. Therefore, the argument for public hunting of wolves to prevent severe sheep losses and protect food security in Slovakia (Kutal & Dula, 2020) lacks evidence. Wolves received year-round protection in Slovakia in 2021, making it the last country in Central Europe to include year-round protection of the species under national law. There are strong political incentives to scapegoat large carnivores (Chapron & López-Bao, 2014), and new attempts for lethal management of wolves in Europe may arise in the near future using similar arguments. Whether the conflict in Slovakia around wolves was mitigated though this public hunting scheme, despite no observable effects on livestock depredations, cannot be answered if no human-dimensions research took place before and after the implementation of this conservation compromise. However, available studies from other regions did not provide much evidence that attitudes towards wolves become more positive after legal wolf hunting (Browne-Nuñez et al., 2015), or that public wolf-hunting schemes will decrease illegal killing of the species (e.g., Chapron & Treves, 2016; Suutarinen & Kojola, 2017).

Nonlethal methods such as livestock guarding dogs or fences have been found effective in livestock protection (see review in van Eeden et al., 2018), although only few studies have had high quality experimental design (Eklund et al., 2017). Yet, there was no relevant mechanism for compensating the increased expenditure on preventive measures by public funds in Slovakia, which can economically burden livestock breeders in higher-risk areas (Kutal & Dula, 2020), even when preventing wildlife attacks on livestock is also a matter of animal welfare, included in EU regulations on livestock welfare (López-Bao & Mateo-Tomás, 2022). Therefore, we urge for the generalized use and support for the effective implementation and maintenance of nonlethal interventions (Frank & Eklund, 2017), and for efforts in increasing acceptance of the use of these measures among end-users (Eklund et al., 2020) in order to facilitate the coexistence of wolves and livestock farmers in this cultural landscape.

AUTHOR CONTRIBUTIONS

MK and JVLB designed the study. MK led the writing of the manuscript. MK, MD, and ARS collected and analyzed data. JVLB and MK ran the analyses. All authors reviewed and commented on the paper.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available at https://zenodo.org/doi/10.5281/zenodo.10086380 .

ETHICS STATEMENT

The search for and sampling of scats involved noninvasive methods did not affect the studied animals.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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