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The effect of predator culling on livestock losses: Ceres, South Africa, 1979 to 1987

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Abstract

Caracal (Caracal caracal) and leopard (Panthera pardus) are perennial problems for sheep farmers on the southern fringe of South Africa's arid Karoo. In the past, farmers responded to the conflict with blanket culling of predators, a strategy that ecologists understand to be harmful. This paper investigates the ability of blanket predator culling to reduce livestock losses. It found the probability of livestock losses to be a function of the number of caracal, leopards, vagrant dogs (Canis familiaris) and other wildlife culled during the previous year, as well as the previous year's trapper effort, the farm's remoteness and three years' worth of rainfall. Other unobserved farm characteristics did not systematically affect losses. Culling an additional caracal or leopard was estimated to increase future livestock losses by 5.7% and 27.2% respectively, while culling a vagrant dog was estimated to reduce the likelihood of future losses by 9.5%. Both trapper effort and remoteness increased the probability of livestock losses. The current and previous years' rainfall decreased the likelihood of future losses, while rainfall from two years prior was positively correlated with future losses. These results are important because they describe general culling effectiveness under a variety of management conditions over a period long enough to allow for adjustment to culling.

Keywords: human-wildlife conflict; culling effectiveness; demographic compensation; sheep

1. Introduction

There is strong environmental opposition to predator culling on livestock farms. Not only is culling considered an unnecessary replacement of natural mortality processes (Knowlton 1972; Gese *et al.* 1989), but it often kills predators that are not guilty of sheep killing (Sacks *et al.* 1999). Till and Knowlton (1983) linked sheep killing to the provisioning of pups and showed that killing could be stopped by removing the pups from the den or culling the breeding pair only. Even targeted culling cannot be condoned fully, as it may actually increase predator densities instead of lowering them. Compared to undisturbed coyote (*Canis latrans*) populations, heavily culled coyote populations are characterised by younger first breeding ages, larger proportions of breeding beta females, larger litter sizes, better pup survival and higher rates of in-migration (Knowlton 1972; Andelt 1985; Gese *et al.* 1989; Knowlton *et al.* 1999).

Since similar demographic compensation has been reported for other predator species as well, including black-backed jackals (*Canis mesomelas*) (Bingham & Purchase 2002), caracals (*Caracal*

caracal) (Marker & Dickman 2005) and grey wolves (*Canis lupus*) (Sidorovich *et al.* 2007), and given the potentially devastating losses caused by predators (Knowlton *et al.* 1999; Mitchell *et al.* 2004), it is vital for livestock farmers all over Africa to understand the effectiveness and potential unintended consequences of predator culling. The literature on human-wildlife conflicts typically either investigates farmers' (in)tolerance of wildlife (Holmern *et al.* 2007; Stronen *et al.* 2007), or tries to model losses (Conner *et al.* 1998; Dar *et al.* 2009; Thorn *et al.* 2012). This paper is an example of the latter; we drew on Conner *et al.* (1998) and Sacks and Neale (2007) to model the probability of livestock losses on a given farm as a function of historical culling on that farm, while explicitly controlling for several other factors known to affect livestock losses.

2. Methodology

2.1 Study area and available data

The domain of the 'Ceres South Hunting Club' was selected as the study area, due to the quality of the culling records kept by the club. We extracted from the club's logbooks a panel dataset covering 152 farms for the period 1979 to 1987.

Ceres lies on the northern side of the Cape Fold Mountains, on a transition from the Fynbos to the Succulent and Nama Karoo Biomes (Mucina & Rutherford 2006). Aggregate data represent Ceres as a primarily fruit-farming district (Statistics South Africa 1981; Conradie *et al.* 2009), but the low rainfall of the Karoo portion of the district makes it suitable for sheep farming only. Wool sheep were the dominant type of livestock kept in Ceres during the study period, accounting for more than 90% of the district's livestock holdings in 1981 (Statistics South Africa 1981). The average size of sheep farms in Ceres was not recorded in the 1981 farm census, but can be inferred from neighbouring Laingsburg to have been in the order of 4 800 hectares and 825 breeding ewes per farm at the time (Statistics South Africa 1981).

In the 1980s, hunting clubs were supported and regulated by the government (Nattrass & Conradie 2013). The main mode of operation of hunting clubs was that a government-employed trapper was called in to attend to wildlife losses. In Ceres the trapper also regularly monitored problem farms. The trapper worked with two assistants. Their culling methods included gin trapping, baited cage trapping, hunting with and without dog packs, and the use of coyote getters. Regular visits usually continued until the problem animal(s) were found. Meticulous handwritten records were kept of each visit, including farm identifier, name of contact person, date, distance travelled, number and type of stock losses (sheep, lambs, goats), number of predators culled (*caracal*, leopard, black-backed jackal, feral dogs (*Canis familiaris*)), number of innocent animals killed (e.g. porcupine, hares, small antelope, African wild cat, silver fox) and culling method used. The logbooks contained brief case descriptions of unusual events, from which it can be inferred that the official trapper was responsible for most of the predator effort in the district. Lacking evidence to the contrary, we assumed that he visited all farms in his area at least once during the study period.

2.2 Data transformations

Daily logbook entries were digitised to compile annual stock loss and culling statistics for each farm. A rainfall variable (E2B) was appended to the dataset from Midgley *et al.* (1994). We assumed unique combinations of farms' and owners' names to indicate unique farms. The majority of entries were null, meaning that the trapper had no dealings with these farms in these years. Most of the remaining farms reported easily classified single incidents. A small proportion of records consisted of multiple incidents involving losses caused by different predators during the course of a

year. For such farms the full list of incidents was inspected to establish the dominant type of predator problem; where it was impossible to do so, predator type was indicated as multiple.

The dataset was restricted to pure wildlife-livestock interactions by constructing three dummy variables, one each for baboon (*Papio ursinus*), stock theft and vagrant dog incidents. Vagrant dogs killed significantly more livestock (14.72 vs. 1.05 sheep) per incident than was lost per incident to all causes ($t_{1366} = -13.45$, $p = 0.000$). Stock theft incidents occurred infrequently but caused larger losses than non-theft incidents (34.00 vs. 1.33 sheep) ($t_{1366} = -12.03$, $p = 0.000$). There was no difference in the number of sheep lost in baboon versus non-baboon incidents ($t_{1366} = 0.86$, $p = 0.3894$), but baboon incidents triggered more visits than non-baboon incidents (8.93 vs. 1.68 visits) ($t_{1366} = -5.12$, $p = 0.000$). Baboon problems accounted for 2% of all trapper visits, and stock theft and vagrant dog incidents for 0.4% and 3% of visits respectively. The restricted sample size was 1 293 observations. We also constructed a variable for ‘all other’ animals culled, which included baboons and porcupines culled in response to crop damage, as well as accidental and inappropriate culling (e.g. of small antelope, hares, fox (*Vulpes chama*), African wildcat (*Felis libyca*), etc.).

2.3 Modelling

Three stock loss models were specified, namely a pure culling response model after Conner *et al.* (1989), a prey-predator dynamics model based on the ideas of Sacks and Neale (2007), and a third model that which combined the culling response and trophic dynamics sub-models. Using annualised data, Conner *et al.* (1998) established trapper effort to be positively correlated with reported livestock losses, and the number of coyotes culled to be positively correlated with trapper effort, but they failed to find a significant relationship between coyotes killed and the following year’s stock losses. If culling was effective, more predators culled in year t should lead to fewer stock losses in year $t+1$, while a positive and significant relationship between the two would indicate predator population compensation. Running the Conner *et al.* (1989) model on the first two years of this dataset (Conradie 2012) failed to result in a statistically significant coefficient on the feedback effect.

Both Conner *et al.* (1989) and Sacks and Neale (2007) described situations in which a single predator (coyotes) preyed on sheep. At least three predators were important in Ceres in the 1980s. Many other animals were killed accidentally or because they were believed to kill lambs, when in fact they were not doing so. We found that specifying culling at the species level for caracal, leopards and vagrant dogs was able to explain the variation in livestock losses better than aggregate culling. Including all other culling as a fourth variable further increased the explanatory power of the model. Specifying the number of baboons culled separately did not affect the results materially. We controlled for trapper effort and defined effort as the number of visits to a given farm in a given year. Both the predators culled and trapper effort variables were lagged by one year (Berger 2006; Sacks & Neale 2007), and squared terms were included to allow for nonlinear relationships for the variables of interest.

Culling response sub-model:

$$\begin{aligned} \text{Stock losses}_t = & a_0 + a_1 \text{caracal culled}_{t-1} + a_2 (\text{caracal culled})_{t-1}^2 + a_3 \text{leopard culled}_{t-1} \\ & + a_4 (\text{leopard culled})_{t-1}^2 + a_5 \text{vagrant dogs culled}_{t-1} + a_6 \text{other animals culled}_{t-1} \\ & + a_7 \text{trapper effort}_{t-1} + a_8 (\text{trapper effort})_{t-1}^2 + a_9 \text{stock losses}_{t-1} + \varepsilon \end{aligned}$$

[1]

We considered using catch per effort as a proxy for predator density (Knowlton 1972), but decided against it because we were interested in the effect of human presence in the environment when controlling for number of predators culled. Karoo farmers believe predators to be deterred by human presence; we therefore expected that the more remote a farm was, the lower its human density would be and the more suitable it would be as a predator habitat (see Woodroffe 2000). A time-invariant remoteness variable was generated from the distance between the trapper’s base in town and the individual farms.

Sacks and Neale’s (2007) model of trophic dynamics found sheep losses to be negatively related to current season’s plant productivity and positively related to current season predator density, while the current season predator density was found to be positively related to the previous season’s primary plant productivity. We had very little with which to model trophic dynamics. Space-invariant rainfall in year t was used as a proxy for primary plant productivity, while lagged rainfall was tried as a (weak) proxy for predator density.

Following Sacks and Neale (2007), the sign on the current rainfall variable was expected to be negative, because an abundance of natural prey in a good year would keep livestock relatively safe. Sacks and Neale (2007) argue that the expected sign on lagged rainfall had to be positive, as a good year would cause an increase in predator density, which would cause more stock losses the following year. In addition, we included a two-year rainfall lag to be able to investigate the adjustment process beyond just one year.

Trophic dynamics sub-model:

$$\begin{aligned}
 \text{Stock losses}_t = & a_0 + a_1 \text{remoteness} + a_2 (\text{remoteness})^2 + a_3 \text{rainfall}_t + a_4 (\text{rainfall})_t^2 + a_5 \text{rainfall}_{t-1} \\
 & + a_6 (\text{rainfall})_{t-1}^2 + a_7 \text{rainfall}_{t-2} + a_8 (\text{rainfall})_{t-2}^2 + a_9 \text{stock losses}_{t-1} + \varepsilon
 \end{aligned}
 \tag{2}$$

Model 3 simply combined the previous two. The dependent variable in all three models was total stock losses, defined as the number of sheep, lambs, kids or goats lost. It ranged from zero to a maximum of 114.

A lagged stock loss variable was added in all three models to check for adequate specification. Ideally it would be insignificant, as significance would indicate systematic differences across farms that were not captured by the specification in question.

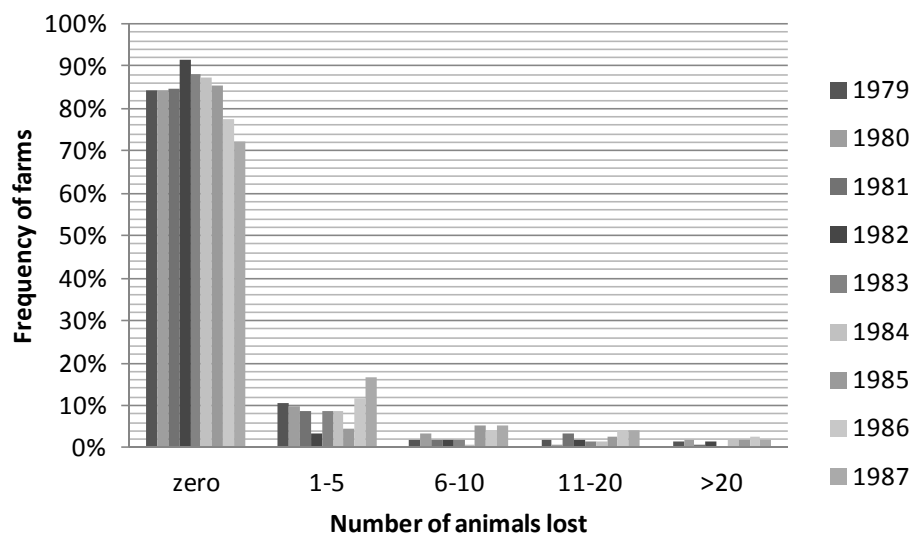


Figure 1: Incidence of livestock losses, Ceres Hunting Club 1979 to 1987

The frequency of farm-level livestock losses per year, illustrated in Figure 1, clearly called for the use of a limited dependent absence/presence model such as binary logit. The logit model is

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = X\beta_i + \varepsilon_{it},$$

where p_{it} = probability of experiencing livestock losses on a given farm in a given year was estimated in Stata10 from a pooled dataset with a maximum likelihood routine. A Huber-White sandwich estimator was used to account for heteroskedasticity (Baum 2006). Given the distribution of the dependent variable, we also experimented with Poisson and negative binomial regressions (Gujarati 2003; Thorn *et al.* 2012) but rejected these functional forms based on poor maximum likelihood statistics.

3. Results

3.1 Descriptive statistics

Table 1 summarises the sample's descriptive statistics. The majority of farms experienced zero stock losses and culled no predators in most years of the study period. The mean number of losses per farm was 1.48 livestock units, and the mean incidence rate, expressed as the proportion of farms experiencing losses, was 16%. The incidence rate varied from 9% in 1982 to 28% in 1987. The highest number of losses per farm in a given year fluctuated considerably, from a low of 14 sheep recorded in 1983 to a high of 114 sheep recorded in 1985. Total losses during the study period came to 1 983 livestock units, with a value of almost R1.2 million (US\$133 000) in 2010 prices. The financial impact demonstrates that this problem should be taken very seriously.

Table 1: Descriptive statistics pooled

Variable	n	Mean	Standard deviation	Minimum	Maximum
Livestock losses	1 368	1.478	6.977	0	114
Caracals culled	1 368	0.159	0.774	0	11
Leopards culled	1 368	0.023	0.194	0	3
Vagrant dogs culled	1 368	0.029	0.246	0	4
All predators culled	1 368	0.213	0.927	0	14
Baboons culled	1 368	0.121	1.263	0	29
Innocent animals culled	1 368	0.119	1.036	0	33
Distance from town (km)	1 368	49.93	31.81	1	140
Trapper visits	1 368	1.827	7.350	0	116
Rainfall (mm)	1 368	240.33	57.53	146	337

In the study period, 217 caracal and 32 leopards were culled in the area, corresponding to mean culling rates of 0.16 caracal and 0.02 leopards per farm per year. The maximum number of individual animals culled on any farm in any year was three leopards and 11 caracals. Problems with black-backed jackals were recorded on only two occasions, when two and three animals respectively were culled. The maximum number of vagrant dogs culled on any farm in any year was four, while the mean rate of culling was 0.03 dogs per farm per year. The maximum and mean numbers of baboons culled were 29 and 0.12 respectively per farm per year. The maximum and mean distances travelled by trappers were 140 and 49 kilometres respectively. The mean trapper effort of 1.83 visits varied from zero to 116 visits per farm per year. The farm that received the most attention had 116 visits (in 1979), in response to a single disastrous jackal attack that killed 24 lambs in one night. The second highest level of effort was observed in 1985, when 80 visits were made to a farm in response to a total of 114 livestock losses during the course of the year. Recorded

rainfall varied from 146 millimetres in 1979 to 337 millimetres in 1987, with a mean annual precipitation of 240 millimetres over the study period.

Table 2: Correlation matrix

	Stock losses _{it}	Leopard culled _{it-1}	Caracal culled _{it-1}	Dogs culled _{it-1}	Other culled _{it-1}	Trapper effort _{it-1}	Dist _i	Rain _t	Rain _{t-1}	Stock _{it-1}
Stock losses _{it}	1.000									
Leopard culled _{it-1}	0.125	1.000								
Caracal culled _{it-1}	0.130	0.307	1.000							
Dogs culled _{it-1}	0.060	0.083	0.110	1.000						
Other culled _{it-1}	0.003	0.032	0.112	-0.006	1.000					
Trapper effort _{it-1}	0.170	0.378	0.740	0.175	0.119	1.000				
Distance _i	0.026	0.022	0.073	-0.053	0.015	0.012	1.000			
Rain _t	-0.100	-0.001	0.015	-0.009	-0.017	0.030	0.000	1.000		
Rain _{t-1}	0.038	0.006	0.006	-0.032	-0.022	-0.016	-0.000	-0.583	1.000	
Stock _{it-1}	0.146	0.373	0.295	0.328	0.004	0.392	0.013	-0.062	-0.000	1.000

Most pair-wise correlations between the explanatory variables were mild or low, as can be seen in Table 2. The correlation of $r = 0.614$ between predators culled and trapper effort is an unsurprising exception, as we have already explained that stock losses typically triggered culling (Conner *et al.* 1998; Conradie 2012). For the same reason, the correlations between trapper effort and leopard ($r = 0.378$) and caracal ($r = 0.740$) culled were also strong. Trapper effort was not strongly correlated with the number of vagrant dogs culled ($r = 0.175$), or the number of innocent animals culled ($r = 0.119$). In multivariate modelling, multicollinearity is sometimes raised as a concern, but no remedy is usually necessary, as coefficients estimated in the presence of multicollinearity are still best and unbiased (Gujarati 2003). High degrees of collinearity produce coefficient estimates with large variances and covariances, which in practice results in variables being dropped from models because they are not statistically significant.

3.2 Regression results

The regression results are presented in Table 3. All three models passed Wald's likelihood ratio joint specification tests. McFadden's pseudo R^2 identified the combined model as the preferred one, a conclusion supported by both Akaike's and Schwarz's Bayesian information criteria. The non-significance of the lagged losses coefficient in Models 1 and 3 indicated that unobserved farm effects did not systematically affect livestock losses. This is not true of Model 2, where the coefficient on lagged losses was positive and significant at $p \leq 0.05$.

The coefficients on caracal and leopards culled were positive and significant at $p < 0.01$ in the culling response sub-model. At the mean, the marginal effect of culling an additional caracal was a 7.4% increase in the probability of suffering stock losses during the next year. This impact decreased at a rate of 0.7% per additional caracal culled. As leopard culling was a relatively rare event, the marginal effect of culling a leopard was to increase the likelihood of subsequent losses by 16% at the mean.

Table 3: Estimation results for pooled logit models explaining farm-level stock losses

	Culling response		Trophic dynamics		Combined	
	Coefficient RSE	Marginal effect	Coefficient RSE	Marginal effect	Coefficient RSE	Marginal effect
Caracals culled _{it-1}	0.702*** 0.266	0.074			0.599** 0.303	0.057
(Caracals culled) ² _{it-1}	-0.070*** 0.026	-0.007			-0.070* 0.036	-0.007
Leopards culled _{it-1}	1.522* 0.836	0.160			2.886*** 1.097	0.272
(Leopards culled) ² _{it-1}	-0.222 0.385	ns			-0.936 0.602	ns
Dogs culled _{it-1}	-0.790* 0.475	-0.083			-1.003* 0.516	-0.095
Other culled _{it-1}	-0.254 0.206	ns			-0.470* 0.258	-0.044
Trapper effort _{it-1}	0.103*** 0.037	0.011			0.094* 0.050	0.009
(Trapper effort) ² _{it-1}	-9.10e-4*** 3.11e-4	-9.57e-5			-1.96e-4 7.15e-4	ns
Distance _i			0.043*** 0.012	0.004	0.031** 0.013	0.003
(Distance) ² _i			-2.49e-4*** 9.14e-5	-2.56e-5	-1.71e-4* 9.37e-5	-1.62e-5
Rainfall _t			-0.119*** 0.043	-0.012	-0.140*** 0.005	-0.013
(Rainfall) ² _t			2.12e-4** 8.36e-5	2.19e-5	2.50e-4*** 9.07e-5	2.35e-5
Rainfall _{t-1}			-0.048 0.032	ns	-0.066* 0.036	-0.006
(Rainfall) ² _{t-1}			9.31e-5 6.35e-5	ns	1.29e-4* 7.06e-5	1.22e-5
Rainfall _{t-2}			0.067*** 0.021	0.007	0.084*** 0.024	0.008
(Rainfall) ² _{t-2}			-1.32e-4*** 4.22e-5	-1.36e-5	-1.62e-4*** 4.67e-5	-1.52e-5
Losses _{it-1}	-4.76e-5 0.011		0.026** 0.012	0.003	-0.003 0.014	ns
Constant	-2.151*** 1.000		10.48* 5.986		13.51** 6.580	
n	1 149		1 005		1 005	
Wald LR test	$\chi_9 = 56.55$	***	$\chi_9 = 46.57$	***	$\chi_{17} = 80.77$	***
McFadden's R ²	0.0899		0.0646		0.1370	
Log likelihood	-408.58		-370.91		-342.18	
Akaike's IC	873.15		761.82		720.36	
Bayesian IC	887.62		810.95		808.79	

*** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 10\%$, ns = not significant

The lack of significance on the squared term of leopards culled implies that its marginal effect is constant. The vagrant dogs coefficient was negative and significant at $p \leq 0.10$, which suggests vagrant dog culling to have been effective. The coefficient on the 'other animals culled' variable was negative but not significant. Trapper effort and its squared term both produced significant coefficients at $p \leq 0.01$ in Model 1. Additional effort increased the likelihood of a farm suffering losses during the next year by 1.1% at the mean, while marginal effect of the squared term indicated this impact to decrease at a rate of 0.009% per additional visit.

In Model 2, the coefficients on the remoteness variables, distance and distance squared, were both significant at $p \leq 0.01$. An additional kilometre out of town increased the likelihood of subsequent stock losses by 0.4%, and this effect was expected to decrease at a rate of 0.0256% per kilometre. The coefficient on rainfall in year t was negative and significant at $p \leq 0.01$. The marginal effects signalled a 1.2% decrease in the probability of livestock losses for every millimetre above mean rainfall and the effect to dissipate at a rate of 0.0219% per millimetre. The coefficient on rainfall in year $t-1$ was not significant in Model 2. In contrast, the coefficient on rainfall in year $t-2$ was positive and significant at $p \leq 0.01$. Marginal effects indicated the probability of losses in year t to increase at a rate of 0.7% per additional millimetre above the mean rainfall, and for the marginal effect to decrease at a rate of 0.013% per millimetre.

In the combined model, patterns of significance and magnitude of marginal effects were similar to those of the two sub-models discussed above. For example, the positive signs on predators culled were confirmed for caracal and leopard, while the coefficient on vagrant dogs culled remained negative and significant at $p \leq 0.10$. The marginal effects of culling were slightly different in Model 3 than in Model 1, and the direction of change was not systematic. The impact of culling a caracal fell from a 7.4% increase to a 5.7% increase in the probability of losses, while for leopard the marginal effect of 16% in Model 1 became 27% in Model 3. For vagrant dog culling, the 8.3% decrease in the probability of losses at the margin became a 9.5% decrease in the probability of losses. The coefficient on other animals culled went from insignificant in Model 1 to significant, at $p \leq 0.10$, in Model 3. The negative sign on other animals culled in Model 3 is problematic, as it suggests that other, untargeted, culling reduces subsequent livestock losses.

The signs and significance of trapper effort and distance from town from Model 1 were confirmed in Model 3. At the margin, the impact of an additional visit decreased from a 1.1% increase to a 0.9% increase, while the marginal effect of an extra kilometre decreased from a 0.4% increase to a 0.3% increase in the probability of losses. The rainfall results improved in Model 3 compared to Model 2, insofar as lagged rainfall became significant at $p \leq 0.10$ in Model 3. The marginal effect of the current year's rainfall increased from a 1.2% decrease in the likelihood of losses to a 1.3% decrease in the likelihood of losses. The marginal effects of rainfall in years $t-1$ and $t-2$ were opposite and of similar magnitude; in year $t-1$ an extra millimetre of rainfall would translate into a 0.6% decrease in the likelihood of losses, and in year $t-2$ the same marginal millimetre of rainfall would imply a 0.8% increase in the probability of livestock losses. The square terms were all significant and of the opposite sign as the level terms, indicating the impact of rainfall slowing down at rainfall levels further away from the mean.

4. Discussion

This paper set out to investigate the ability of predator culling to reduce livestock losses. The positive demographic compensation in response to culling found for caracals and leopards confirms ecological expectations (Knowlton 1972; Knowlton *et al.* 1999; Sacks *et al.* 1999) and improves on the findings of Conner *et al.* (1989) and Conradie (2012), who failed to establish a link between culling and subsequent livestock losses. The result was robust to specification, but it is difficult to explain why culling other innocent wildlife reduced livestock losses. At mean rates, culling an additional caracal was shown to increase the probability of a farm suffering livestock losses during the next season by between 5% and 7%. Given the lack of other comparable estimates, we do not know what these results mean or how they might vary with season, terrain and management practices. However, we can say that it looks as if culling a leopard might be more harmful than killing a caracal, as the marginal effect of leopard culling was five times larger than the marginal effect of caracal culling, perhaps because leopards are the apex species in the southern Karoo.

Surprisingly, we found more trapper effort to systematically worsen livestock losses when controlling for the amount of animals culled, an effect that, as far as we know, has not been documented before. This finding is hard to explain, as it flies in the face of the assumption that human presence in the ecosystem acts as a deterrent to predation.

The lack of significance of the lagged losses variable in Models 1 and 3 means that the culling efficiency models produced better results than the ecological dynamics model (Model 2), where the significance of the lagged losses variable pointed to unobserved farm characteristics systematically affecting livestock losses. However, given the data limitations, we were pleasantly surprised by the explanatory power of Model 2. It not only confirmed Sacks and Neale's (2007) finding that higher plant productivity in year $t-1$ increase predation in year t , but potentially also uncovered more complicated rainfall-prey-predator dynamics.

Finally, farmers will remain sceptical of any culling effectiveness result that derives from spot treatments, as spot treatments are well known not to work as predator control strategy (Gese *et al.* 1989; Knowlton *et al.* 1999). For farmers, the real question is what the compensation dynamics and culling effectiveness would be if area-wide culling could be achieved. It is quite possible that the Ceres trappers' efforts achieved blanket control, but without knowing the location of individual farms relative to each other it is impossible with this dataset to establish whether blanket control would have the same detrimental effect as spot treatments.

5. Conclusions

This study investigated the effectiveness of predator culling as protection against livestock losses. It found culling to systematically increase subsequent livestock losses when controlling for trophic dynamics, culling effort and remoteness, which suggests that farmers should stop culling predators. However, since farmers stand to lose a great deal to predators if populations get out of hand, it is important to confirm this result where blanket culling can be proved and where trophic dynamics are more fully documented.

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