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The impact of predation on Merino and Dorper sheep flocks in the central Free State Province, South Africa

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Abstract

Predation losses reported by producers and claims by livestock industries that predation has severe impacts on the livestock trade are often cast in doubt. Here, the effects of predation on the reproduction and production of five Merino flocks and a Dorper flock, on a strictly monitored government entity (the Glen Agricultural Institute), from 1999 to 2007, are reported. These predation losses also cover other sheep losses from diseases, metabolic disorders, accidents, and livestock theft. Additional indirect financial losses, namely veterinary, shearing, supplementary feeding (lick), labour, and planted pasture costs, were calculated. The calculations were used to determine a more realistic cost of predation and to compare the extent to which financial losses ascribed to predation exceeded other losses. The Merino and Dorper flock numbers decreased significantly over the nine years covered in the study. Less reproductive ewes were available for mating and consequently resulting in less lambs that were born. The pre-weaned and post-weaned lambs were also severely impacted by predation. Due to predation, some ewes could not raise a single lamb in a six-year reproduction cycle. Therefore, it became challenging to replace older ewes and maintain flock sizes. An exception was the Merino flock that utilized ryegrass (*Lolium multiflorum* and *L. perenne*) because of protection from predation during critical phases in the reproduction cycle. Predation contributed 72% of annual financial losses, metabolic disorders, and accidents 20%, livestock theft 6%, and diseases 2%. Black-backed jackal (*Lupullela mesomelas*) alone accounted for 730 post-weaning losses, constituting 70% of all predation losses from 2003 to 2007. The negative effect of livestock predation made it impossible to evaluate the economic viability and sustainability of the four Merino treatment flocks as envisaged. A marked component of the genetic base of the two sheep breeds at the Glen Agricultural Institute (Glen AI) has also been lost permanently because of predation.

KEYWORDS: diseases, livestock theft, metabolic disorder and accidents, predation

INTRODUCTION

Commercial small livestock farmers in South Africa are, annually, estimated to suffer loses of between 3 and 13% of small stock, amounting to at least R2.34 billion, to predation (Turpie & Babatopie 2018). Losses in the Free State Province contribute *c.* 17.8% to this amount (= R0.25 billion in 2009; Van Niekerk 2010). The Black-backed jackal (*Lupulella mesomelas*; previously known as *Canis mesomelas*, Atickem *et al.* 2017) and Caracal (*Caracal caracal*) are mainly implicated for these predation losses. Vagrant domestic Dogs (*Canis familiaris*) also cause considerable losses among small livestock, especially near human settlements (De Waal 2009, 2021; Van Niekerk 2010). The cost of predation is typically reported as the direct losses of small livestock, be it lambs or kids or mature sheep or goats. However, additional fruitless expenditures should also be considered (Shwiff & Bodenchuk 2004).

Critics of predation control often refute losses reported by individual producers or claims of the impact of livestock predation by the sheep industry. On the South African National Wool Growers Association's monitor farms, 46% of lamb mortalities have been ascribed to predation (Viljoen 2016). Kerley *et al.* (2018) questioned the reliability of the data collected precisely because of sample sizes being too small and not representative, irregular visits of the kill sites by farmers, the people who collected the data, and the accuracy of predator identification. Therefore, this study aimed to quantify the direct and indirect financial losses due to predation versus the production and reproduction losses on a strictly monitored government entity, the Glen AI, in the central Free State Province.

The situation at the Glen AI, the main facility for livestock research and training of the Free State Department of Agriculture and Rural Development, seems to be no different from private sheep farms in the rest of the province regarding the harmful effects of livestock predation. Similar to the surrounding private sheep farms, sheep predation at the Glen AI was relatively negligible during the 1980s to late 1990s (De Waal & Combrinck 2000). This situation changed dramatically from the early 2000s, when it

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became evident that predation was severely affecting livestock production at Glen AI.

To reduce the effects of predation on livestock at Glen AI, a range of non-lethal and lethal preventive and remedial methods (Du Plessis *et al.* 2018) were used throughout the five-year (2003-2007) study period. They were undertaken by the trained Animal Damage Control (ADC) flock manager (A.J. Strauss), closely supported by the ADC officers from the Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs (DESTEA). Therefore, ADC was considered relatively informed and equally, or more effective, compared to other small livestock farms in the Free State Province.

MATERIAL AND METHODS

The Free State Wool Sheep Project was initiated in 1998 to develop profitable and sustainable wool farming production systems on the available combination of nutrition resources at Glen AI (Strauss 2009). The Glen AI comprises 4 614 ha natural pasture (veld) described as a *Themeda-Cymbopogon* veld type (Acocks 1988; De Waal & Combrinck 2000). Camp sizes varied between 10 and 25 ha.

The Free State Wool Sheep Project was implemented with 280 Merino ewes of breeding age, ranging from one to six years old and randomly divided (per age group) into four flocks with four different production system treatments (see below). Each flock lambed only once per year, vs the common practice on the average central Free State farm where two lambing seasons, autumn and spring, is the norm.

Treatment SL-V(C)

Spring Lambing season (September/October) on veld with a salt (NaCl) lick (Control).

Treatment SL-V&S

Spring Lambing season (September/October) on Veld with Supplementary feeding [production lick: a mixture of 40% Voermol Maxiwol, 49% maize meal, 10% salt (NaCl), and 1% feed lime. Maxiwol contains (g/kg) 350 g crude protein, 100 g fibre, 160 g moisture, 12.2 g calcium (Ca), 3.6 g phosphorus (P), 6.7 g sulphur (S), 200 mg manganese (Mg), 30 mg copper (Cu), 1 mg cobalt (Co), 150 mg iron (Fe), 6 mg iodine (I), 240 mg zinc (Zn), and 1 mg selenium (Se)].

Treatment SL-R&V

Spring Lambing season (August/September) on irrigated Ryegrass (*Lolium multiflorum* and *L. perenne*) pasture and veld.

Treatment AL-O&V

Autumn Lambing (May/June) season on Oats (*Avena sativa*) pasture in winter and on veld in summer and spring.

Best practices in animal husbandry were applied to optimize veld utilization and ensure optimum treatment groups' production and reproduction. Sheep were counted daily, and independent auditors verified the weekly, quarterly, and annual biological asset reports. Lambs were weighed and tagged within 24 hours after birth, weighed again at 35-days and at weaning (110 days). The ewes were weighed before mating, after mating, at lambing and weaning of their lambs. The four treatment Merino flocks utilized veld and planted pasture for the course of the year, as outlined in Table 1.

A negative predation effect on the Merino flocks was not foreseen when the Free State Wool Sheep Project was conceptualized. Two other flocks were also kept at Glen AI: (i) a Merino shearing flock, specifically maintained to augment the number of fleeces needed annually for student training, and (ii) a Dorper flock (De Waal & Combrinck 2000). These two flocks were managed in the same way as the Merino ewes in Treatment SL-V(C). However, they were mated later to lamb in October/November (Strauss 2009). As predation also severely affected these two flocks (Merino and Dorper), it was decided to include their information here, giving a total of 1 130 sheep in this report.

The effects of predation on the reproduction and production of Merino and Dorper flocks were reported from 1999 to 2007. Four categories of sheep losses were identified, namely predation, diseases, metabolic disorders or accidents, and livestock theft. Three departmental officials recorded losses

Table 1. The months (x) during which the Merino ewes in the four treatment flocks of the Free State Wool Sheep Project utilized veld at Glen AI.

	Months											
Treatment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SL-V(C)	x	x	x	x	x	x	x	x	x	x	x	x
SL-V&S	x	x	x	x	x	x	x	x	x	x	x	x
SL-R&V	x	x										x
AL-O&V	x	x	x							x	x	x

daily using a 'lamb book' (losses before weaning) and a 'mortality certificate' (losses post-weaning). Diseases and metabolic disorders were confirmed by specialized staff (animal health technicians and state veterinarian), and 'predation' was identified jointly in cooperation with ADC officers of DESTEA. Records on the mortality certificate included the date, animal number, age, camp number, and photos. In the case of losses due to predation, GPS coordinates of the death site were also included. Guidelines for the killing and feeding methods of predators were used to determine which predator was responsible for the killing (Rowe-Rowe 1983). It was not always possible to identify the predator species accountable for the massacre before weaning (as the small lamb carcasses were typically mostly devoured, and only parts of the carcasses were retrieved). Therefore, if pre-weaned and post-weaned (= easier to identify the responsible predator) losses occurred on the same date in the same or neighbouring camps, the predator implicated for the post-weaning losses was also made accountable for the pre-weaning losses. Tracks found around the partially retrieved carcasses of the pre-weaned lambs also played a vital role in implicating the predator. Such pre-weaned losses occurred during lambing time, which was typically from September to November.

During the course of the study, a range of lethal and non-lethal methods were used to reduce predation losses. Non-lethal methods included jackal proof fences, kraaling, electric fencing, King LPC (Livestock Protection Collars), sheep bells, and ostriches. Lethal methods included leg-holding devices, humane coyote getters, cage traps, and lethal LPC's (Protect-A-Lamb), which contained a poison (Compound 1080; sodium monofluoroacetate). Furthermore, specific predators were shot at night by an experienced ADC official of DESTEA after being lured by animating specific conspecific and prey sounds.

Direct financial expenses, namely veterinary, shearing, lick, labour and planted pasture costs, were associated with, and added to the direct loss of small livestock entities and calculated for each of the four categories of losses. The extent to which financial losses ascribed to predation exceeded or fell short of the economic losses due to diseases, metabolic disorders or accidents, and stock theft could, therefore, be determined.

As government or public assets, such as livestock, are notoriously undervalued compared to free market prices, the small livestock values at the Glen AI were determined as follows. The direct losses were based on the monetary values for sheep of the specific age groups obtained from eight study groups, namely in Barkly-East (Clifford), Rietbron, Sterkstroom, Hanover/Richmond, Klipplaat, Noupoort, Tarkastad and the southern Free State Province (Trompsburg, Smithfield and Springfontein). The monetary values given to livestock were averaged across the eight study groups (Dr A.C. Geyer, Department of Agricultural Economics, UFS, Bloemfontein; pers. comm. 2008) and verified with livestock traders in the specific years of losses.

The veterinary, shearing, lick, labour and planted pasture costs were calculated for sheep lost in each category of losses and between the different treatment flocks. A mean baseline value for such costs was estimated based on prices quoted by suppliers in Bloemfontein in October 2008. The actual prices of most of these expenses could not be traced back to individual years, as many of these costs increase and decrease over time (≈ related to the fuel price). These input costs for the sheep during the year were classified as fruitless expenditure after a loss occurred.

RESULTS AND DISCUSSION

Sheep of all ages (from pre-weaned lambs to breeding ewes and rams) were predated on, with Black-backed jackal, vagrant Dog and Caracal the causative predators (Strauss 2009). Black-backed jackal had by far the largest impact on the sheep flocks, responsible for 70.4% of post-weaned losses over the five years from 2003 to 2007 (Strauss 2009).

The number of lambs born declined gradually as fewer and fewer ewes were available for mating (Figure 1). Relative predation losses, expressed as a percentage of the total number of lambs born, increased from 36% in 2003 to 43% in 2006. The decrease in relative predation losses in 2007 was a direct result of introducing the practice of kraaling the Dorper flock at night and the partial but incomplete protection of the Merino shearing flock inside electric fencing. When expressed as a percentage of the total number of lamb losses and mortalities, the number of lambs lost to predators increased from 75.6% (2003) to 81.4% (2006). For the four flocks kept on the veld, the relative numbers of pre-weaned lambs that died due to predators increased from 86.6% (2003) to 93.7% (2006).

The majority of annual losses of post-weaning lambs (older than four months of age) were also attributed to predation (Table 2). From 1999 to 2007, predators were responsible for 78.2% of all post-weaning losses. The losses increased sharply from 1999 to 2002. Although the losses decreased after 2002, it was still very high, with between 93 and 174 sheep killed annually by predators. Like pre-weaned lambs, Merino sheep that were not kraaled or kept behind electrified fences suffered the most post-weaned losses due to predation (Strauss 2009).

Sheep mortalities ascribed to metabolic disorders and accidents as well as diseases accounted for considerable losses, which could have been reduced

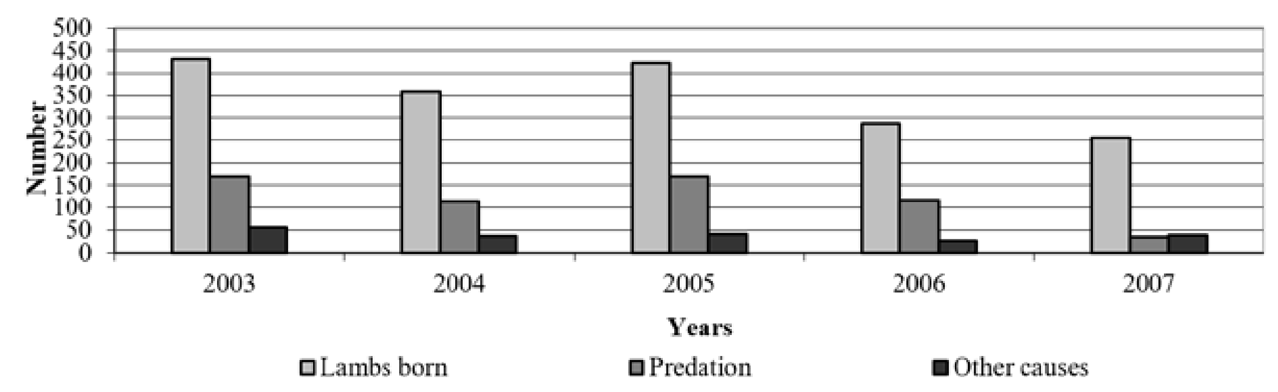

Figure 1. Number of lambs born and number of lambs lost to predation or other causes before weaning for all the sheep flocks over five years at Glen AI.

Table 2. Annual post-weaning losses and mortalities for the five Merino flocks and the Dorper flock over nine years at Glen AI.

Year	Predation		Diseases[1]		Metabolic disorders[2] & Accidents		Theft		Total
	n	%	n	%	n	%	n	%	n
1999	76	55.1	31	22.5	11	8.0	20	14.5	138
2000	154	75.5	6	2.9	31	15.2	13	6.4	204
2001	208	93.3	1	0.5	9	4.0	5	2.2	223
2002	254	92.7	1	0.4	11	4.0	8	2.9	274
2003	174	78.7	3	1.4	39	17.7	5	2.3	221
2004	166	65.1	21	8.2	48	18.8	20	7.8	255
2005	155	73.1	6	2.8	29	13.7	22	10.4	212
2006	93	73.8	4	3.2	25	19.8	4	3.2	126
2007	142	85.5	3	1.8	17	10.2	4	2.4	166
Total	**1422**	**78.2**	**76**	**4.2**	**220**	**12.1**	**101**	**5.6**	**1819**

[1] Pulpy kidney, Pasteurella, blue tongue, blue udder, and black quarter.
[2] Acidosis and bloat.

by maintaining the fences regularly. Sheep often crawled under or through poorly maintained fences, resulting in them gaining access to maize lands, and resulting in mortalities due to acidosis (a metabolic disorder, causing a sharp drop in the pH of the reticulo-rumen) or pulpy kidney (a disease). Mortalities caused by accident were mainly recorded for older ewes during lambing or who died because of weakness. Bloat as a cause of death, was classified as a metabolic disorder. Accordingly, accidental, and metabolic disorder losses were summed in this study and contributed less than 13% of all losses (Table 2). Less than 4.5% of all losses were ascribed to diseases, mostly pulpy kidney, blue udder, Pasteurella, black quarter, and blue tongue.

Livestock theft occurred every year, with the most considerable losses recorded during 1999, 2004 and 2005. Compared to predation (78.2%), the losses due to livestock theft (mean = 5.6%) were relatively small (Table 2).

To put the impact of predation into perspective, the data in Table 2 were converted into annual post-weaning losses as a percentage of total flock size (Table 3). The lowest percentage loss (relative to total flock size) was recorded in 1999. After that, the predation losses doubled in 2000 and doubled again from 2000 to 2002. In 2003, the percentage losses due to predation accounted for 20.4% of all sheep losses at the Glen AI. The percentage loss due to predation remained high and increased in 2007 to 25.8% of the total number of sheep, despite the Dorpers now been kraaled at night. Two of the Merino flocks were kept relatively safe behind electric fences.

By comparison, the losses due to diseases, metabolic disorders and accidents, and livestock theft were markedly lower. Percentage losses due to metabolic disorders and accidents were slightly higher from 2003 onwards (Table 3). When the losses in each category were compared, it is evident that predation was the

Table 3. Annual post-weaning losses as a percentage of total flock size (Merino and Dorper) over nine years (1999-2007) at Glen AI.

	Flock Size	Predation	Diseases[1]	Metabolic disorders[2] & Accidents	Theft	Total
Year	n	%	%	%	%	%
1999	1130	6.7	2.7	1.0	1.8	12.2
2000	1165	13.2	0.5	2.7	1.1	17.5
2001	1062	19.6	0.1	0.9	0.5	21.1
2002	963	26.3	0.1	1.1	0.8	28.3
2003	854	20.4	0.4	4.6	0.6	26.0
2004	823	20.2	2.6	5.8	2.4	31.0
2005	789	19.7	0.8	3.7	2.8	26.9
2006	586	15.9	0.7	4.3	0.7	21.5
2007	552	25.8	0.5	3.1	0.7	30.1
Average		**18.6**	**0.9**	**3.0**	**1.3**	**23.8**

[1] Pulpy kidney, Pasteurella, blue tongue, blue udder, and black quarter.
[2] Acidosis and bloat.

highest, with an average loss of 18.6% of the total sheep over nine years. Losses due to predation were, therefore, 20.7 times more than losses due to diseases (0.9%), 6.2 times more than metabolic disorders and accidents (3.0%), and 14.3 times more than livestock theft (1.3%).

The direct financial losses were calculated according to the economic values for the different age and gender classes from 2003 to 2007 (Table 4). Accordingly, annual sheep losses (all age groups) resulting from predation were very high, varying from R59 900 to R165 400 at the Glen AI (Table 5).

The minimum impact of R59 900 due to predation (2003) was still R18 500 more than the maximum impact due to the second highest loss category, namely metabolic disorders, and accidents (2005). Predation contributed 73% to the total financial loss, diseases 2%, metabolic disorders and accidental mortalities 19%, and livestock theft 6% (Table 5).

Fruitless expenditure (veterinary supplies and shearing cost) was calculated for each age group, namely pre-weaned, 4-12-month, 2-tooth age and mature sheep, (Table 6). The veterinary and sundry costs calculated for sheep losses in different age categories after weaning were done as follows:

Table 4. Economic values designated by eight study groups[1] for different classes of Merino and Dorper sheep.

	South African Rand (ZAR)					
Year		Before weaning	4-12 months	2-tooth	Breeding ewes	Breeding rams
2003	Merino	100	150	300	400	1 000
	Dorper	200	300	400	600	1 000
2004	Merino	200	300	400	500	1 500
	Dorper	300	400	500	700	1 500
2005	Merino	300	400	500	700	2 000
	Dorper	400	500	600	800	2 000
2006	Merino	300	400	600	700	2 000
	Dorper	400	500	600	800	2 000
2007	Merino	350	450	550	800	2 500
	Dorper	450	600	700	900	2 500

[1]See text for detail.

Table 5. Direct financial implications of losses and mortalities for the five Merino flocks and the Dorper flock over five years at Glen AI.

South African Rand (ZAR)					
Year	Predation	Disease	Metabolic disorders & Accidents	Theft	Total
2003	59 900	1 050	22 700	1 450	85 100
2004	108 100	7 700	33 300	11 800	160 900
2005	165 400	5 000	41 400	29 000	240 800
2006	98 700	2 700	25 400	2 600	129 400
2007	147 950	1 700	31 850	2 200	183 700
Total	**580 050**	**18 150**	**154 650**	**47 050**	**799 900**

Table 6. A breakdown of veterinary and sundry costs per animal for the different age classes in the Merino and Dorper flocks over five years at Glen AI.

			4-12 months		2-tooth		Mature	
Veterinary supplies	ZAR*	Lamb	Ewe	Ram	Ewe	Ram	Ewe	Ram
Tags	3.65	1						
Castrator rings	0.13	1						
Dosing[2]	2.40	1	2	2	2	2	2	2
Pour-on dip Vaccines	0.20	1	1	1	1	1	1	1
Pulpy kidney	5.24	1	2	2	2	2	2	2
Blue tongue[3]	2.33		1	1	1	1	1	1
Blue udder	1.00				1		1	
Enzootic abortion	4.64				1		1	
Rev[1]	2.87			1				
Shearing cost	4.63		1	1	1	3	1	3
Total R/c		**11.62**	**22.44**	**25.31**	**28.08**	**31.70**	**28.08**	**31.70**

*South African Rand
[1] Values applied for 2003-2007.
[2] Treatment SL-R&V received an additional dosing per year.
[3] Not applied to the Dorper flock.

4-12 months:

Direct expenditure before weaning (plus inoculations and dosing) and direct costs up to 12 months of age.

12-24 months (2-tooth):

Direct expenditure for the year in which the loss occurred.

>24 months (mature):

Direct expenditure for the year in which the loss occurred.

This study calculates the production costs incurred annually, from one lambing season to the next. Although sheep were caught throughout the year, most of the losses occurred between September and November with each new lambing season (on veld). If a lamb, for example, died at the age of five months, it was classed in the 4-12 months category, and the entire cost for that period was considered. The input cost of any specific individual may be overestimated but most of the losses occurred at the end of this age category. Therefore, if the total cost for the whole period in an age category was considered, a good reflection of the costs could still be obtained.

The vaccine cost for bluetongue (R2.33 per individual) is only applicable for the Merino Treatment flocks and was not given to the Dorper flock. Furthermore, although the shearing cost for rams in the age categories 2-tooth and mature are three times more than for ewes, these calculations were not reflected in Table 6 (≈ the cost per ewe were applied throughout).

Table 7. Annual production costs per hectare (ha) of irrigated ryegrass pasture for the Merino ewes in Treatment SL-R&V at Glen AI.

Ryegrass (*Lolium multiflorum* and *L. perenne*)						
Inputs	Product	Unit	Quantity	R/Unit	R/ha	R/ewe
Fuel	Diesel	litre	85.00	9.26	787.10	
Fertilizer[1]	N	kg	252.00	29.91	7 537.32	
Seed[2]	Midmar/Dargle	kg	20.00	30.10	602.00	
Irrigation	Eskom	mm	1200.00	0.90	1 080.00	
Irrigation	Water	mm	1200.00	0.63	756.00	
Mechanical	Repair		1.00	360.64	360.64	
Irrigation	Repair		1.00	241.50	241.50	
Labour[3]		h	48.00	5.65	271.20	15.95
Direct production costs (pasture and workforce)					11 635.76	684.46
Salt lick		kg	31.11	0.84	26.13	1.54
Workforce		h	8.00	5.65	45.20	2.66
Total production costs (intensive and extensive)						**688.66**

[1](85 kg N was applied x 3) (R8 374.80/t) (Price/ton obtained in 2008).

[2]Midmar was only available until 2006.

[3](17ewes/ha for nine months) (1 assistant/1 000 sheep/year @ 40 working hours/week).

Table 8. Annual production costs per hectare of oats pasture under dryland conditions for the Merino ewes in Treatment AL-O&V at the Glen AI.

Oats (*Avena sativa*)[1]						
Inputs	Product	Unit	Quantity	R/Unit	R/ha	R/ewe
Fuel	Diesel	Litre	79.00	9.26	731.54	
Fertilizer	N	kg	28.00	29.91	837.48	
Seed		kg	30.00	6.16	184.80	
Irrigation	Eskom	mm	0.00	0.0	0.00	
Irrigation	Water	mm	0.00	0.0	0.00	
Mechanical	Repair		1.00	336.64	336.64	
Irrigation	Repair		0.00	0.0	0.00	
Labour[2]		h	23.00	5.65	129.95	
Total					**2 220.41**	**185.03**
Salt lick		kg	21.96	0.84	18.47	1.54
Workforce		h	12.00	5.65	67.80	5.65
Total					**2 306.68**	**192.22**

[1]Dry land oats (GWK, 2008) and (SENWES, 2008).

[2](12 ewes/ha for 6 months) (1 assistant/1 000 sheep/year @ 40 working hours/week).

For losses that occurred in Treatment SL-R&V and Treatment AL-O&V, the fruitless expenditure (for ewes) on the planted pastures was also calculated (Tables 7 and 8, respectively). The total fruitless cost, when planted pasture costs were included, was high (Table 9), substantially increasing the total annual financial losses (Table 10).

The veterinary and shearing cost contributed 4% in all groups to the direct economic value for a breeding ewe in 2007 (Table 4). Lick, labour and pasture cost contributed 1% in Treatment SL-V(C), 11% in Treatment SL-V&S, 86% in Treatment SL-R&V and 24% in Treatment AL-O&V to the direct economic value for a breeding

Table 9. Total financial expenditure due to fruitless expenses for the five Merino flocks and the Dorper flock at Glen AI.

	South African Rand (ZAR)				
Year	Predation	Disease	Metabolic disorders & Accidents	Theft	Total
2003	12 929	233	3 927	242	17 331
2004	15 292	1 727	5 255	763	23 037
2005	14 568	468	3 056	900	18 992
2006	9 888	823	5 653	153	16 517
2007	15 087	285	3 948	108	19 428
Total	**67 764**	**3 536**	**21 839**	**2 166**	**95 305**

Table 10. Total annual financial losses for the four Merino treatment flocks, the Merino shearing flock, and the Dorper flock at Glen AI.

	South African Rand (ZAR)				
Year	Predation	Disease	Metabolic disorders & Accidents	Theft	Total
2003	72 829	1 283	26 627	1 692	102 431
2004	123 392	9 427	38 555	12 563	183 937
2005	179 968	5 468	44 456	29 900	259 792
2006	108 588	3 523	31 053	2 753	145 917
2007	163 037	1 985	35 798	2 308	203 128
Total	**647 814**	**21 686**	**176 489**	**49 216**	**895 205**

ewe in 2007, respectively (Table 4). Exceptionally high 2008 fertilization prices were obtained when calculations were done, resulting in a high cost per hectare and ewe on the ryegrass (Table 7). However, even if the fertilization price was halved, the direct production costs per hectare were still high at R7 867.10/ha and R466.97/ewe (total production cost/ewe). This cost per ewe equated to 58% of the direct economic value for a Merino breeding ewe in 2007 (see Table 4).

Losses from predation were 75%, 66%, 77%, 60% and 78%, respectively, of the total fruitless expenses for the five years from 2003 to 2007 (Table 9). The greatest fruitless expenses for the second highest loss category, namely metabolic disorders, and accidents, were recorded in 2006, contributing 34% to the total expenses. Predation contributed 71% to the total fruitless expenses, diseases 4%, metabolic disorders and accidental mortalities 23%, and livestock theft 2%.

Overall, fruitless expenditure (Table 9) contributed 10.64% to the total loss (Table 10). The total annual financial loss due to predation (average R129 562/year) was markedly higher than losses due to diseases (average R4 337/year), metabolic disorders and accidents (average R35 299/year), and livestock theft (average R9 843/year) (Table 10). Predation contributed 72% to the total financial loss, diseases 2%, metabolic disorders and accidents 20%, and livestock theft 6%.

The total expenditure ascribed to predation today will be much higher than the amounts reported here. To put the direct economic expenses of post-weaning losses into perspective, for example, calculations with July 2021 on the hoof prices (Myburg 2021) and using the average live weights of the different Treatment and age categories, amounts to the following:

4-12 months:
(28.4kg x R54.5/kg = R1547.80; vs R525.00 in 2007)

2-tooth:
(47.5kg x R37.5/kg = R1781.25; vs R625.00 in 2007)

Breeding ewe:
(59.25kg x R30/kg = R1777.50; vs R850.00 in 2007)

Breeding ram:
(79kg x R24/kg = R1896.00; vs R2500.00 in 2007)

If the same losses would occur today, as it had over the 5-year study period, the financial implications of direct predation losses, alone, would be R1 218 283 (more than double the R580 050 of 2007; see Table 5). Predation, therefore, does have a marked financial impact on small livestock farms in central South Africa. So much more if we consider the costs of predation management and erecting predator-proof fences, which was not included in this study, and should strictly speaking also be added. Furthermore, the ewes were fertile and produced at optimum levels in the Free State Wool Sheep Project (conducted with breeding sheep). However, some Merino ewes could not raise a single lamb in a 6-year production cycle. The unaccounted carry-over effects should also be included in the predation calculations: for example, production costs in this study have been accounted for one production year only, or up to the month in which the loss occurred; the financial impact would be much higher if calculated over six years, during which the affected ewes' offspring could also have reproduced. Strictly speaking, the cost of genetic losses should also be included in the predation calculations.

CONCLUSIONS

This article is the first attempt at a detailed breakdown of small stock predation costs in southern Africa. Unique daily records and veterinary reports of new small stock arrivals and deceased individuals were strictly kept, while dedicated ADC officials confirmed predation loss information. The expected increase in flock size and ewe productivity was negatively influenced by predation, and a mean decrease of 21.1 ± 3.7% of the total annual flock size was recorded over the 7-year study period (2001 to 2007). The flock was decimated, and the Free State Wool Sheep Project in this format was discontinued. Predation (average cost = R129 562/year) accounted for 72% of the total (≈ direct losses + fruitless expenses) annual financial losses, and diseases contributed 2% (R4 337/year), metabolic disorders and accidents 20% (R35 299/year), and livestock theft 6% (R9 843/year). Over the relatively short period of five years from 2003 to 2007, the total financial loss due to predation at the Glen AI accrued to R647 814 (predation management, fencing, carry-over reproduction and genetic costs not included). Some of the ewes in the five Merino flocks could not raise a single lamb in the 6-year production cycle; the only income from these ewes came from their wool yield. This loss is considered very high, given that data was only collected from a relatively small number of sheep.

Assuming an equivalent rate of predation losses as suffered by the Merino and Dorper flocks of Glen AI over the study period, the current direct financial implications of predation losses (estimated at R1 218 283) will have a significant effect on a similar sheep enterprise today.

Thus far, only the direct cost of sheep loss has been reported as 'predation loss' in southern Africa. However, it is essential also to include the indirect cost. In the current study, veterinary and shearing costs contributed 4% to the direct economic loss, and lick, labour and pasture cost varied between 1% and 11% of the direct economic value for the veld groups, and between 24% and 86% for sheep on planted pastures. Fertilizer prices had the biggest impact on the pasture costs, followed by the diesel and electricity prices – which all contribute to the financial loss when a sheep has been predated. Considering the genetic losses due to predation and the carry-over effect of some ewes not raising their lambs (costs not included here), the actual losses were considerably more than the total financial losses calculated in this study. Furthermore, comparison between flocks kept in protected conditions (kraaled or electrified fencing) and those which were left unprotected indicate that farming with sheep in unprotected camps at Glen AI was unsustainable.

This is only the third recorded instance where sheep flocks at public institutions have been greatly curtailed due to predation. Only one other South Africa flock (wool sheep flock at a government institution near Potchefstroom) was saved after erecting a predator-proof electric fence (Postma *et al.* 1993). The other two institutions were the Texas Agricultural Experiment Station at McGregor, Texas, USA (Shelton 1972) and the Hopland Research and Extension Centre, California, USA (a flock maintained by the University of California; Timm & Connolly 2001; Jaeger 2004). As with the Glen AI, and most central South African farms, several practical non-lethal and lethal methods to prevent or control predation were utilised at the Hopland Research and Extension Centre. Predation at Hopland remained a management challenge, reflecting the experience of thousands of sheep producers in the USA (Timm & Connolly 2001).

Scenarios regarding predation on sheep are very similar in the USA and South Africa, with highly comparable damage-causing animal composition. Where Black-backed jackal and Caracal are often cited as the primary culprits in South Africa, Coyote (*Canis latrans*) and Bobcat (*Lynx rufus*) are their counterparts in the USA. Therefore, it is alarming that, in Texas, farmers cited predation as a primary reason for leaving sheep and goat farming (Shelton 2004). A similar trend is already observable in South Africa with many farmers having already left sheep farming (Du Plessis 2013). The current study has shown that sheep farms in central South Africa may find it challenging to survive using the current predator control management approach. While more farmers are today collaborating with researchers (e.g. Drouilly *et al*. 2020, 2021; Van der Weyde *et al*. 2020; Marker *et al*. 2021; Schurch *et al*. 2021) and predation managers (Uys 2021) to find a more acceptable approach, reliable data on the efficacy of the predator control measures in reducing the long term impact of predation on livestock, are still lacking (Thorn *et al*. 2012; 2013; Bergman *et al.* 2013; Du Plessis 2013; Van Niekerk *et al*. 2013; Badenhorst 2014; Du Plessis *et al*. 2018; Kruger *et al.* 2020; De Waal 2021).

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