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Evaluation of physical and behavioral traits of llamas associated with aggressiveness toward sheep-threatening canids

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Abstract

Llamas (*Lama glama*) are frequently used as guard animals by sheep producers as part of their predation management programs. However, few data are available concerning physical and behavioral attributes that distinguish between effective and ineffective guardian llamas. Our study addressed this issue and evaluated aggressiveness of llamas toward dogs. Initially, we identified physical and behavioral traits of individual llamas. Twenty llamas were randomly assigned to one of four groups ($n = 5$ per group). We used focal group sampling techniques to rank individual llamas according to frequencies with which they displayed alertness, leadership, dominant, aggressive, and threatening behaviors as well as postures indicating dominance or subordination. We then examined the behavior of individual llamas with sheep. Finally, we documented interactions among llamas, sheep, and a surrogate predator (border collie). Our results showed that leadership, alertness, and weight of llamas were correlated with aggressiveness displayed toward the dog ($p_s = 0.064$, 0.012, and 0.039 respectively). These traits are easily recognized and can be used by producers to select llamas as livestock guardians. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: *Canis latrans*; Coyote; Depredation; *Lama glama*; Llama; Predation control

1. Introduction

Killing predators to protect livestock is one of the more controversial issues in natural resource management (Wagner, 1988). Not surprisingly, there is increasing interest in

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the use of nonlethal methods to reduce predation on sheep (Sterner and Shumake, 1978; Linhart, 1981; U.S. Department of Agriculture, 1994). Use of guardian animals has received special attention (Green and Woodruff, 1980). A variety of animals have been tested for this purpose, including donkeys (Green, 1989a; Walton and Feild, 1989), kangaroos (*Macropus giganteus*) (Franklin and Powell, 1993; Cooper, 1994), ostriches (*Struthio camelus*) (Franklin and Powell, 1993; Cooper, 1994), and llamas (*Lama glama*) (Markham, 1990; Markham, 1992; Markham, 1993; Powell, 1993; Franklin and Powell, 1993). Dogs are the most commonly used species (Linhart et al., 1979; Green and Woodruff, 1980; Green et al., 1980, 1984, 1994; Coppinger and Coppinger, 1982; Coppinger et al., 1983; Green and Woodruff, 1988, 1990a; Andelt, 1992).

Properly trained and maintained, dogs can reduce sheep losses to predation (Linhart et al., 1979; McGrew and Blakesley, 1982; Green, 1983; Black and Green, 1984; Andelt, 1985; Lorenz et al., 1986; Coppinger et al., 1987; Green, 1990; Green and Woodruff, 1990b; Green et al., 1994), although benefits may not be immediately apparent (Green and Woodruff, 1990a). Factors influencing the effectiveness of a dog include genetic background, rearing, socialization with sheep, and appropriate placement.

Some disadvantages of using dogs as livestock guardians have been reported. Green (1983) identified several problems, including: (1) injury or death of sheep resulting from playful behavior or outright attacks by the dogs; (2) aggressiveness toward people; and (3) destruction of property by chewing or digging. Timm and Schmidt (1990) reported guard dogs straying to adjacent properties as well as killing some species of wildlife. The premature deaths of many guard dogs (an average career tenure ≤ 2 years) detracts from their utility (Lorenz et al., 1986; Green, 1989b), as does the fact that use of dogs complicates the application of other depredation control tools (Green and Woodruff, 1990b). Traps, snares, and M-44 cyanide ejectors are generally precluded in the vicinity of guard dogs because of the risks such devices pose to them.

As an alternative to dogs, llamas are becoming popular among some livestock producers (Markham, 1993; Markham et al., 1993), particularly in the western United States (Franklin and Powell, 1993). Developed by selective breeding of guanacos (*Lama guanicoe*) in South America, llamas are territorial, with males gathering and defending females within their territories (Markham, 1990; Franklin and Powell, 1993; Markham et al., 1993). Llamas are typically aggressive toward dogs and appear to readily bond with sheep and aggressively protect them, when pastured away from other llamas. In a study conducted by Iowa State University (ISU) 80% of sheep producers using llamas rated them as 'very effective' or 'effective' in deterring predation (Franklin and Powell, 1993; Powell, 1993). Another 15% rated llamas somewhat effective. Only 5% considered llamas to be ineffective guardians. On average, producers reported that annual losses dropped from 21% to 7% when llamas were present.

Unlike dogs, llamas do not have to be raised in close association with sheep from a very young age. The average age at which llamas are initially paired with sheep is 2.1 years, with a range of 0.5 to 12 years (Franklin and Powell, 1993). Producers suggest the greatest success occurs with large, curious, attentive animals, with some evidence that aggressiveness might also be important (Franklin and Powell, 1993). To date, however, no systematic investigation has attempted to identify and quantify traits associated with good guarding behaviors. The present study attempted to address this issue. Evaluating whether a llama is an effective guardian prior to purchase could minimize financial, environmental, and social conflicts.

2. Methods

Our study was conducted at the Predator Research Facility of the National Wildlife Research Center near Millville, UT. During the first phase of the study, we determined physical and behavioral traits of individual llamas. The second phase assessed activity patterns of individual llamas with sheep. Finally we examined interactions among llamas, sheep, and a trained domestic sheep dog to assess the aggressiveness of individual llamas toward canids.

2.1. Data collection

Twenty gelded male llamas were purchased from commercial producers and randomly assigned to four groups ($n = 5$ per group). None of the experimental animals had extensive experience with sheep or dogs prior to purchase. All llamas were individually weighed using a livestock scale and physical characteristics (weight, age, and coloration) noted. Sixty percent of the llamas were under 4 years of age, 25% were between 4 and 5 years old, and 15% were older than 5 years. Llamas ranged from 93.8 to 203.4 kg, with 70% of the animals weighing less and 30% weighing more than 150 kg. Forty percent of the llamas were categorized as dark colored (brown or black), 40% were light colored (cream or white), and 20% were mixed (Table 1). Each group was brought to the study site 2 days prior to initiating data collection. All animals were individually identified by colored halters with numbered plastic tags. Animals were fed alfalfa daily and water was available ad libitum.

2.1.1. Phase I

Observations of social interactions among llamas were made from a 9-m tall building overlooking a fenced 4-ha pen where the animals were kept. The observer stayed 6 m above ground level and recorded behavioral observations without disturbing the animals' routine. Observations encompassed 4 h each day for 8 consecutive days. Two time blocks (0800 to 1200 h and 1400 to 1800 h) were used on alternate days. Focal group sampling (Altmann, 1974) was used to tabulate the frequency of various behaviors (Table 2) exhibited in interactions among individuals.

We were particularly interested in social interactions involving agonistic encounters, leadership, and alertness. Evidence suggests behaviors of llamas, guanacos, and vicunas (*Vicugna vicugna*) are similar (Fernandez-Baca, 1978; Franklin, 1982; Tomka, 1992; Hoffman, 1993). Franklin (1978, 1983) reported that threatening behaviors among wild camelids include postures, vocalizations, scent marking, and locomotion displays for guanacos and vicunas. In a study of vicuna social behavior, Franklin (1978) reported that during agonistic interactions, both participants dropped their ears, but the dominant

Table 1
Physical characteristics of gelded male llamas used in this study

Group	Animal	Coloration	Age (months)	Weight (kg)
1	20	light	43	122.31
	25	light	43	105.55
	53	dark	44	103.74
	19	light	53	161.27
	14	light	55	185.73
2	58	dark	44	112.80
	59	light	81	121.86
	62	dark	42	117.33
	60	dark	43	119.59
	16	light	55	203.40
3	63	mixed	63	117.78
	52	dark	42	130.46
	54	dark	45	111.00
	21	light	76	189.35
	26	light	43	149.04
4	55	mixed	57	136.81
	57	mixed	41	93.77
	56	dark	45	125.03
	51	dark	44	110.08
	18	mixed	55	185.28

animal usually dropped its ears to a lower level than the other. Consequently, ''the individual with lower ear position was invariably the dominant individual of an interacting pair'' (p. 124). Aggression is also indicated by spitting (Hoffman, 1993). We were especially interested in threatening behaviors among llamas, as defined by specific movements and positions of head and ears and spitting. We recorded a threat if an animal exhibited at least one of the following behaviors: (1) lifted its head, (2) thrust its ears back, (3) tilted its chin upward, or (4) spit.

Subordination/withdrawal was assessed separately from threats and was operationally defined as obvious retreating or turning away (i.e., averting its' head or body, walking aside, or walking away) in response to a threat from another animal. Passive avoidance (i.e., one animal avoiding another by not approaching; Rowell, 1974) was not considered because it was too difficult to assess in this context. Leadership was based on the frequency with which individuals were followed by others when they initiated a movement (a walk, a run, or a defecation). Records were also kept regarding the frequency with which individuals were 'followers.' Frequencies with which llamas approached one another were registered as a measure of social interest and were recorded whenever one animal approached another for no other apparent reason (e.g., to approach the feeder or water trough). Records of the responses displayed to each approach were also kept. Alertness of individual llamas were measured by examining ear positions and body postures (Table 2).

Social dominance could be an important component of good guardian behavior and is a widely used concept in animal behavior. However, standard methods for measuring

Table 2
Definition of behaviors recorded during phase I of study

Behavior	Description
Threatening behaviors	
Ear threats	Categorized as indirect aggression patterns, ear threats consist of lowering the ears backwards. Ear threats can be performed with different intensities[a] and in conjunction with tilting the head and the chin upward
Spitting	Considered a form of direct aggression, a component of an intensive encounter
Submissive behaviors	
Avert head	Turn head away from aggressor in response to an ear threat
Avert body	Performed as a response to a threat, the whole body turns away from the aggressor
Walk aside	Usually follows a head or body turn, with submissive animal walking 1–3 steps away from the threatening individual
Walk away	Recipient of a threat walks away from the initiator
Nonaggressive behaviors	
Approach	Approach of another animal for no other apparent reason (i.e., to approach the feeder or water trough), recorded as a measure of interest in other llamas
Leading	Recorded for animals which initiated movements and were followed by others
Following	Recorded for individuals who followed others upon the initiation of a movement (running, walking, defecating)
Alertness	Displayed by animals showing a frozen posture, with head raised high and ears erect and forward

[a]For a more detailed description of ear threats and their different intensities, the reader is referred to Franklin (1982).

social dominance have not been developed. Craig and Guhl (1969) and Craig et al. (1969) suggested, respectively, the use of 'dominance values' and 'social-tension indexes.' Dominance hierarchies within each group of llamas were defined by methods described by Craig and Guhl (1969) and Craig et al. (1969), with dominance values and social-tension indexes calculated for each individual. An index of aggressiveness among llamas was also calculated for each individual by dividing the total number of agonistic interactions each llama won (with other llamas within its group) by the total number of interactions in which it participated that contained at least one aggressive component. Animals were recognized as winners when they displayed more intense threats than the other llamas participating in a specific encounter.

2.1.2. Phase II

For this phase of the study, each llama was placed in a 1-ha pen with a flock of five sheep, the minimum number necessary to form a stable flock (Baldry in Anderson et al., 1987; Lynch et al., 1992). Each sheep was individually marked with a 25 × 25-cm colored square painted on each haunch. The animals were allowed 5 days of pretrial conditioning before observations were initiated. Observations were made from a 6-m tall building overlooking the pen where the animals were kept. The observer stayed 3 m above ground level behind a glass window and recorded behavioral observations without disturbing the animals' activities. Observations occurred on 5 consecutive days during two 3-h time blocks (0800 to 1100 h and 1400 to 1700 h), alternating between blocks on consecutive days. We used instantaneous scan sampling at 15-min intervals (Altmann, 1974) to assess activity patterns and cohesiveness among llama and sheep. During each scan, the activity category (walking, lying down in sternal recumbency or lying down in lateral recumbency, standing, grazing, drinking, alert, and feeding) and location of each animal were recorded. Markers along fences and within the study arena facilitated plotting individual locations and estimating interanimal distances.

2.1.3. Phase III

During this phase of the study, each llama–sheep group from Phase II was exposed to a trained border collie during two 10-min trials. The dog was introduced into the pen and directed, via hand signals from an experienced handler, to gather and move the sheep. Reactions of the llama to the dog were recorded on videotape for later analysis. Subsequently llamas were ranked on their aggressiveness toward the dog value based on a combination of two criteria: (1) their behavior toward the dog—whether they appeared fearful (walked or ran away from the dog), inquisitive (slowly approached the dog), or aggressive (chased the dog), and (2) their affinity for sheep—whether or not they stayed close to the sheep. Observations were made from the same 6-m-tall building used on Phase II. The observer stayed 3 m above ground and did not disturb the interactions among the animals. The dog handler stayed in one corner of the pen for the duration of each trial, which standardized this potential source of bias with a more consistent presentation of stimuli to each individual llama. Therefore, direct comparisons are reasonable.

2.2. Data analysis

We pooled and tabulated the information collected in Phase I regarding frequencies of each behavior displayed by each llama. We then used chi-square tests of independence to evaluate associations among physical characteristics of llamas (Agresti, 1990).

Within groups, we tabulated and rank-ordered llamas according to the frequencies with which they displayed each behavior and used Spearman rank-order correlation coefficients (Siegel and Castellan, 1988) to assess associations among rankings of behaviors. Spearman partial correlation coefficients were used, when necessary, to eliminate possible group effects.

We calculated and rank-ordered interspecific distances for each llama to evaluate cohesiveness between llamas and sheep. The distribution of activities for both llamas and sheep was determined by the percentage of time each animal spent at each activity, based on the fraction of scans in which that activity was recorded. We then used the Cramér coefficient C to assess the degree of association between each individual llama's activities and that of their respective group of sheep (Siegel and Castellan, 1988). A contingency table was constructed for the activities of each llama and its respective group of sheep. We pooled the activities recorded for each group into three main categories (grazing, resting, and other) to avoid empty cells in the contingency tables. Since frequencies of sheep behavior within groups were not probabilistically independent, we divided the chi-square statistic used to calculate Cramér coefficients by the number of sheep (five) in each group (Wickens, 1989) and then ranked llamas, according to Cramér coefficients, from the most to the least synchronized with the sheep. We subsequently used Spearman rank-order correlation coefficients (Siegel and Castellan, 1988) to assess whether there was a correlation between llama and sheep cohesiveness, or between the 'synchronicity of llama and sheep activity' (Cramér coefficients), and the level of aggressiveness llamas displayed toward the dog. We also used Spearman rank-order correlation coefficients to assess the associations between each behavioral or physical trait of llamas and the degree of aggressiveness llamas displayed toward the dog. A chi-square test of independence was used to evaluate the association between coloration of llamas and the level of aggressiveness they displayed toward the dog (Agresti, 1990). Statistical analyses were computed using SAS Release 6.11 (SAS Institute, 1985, 1996).

Table 3
Frequencies of social interactions displayed in phase I among four groups of five llamas

Group	Llama	Threats[a]	Withdrawals[a]	Leading/ Following	Approaches[a]	Alertness
1	20	14/15	3/0	9/10	17/22	54
	25	16/10	2/10	9/9	34/8	32
	53	5/14	6/2	5/10	18/31	41
	19	32/37	18/0	8/6	33/30	43
	14	39/30	1/18	7/3	25/36	64
	Total	106	30	38	127	234
2	58	9/9	6/1	5/11	21/9	28
	59	20/8	0/18	11/1	13/33	56
	62	8/26	13/0	1/12	38/21	40
	60	11/24	8/3	4/1	19/13	26
	16	24/5	0/5	5/1	9/24	49
	Total	72	27	26	100	199
3	63	33/21	1/7	15/37	36/5	49
	52	5/18	2/2	9/12	14/15	33
	54	18/19	5/18	31/11	22/21	24
	21	10/18	22/1	2/0	9/28	27
	26	11/1	0/2	8/5	4/16	24
	Total	77	30	65	85	157
4	55	12/7	0/4	17/9	10/17	39
	57	9/23	6/2	7/17	29/12	32
	56	11/18	5/2	7/19	24/16	49
	51	35/12	2/17	10/17	15/22	36
	18	8/15	12/0	21/0	1/12	42
	Total	75	25	62	79	198

[a] Initiated/received.

Table 4
Spearman partial rank-order correlation coefficients and observed significance levels[a] for associations among behaviors observed in phase I, controlling for group associations

	Threats received	Withdrawals	Withdrawn from	Leading	Following	Approaches	Approached	Alertness
Threats given	−0.005	−0.506	0.644	0.423	−0.011	0.123	0.241	0.363
	0.983	0.038[b]	0.005[b]	0.091[c]	0.965	0.637	0.351	0.151
Threats received		0.595	−0.173	−0.280	0.241	0.647	−0.019	0.065
		0.012[b]	0.506	0.275	0.350	0.005[b]	0.942	0.805
Withdrawal			−0.659	−0.481	−0.027	0.237	−0.093	−0.378
			0.004[b]	0.050[b]	0.917	0.360	0.723	0.135
Withdrawn from				0.418	0.038	0.091	0.165	0.126
				0.095[c]	0.883	0.727	0.526	0.629
Leading					−0.048	0.105	−0.092	0.274
					0.856	0.689	0.726	0.288
Following						0.736	−0.314	0.066
						0.001[b]	0.219	0.802
Approaches							−0.401	−0.029
							0.110	0.911
Approached								0.339
								0.183

[a]Within each cell, top value is the correlation coefficient and bottom value is associated p-value.
[b]$p < 0.05$.
[c]$p < 0.10$.

3. Results

3.1. Physical characteristics

There was a positive correlation between the age of the llamas and their weight ($r = 0.505$, $p = 0.038$), indicating older llamas were heavier than younger ones. Coloration of llamas was not independent of weight ($\chi^2 = 7.49$, $df = 2$, $p = 0.024$) or age of llamas ($\chi^2 = 9.05$, $df = 2$, $p = 0.011$).

3.2. Llama social behavior

Frequencies with which individual llamas initiated and received behaviors (Table 3) were used to calculate Spearman partial rank-order correlation coefficients among various behaviors (Table 4). A negative correlation between 'threats given' and 'withdrawals' and a positive correlation between 'threats given' and 'withdrawn from' indicates the llamas that threatened others most, withdrew from others the least, and were 'withdrawn from' the most. Animals that received the most threats withdrew most from other llamas. Llamas that were 'withdrawn from' the most, withdrew from others the least. Llamas that approached other llamas more often, received more threats and tended to follow other llamas more. However, such rankings (Table 4) are not useful for all behaviors (e.g., alertness and following were not correlated with other recorded behaviors).

Table 5
Dominance hierarchies determined within groups according to two indices

Group	Llama no.	Dominance value[a]	Llama no.	Social-tension index[b]
1	14	0.32	14	9.00
	19	0.25	25	6.00
	25	0.23	20	−1.00
	20	0.20	19	−5.00
	53	0.08	53	−9.00
2	16	0.38	16	19.00
	59	0.29	59	12.00
	58	0.19	58	0.00
	60	0.17	60	−13.00
	62	0.09	62	−18.00
3	63	0.37	63	12.00
	26	0.34	26	10.00
	54	0.26	54	−1.00
	21	0.20	21	−8.00
	52	0.10	52	−13.00
4	51	0.43	51	23.00
	55	0.27	55	5.00
	18	0.23	18	−7.00
	56	0.16	56	−7.00
	57	0.13	57	−14.00

[a] Craig and Guhl (1969).
[b] Craig et al. (1969).

Strong agreement is evident between the two indices of social dominance among llamas (Table 5). Dominant and aggressive individuals have large positive social-tension indices, whereas submissive individuals have large negative indices. By definition, the mean social-tension index (Craig et al., 1969) within each group is zero, but the magnitude of variation, or range, was different among groups: 18.00, 37.00, 25.00, and 37.00 for groups 1, 2, 3, and 4, respectively.

3.3. Interactions with sheep

Individual llamas varied in the proximity they tended to maintain with the sheep (mean = 48.2 m ± 3., range = 46.8, SD = 15.54) (Table 6). Cramér coefficients (Table 6) provided a measure of synchronicity between the activities of each llama and their respective flocks of sheep, representing the degree to which sheep and llamas were engaged in the same activity at the same time.

3.4. Llama–sheep–dog interactions

Almost all llamas were curious about the dog, whether they chased it or not. Llamas varied in their aggressiveness toward the dog; some chased the dog while others ran from it. Some llamas stayed close to the sheep and others did not. Llama #16 was an

Table 6
Mean interspecific distances and synchronicity in activity between individual llamas and flocks of 5 sheep

Llama no.	Mean interspecific distances (m)	Synchronicity with sheep (Cramér coefficient[a])
20	42.65	0.09
25	48.33	0.15
53	45.56	0.09
19	29.47	0.09
14	30.03	0.09
58	39.18	0.17
59	28.83	0.06
62	31.86	0.18
60	29.72	0.09
16	75.59	0.07
63	57.04	0.14
52	73.76	0.11
54	53.19	0.18
21	34.70	0.07
26	43.66	0.11
55	56.03	0.16
57	70.86	0.05
56	66.76	0.13
51	61.21	0.11
18	45.05	0.11

[a]Siegel and Castellan (1988).

Table 7
Distribution of llamas according to responses to the dog

Affinity for sheep	Behavior toward dog		
	Afraid	Curious	Aggressive
Close to sheep	0	4	9
Not close to sheep	2	2	1
Total[a]	2	6	10

[a] $n = 18$: llama no. 16 was not afraid, curious, or aggressive and the record for llama no. 57 lost due to video malfunction.

exception; it watched from a distance and only arose from its resting position when the dog chased the sheep directly toward it. Llamas with top ranks for aggressiveness were curious and chased the dog, but stayed close to the sheep or frequently ran back to the

Table 8
Spearman rank order correlation coefficients (r_s) and observed significance levels (p) for associations between various llama characteristics and aggressiveness toward domestic dog

Characteristic	r_s	p
Physical attributes		
Age	0.337	0.158
Weight	0.475	0.039[a]
Color	–	0.049[ab]
Behavioral patterns among llamas (phase I)		
Threats given	0.311	0.241
Threats received	0.004	0.988
Withdrawals	−0.049	0.855
Withdrawn from	−0.244	0.361
Leading	0.472	0.064[c]
Following	−0.182	0.499
Approaching	−0.194	0.471
Approached	0.204	0.448
Alertness	0.607	0.012[a]
Dominance value	0.385	0.141
Social tension index	0.265	0.321
Llama–llama aggression	0.233	0.385
Llama–sheep relationships (phase II)		
Llama activities (portion of time spent)		
Walking	0.037	0.241
Grazing	−0.091	0.710
Resting	−0.228	0.350
Alert	0.490	0.033[a]
Standing	−0.046	0.853
Interspecific distances	0.385	0.141
Interspecific synchronicity	−0.258	0.286

[a] $p < 0.05$.
[b] $\chi^2 = 6.003$, $df = 2$.
[c] $p < 0.10$.

flock after chasing the dog, while bottom-ranked individuals ignored the sheep and ran from the dog (Table 7).

3.5. Evaluation of physical and behavioral traits as predictors of the aggressiveness llamas direct toward the dog

Age and weight were correlated, and although there was a positive correlation between weight and aggressiveness toward the dog ($r = 0.475$, $p = 0.039$), with heavier llamas being more aggressive, age and aggressiveness were not correlated ($r = 0.337$, $p = 0.158$). Similarly, llama coloration appeared associated with aggressiveness toward the dog ($\chi^2 = 6.003$, $df = 2$, $p = 0.049$), but interpretations would be speculative because coloration and weight were confounded. Among behaviors listed in Table 1, only leading and alertness were correlated with aggressiveness toward the dog (Table 8). Although aggressiveness among llamas (intraspecific aggression) was correlated with age ($r = 0.544$, $p = 0.024$) and weight ($r = 0.441$, $p = 0.076$) of the llamas, this was not correlated with aggressiveness toward the dog ($r = 0.233$, $p = 0.385$). There was a positive correlation between the proportion of time llamas displayed alertness in Phase II and the degree of aggressiveness they displayed toward the dog ($r = 0.490$, $p = 0.033$) (Table 8). This was consistent with results obtained in Phase I. Llamas that displayed alertness more often were also more aggressive toward the dog.

4. Discussion

Predators accounted for 38.9% of the total sheep and lamb losses in United States in 1994 (National Agricultural Statistics Service, 1995). Among predatory losses, canids were the major cause, accounting for 80.6% (coyotes—66.2%, domestic dogs—11.0%, and foxes—3.4%). In this study, a border collie trained to work with sheep was used as a surrogate predator. Some physical and behavioral traits of llamas were identified that were correlated with the aggressiveness the llamas displayed toward the border collie. The aggression llamas displayed toward the dog varied. Some individuals actively protected the flock by unhesitatingly chasing the dog; others were 'passive guards,' simply standing between the sheep and the dog. We assumed a good guard llama was one that chased the dog but stayed close to the flock during the dog's 'attack.' According to Lehner (1976), coyotes are primarily visually oriented predators with attack behavior elicited by running prey. Passive guard llamas might be as effective as active guards for reducing canid predation on sheep merely by their physical presence. In this experiment however, llamas were kept with a flock of five sheep. As a management practice, a llama might be kept with a flock as large as 500 animals or more. In such situations, it may be impractical for the llama to intervene between the entire flock and the predator. Therefore, active defense may provide better protection by chasing the predator to distract it or keep it away from the flock.

Traits correlated with llama aggressiveness toward dogs were alertness, leadership behavior, and weight; all characteristics that are easily recognized. These are some of the same characteristics suggested by the producers using guard llamas who were interviewed by Powell (1993).

The ability to detect approaching predators may be a key factor for a llama to successfully protect a flock of sheep. Unlike guard dogs who were alerted to the presence of coyotes by the behavior of sheep (McGrew and Blakesley, 1982), most llamas in this study started approaching the dog before the sheep seemed aware of it.

Leadership among llamas was correlated with the aggressiveness they displayed toward the dog. We addressed this in a spatial context, recording individuals that were followed when they initiated activities. Syme and Syme (1979), however, provided a different insight to the notion of leadership. In addition to 'spatial leadership,' a term concerned with group movement, these authors mentioned the concept of 'social leadership,' concerning the welfare of the group. According to them, social leadership includes ''protection of other members when the group is faced with threat or predation. Social leadership may thus be regarded as providing a relatively complex role for some members of the group'' p. 79. This concept may be important in selecting a guard llama, because individuals exhibiting leadership behavior might be more effective than others in providing protection to sheep against predators.

Heavier llamas displayed a higher level of aggressiveness toward the dog than smaller ones. This may be a function of the age of the animals, which was correlated with weight. Larger llamas may also be more self-confident against a medium-sized predator such as a coyote, dog, or fox. A larger llama might also be more intimidating to a predator.

Statistically, coat color was not independent from the level of aggressiveness llamas displayed toward the dog. Although there was evidence suggesting these factors are associated, this could be a spurious association with weight. There were no heavy dark llamas among the study animals. Llamas ranged from 93.8 to 203.4 kg. The heaviest dark llama weighed 130.5 kg, nearly 5 kg less than the average weight of all llamas in the study.

Thirteen percent of producers in the ISU survey (Powell, 1993) suggested aggressiveness as a desirable trait in a guard llama. In this study, aggressiveness among llamas was not correlated with aggressiveness toward the dog. Lack of correlation between these situations may result from: (1) not using relevant parameters in assessing aggressiveness among llamas, or (2) the aggressiveness llamas display among themselves is different from the aggressiveness they display toward canids.

Table 4 suggests there was a dominance hierarchy within each group of llamas. A common pattern was observed. However, groups differed in the magnitude of variation or the range in social-tension indices. Results suggest that groups 1 and 3 formed stronger hierarchies than groups 2 and 4. According to Beilharz and Cox (1967) and Beilharz and Zeeb (1982), among groups of equal size, the greater the variance of rank values found within groups, the more clearly dominance is expressed, and the more consistent or more defined the relationships within the group. However, because withdrawals occurred less frequently (mean = 0.7 withdrawals per group per hour) than threats (mean = 2.1 threats per group per hour), the hierarchy in these groups may not be as well formed or as rigid. Because threats occurred so often in this study, one might conclude that individuals were still attempting to establish a stable hierarchy. However, social status among llamas was not correlated with the aggressiveness llamas displayed toward the dog.

Average distances between llamas and sheep were not correlated with aggressiveness toward the dog. It should not be construed that distant llamas are not guarding the flock. Several producers participating in the ISU survey reported their llama did not stay close to the sheep but still seemed attentive (Powell, 1993). In the wild, territorial male guanacos commonly position themselves on hilltops or other elevated areas to detect invading animals and predators (Franklin, 1983). An effective guard llama may not necessarily be one that stays in close proximity to sheep at all times, although maintaining visual contact with the flock would seemingly be important.

This study was conducted under an experimental situation where several variables were controlled (i.e., size of pens, size of flocks, behavior of a surrogate predator, amount of time llamas spent with sheep and with other llamas prior to data collection). Although experimental control is desirable, it is achieved at the cost of situations more analogous to sheep operations. Pens utilized in this study were relatively small (1 ha). Hence, when llamas detected the approaching dog, it was typically within 150 m. Similarly, experimental flocks of sheep were very small (five animals). Further experiments should document how llamas react to canid predators in larger, fenced pastures, in open-range situations, and with flocks of different sizes. In addition, it would be interesting to determine whether longer interspecific socialization (i.e., llama and sheep) has any effect on a llama's aggressiveness and protection of the flock.

The reaction of guard llamas to the approach of more than one predator may also be instructive. Coyotes, for example, are opportunistic animals, able to quickly adapt to new situations. Bowen (1981), Gese and Grothe (1995), and Gese et al. (1996) reported coyotes hunting alone, in pairs, and even in small groups. Research is needed to determine how guard llamas react in such circumstances.

Traits that appear correlated with llama aggressiveness toward dogs, weight, alertness, and leadership, are easily identifiable and sheep producers interested in acquiring a llama should consider them when selecting potential livestock guardians. Although selecting guard llamas based on these traits may improve the likelihood of getting 'better' guardians, sheep producers should keep in mind that no depredation control technique has proven 100% effective. The use of better guardians, however, may significantly improve a producer's predator management program.

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