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Evaluation of Physical and Behavioral Traits of Llamas (*Lama glama*) Associated with Aggressiveness Toward Sheep-Threatening Canids

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EVALUATION OF PHYSICAL AND BEHAVIORAL TRAITS OF LLAMAS

(LAMA GLAMA) ASSOCIATED WITH AGGRESSIVENESS

TOWARD SHEEP-THREATENING CANIDS

by

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ABSTRACT

Evaluation of Physical and Behavioral Traits of Llamas

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by

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Canid predation poses a serious threat to the sheep industry in the United States. Llamas are becoming popular among livestock producers as part of their predation management programs but there is little information on the factors associated with llama guarding behavior. This study examined several physical and behavioral attributes of individual llamas to assess whether they might predict the aggressiveness llamas display toward canids. The study was conducted in three phases. The first involved determining some physical and behavioral traits of individual llamas. Twenty individuals were randomly assigned to one of four groups (n = 5/group) and frequencies with which animals initiated and responded to various behaviors, e.g., dominance, aggression, threats, subordination, leadership, and alertness, were documented using focal-group sampling. Individuals were then ranked according to the frequency with which they displayed each behavior. In the second phase, activity patterns of individual llamas with sheep were assessed. Llamas varied in how close to sheep they stayed (mean = 48.2 m ± 3.5) as well as in the way they distributed their activities. The third phase examined interactions among llamas, sheep, and a domestic sheep dog to assess their individual aggressiveness toward canids.

Llamas varied in the degree of aggressiveness displayed toward the dog; some chased the dog, others ran from it, some stayed with the flock, and others did not. Llamas were ranked based on these responses. Llamas with top ranks were curious and chased the dog, but stayed close to the sheep. Bottom-ranked individuals ignored the sheep and ran from the dog. Physical and behavioral traits of llamas and their behavioral patterns with sheep were then compared with aggressiveness they displayed toward the dog. Leadership and alert behaviors were correlated with aggressiveness ($r = 0.472$, $p = 0.064$ and $r = 0.607$, $p = 0.012$, respectively). Weight of llamas was also correlated with aggressiveness ($r = 0.475$, $p = 0.039$). Llama coloration was associated with aggressiveness they displayed toward the dog ($\chi^2 = 6.003$, df = 2, $p = 0.049$), however, color was also associated with the weight of llamas ($\chi^2 = 7.49$, df = 2, $p = 0.024$). Traits correlated with llama aggressiveness are easily recognized and sheep producers interested in acquiring a llama should consider them when selecting livestock guardians.

(58 pages)

DEDICATION

This work is dedicated in loving memory of my mother.

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Sandra M. C. Cavalcanti

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CHAPTER 1

INTRODUCTION

Canid predation, especially by coyotes (Canis latrans), poses a serious threat to the sheep (Ovis aries) industry in the western United States. According to the National Agricultural Statistics Service (NASS, 1995), predators accounted for 38.9% of the total sheep and lamb losses in the United States in 1994.

Predator control by the federal government has been one of the more controversial issues facing natural resource management (Wagner, 1988). Traditionally, livestock producers have relied upon removal of predators. To some people, this poses ethical questions, especially since such removals typically provide only temporary relief. Public concerns with traditional programs, as well as restrictions in the use of some techniques, have resulted in increased efforts to identify non-lethal methods for reducing coyote predation on sheep (Sterner and Shumake, 1978; Linhart, 1981; U. S. Department of Agriculture, 1994).

Use of livestock guarding animals to protect flocks from depredations without necessarily removing predators has received special attention (Green and Woodruff, 1980). Critics of traditional predator removal programs frequently consider use of livestock guarding animals as a non-lethal and environmentally acceptable way of reducing depredations (Arthur, 1981).

A variety of animals has been used to guard livestock, including dogs (Canis familiaris) (Linhart et al., 1979; Green and Woodruff, 1980; Green et al., 1980; Coppinger and Coppinger, 1982; Coppinger et al., 1983; Green et al., 1984; Green and Woodruff, 1988; Green and Woodruff, 1990a; Andelt, 1992; Green et al., 1994), donkeys (Equus asinus) (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 species most commonly suggested and used.

Various studies indicate livestock guard 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). However, experienced and competent dogs are not always readily available and livestock producers acquiring guard dogs cannot expect immediate resolution of predation problems. Considerable time, effort, and patience are required for a pup to develop into an effective livestock guardian (Green and Woodruff, 1990a), with success being a function of genetic background, proper rearing, socialization with sheep, and appropriate placement.

Green (1983) identified several problems that sometimes occur with the use of guard dogs, 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 dogs straying to adjacent properties and dogs killing some species of wildlife. In addition, the premature death of many guard dogs (an average career tenure $\leq$ 2 years) detracts from their utility (Lorenz et al., 1986; Green, 1989b).

Other aspects to be considered involve compatibility of guard dogs with other depredation control tools (Green and Woodruff, 1990b). More specifically, use of traps, snares, and M-44 cyanide ejectors are generally precluded in the vicinity of guard dogs because of the risks such devices pose to dogs.

As an alternative, llamas are becoming popular among some livestock producers as part of their predation management programs (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 canines and appear to readily bond with sheep and aggressively protect them, when pastured away from other llamas.

A survey conducted by Iowa State University (ISU) among sheep producers using llamas indicated 80% of them rated llamas as "very effective" or "effective" in deterring predation (Franklin and Powell, 1993; Powell, 1993). Another 15% rated them somewhat effective, and only 5% considered their llamas ineffective. However, 36% of the respondents reported problems or disadvantages of using llamas, the most common being overprotectiveness and interference with sheep management programs. Nevertheless, producers reported that average annual losses of sheep dropped from 21% to 7% of their flocks after obtaining guard llamas.

As opposed to dogs, llamas do not have to be raised in close association with sheep from a very young age. According to Franklin and Powell (1993), the ages at which producers initially introduced llamas to sheep varied from 0.5 to 12 years, with the average being 2.1 years of age. There is, however, a lack of understanding about the factors that contribute to the development of competent guard llamas. Despite a plethora of anecdotal articles and producer testimonials concerning guard llamas, there is little quantitative information regarding their use as livestock guardians. The few studies conducted, based on surveys and producer interviews, suggest llamas may effectively decrease coyote predation on sheep. However, there is little reliable evidence on how this is accomplished, and whether llamas vary in their guarding abilities.

Sheep producers participating in the ISU survey were asked for recommendations regarding behavioral and physical characteristics of a potential guard llama. Twenty-three percent of respondents volunteered that llamas with curious, attentive, alert, and self-confident behaviors were more desireable. Aggressiveness was suggested by 13% of the respondents, while 12% suggested that llamas should be bonded or raised with sheep. Nine percent advised getting "younger" animals, and 6% suggested large size. Five percent of the respondents recommended llamas with "natural guarding instinct," but did not elaborate.

To date, there have been no studies identifying characteristics associated with guarding behavior among llamas. This study attempted to identify some physical and behavioral traits of llamas that might predict good guardian behavior.

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 social dominance have not been developed. Since the concept was introduced by the Norwegian naturalist Schjelderup-Ebbe in 1922, there has been disagreement about the concepts of social dominance and aggression. The most common criterion for the expression of a dominant relationship is the priority of access to a limited resource (e.g., food, shelter, water, space) (Van Kreveld, 1970; Rowell, 1974; Black and Owen, 1986; Martin and Bateson, 1986; Lynch et al., 1992). Beilharz and Zeeb (1982) restricted social dominance among cattle to the behavior of one animal being inhibited in the presence of another. Aggression, on the other hand, involves motivation and behavior that results in repelling other animals. However, in an observed interaction between two animals, the direction of dominance is usually determined by aggressive acts. Therefore, it is not always easy to measure these concepts separately.

Dominance hierarchies have been assessed by various researchers for several domestic and wild species. Some researchers base hierarchies on the measurements of threatening behaviors (Kiley-Worthington, 1978), and others on encounters won (Beilharz and Cox, 1967; Appleby, 1981; Barrette and Vandal, 1986); some have measured the amount of time an animal spent feeding (Sereni and Bouissou, 1978), yet others measured avoidance (McBride et al., 1964). Craig and Guhl (1969) suggested the use of an index they called "dominance value" to estimate social ranks. This is based on the ratio of aggressive acts delivered by an animal to all agonistic interactions in which it was involved. Craig et al. (1969) proposed a "social-tension index," defined as the total number of aggressive acts delivered by an individual minus the number of aggressive acts it received. There have been other indices based on "agonistic acts initiated" suggested in the literature; however, the two methods described above appear more useful, since they consider submissive as well as aggressive acts.

Threatening behaviors among wild camelids reported by Franklin (1978, 1983) include postures, vocalizations, scent marking, and locomotion displays for guanacos and vicunas (Vicugna vicugna). Evidence indicates the behaviors of these species are similar to those of the llama (Pilters, 1954; Fernandez-Baca, 1978; Franklin, 1982; Tomka, 1992; Hoffman, 1993). Among camelids, lifting the head, thrusting the ears back, and tilting the chin upward are threatening postures. In his study of vicuna social behavior, Franklin (1978) reported that during agonistic interactions, both participants dropped their ears, but the dominant 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).

Leadership is another behavior that could influence a llama's guarding behavior and can be easily assessed among animals. According to Lynch et al. (1992), leadership is expressed by animals which initiate movement and are followed by others. These authors suggest leadership is a behavior that functions to maintain knowledge of an environment, and to coordinate group cohesion in terms of movement to food and water.

Another possible component of a good guardian behavior is alertness. An aroused guanaco shows an alert body position by rotating its ears forward toward whatever has piqued its curiosity (Hoffman, 1993). A vicuna in an alert position looks at its point of attention with its head raised and its ears erect (Vila and Roig, 1992). For feral, wild, and domestic sheep, Lynch et al. (1992) described an "attention behavior" as a "frozen" posture with the animal staring in the direction of interest.

Evaluating whether a llama is an effective guardian prior to purchase can minimize financial, environmental, and social conflicts. The purpose of this study was to examine behavioral and physical attributes of individual llamas and assess whether these factors might predict the level of aggressiveness llamas display toward canids. In addition, interactions between llamas and sheep were examined to determine whether behavioral and physical attributes of individual llamas were correlated with guarding behavior.

Specific objectives were to:

1. Identify physical and behavioral traits of individual llamas;
2. Assess behavioral relationships between llamas and domestic sheep; and
3. Determine whether physical traits and identified parameters of social behavior were correlated with the aggressiveness llamas display toward canids.

CHAPTER 2

METHODS

This study was conducted at the Predator Research Facility of the National Wildlife Research Center near Millville, Utah. The study was conducted in three phases: the first involved determining physical and behavioral traits of individual llamas; in the second, activity patterns of individual llamas with sheep were assessed; and the third phase 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 adult (2 to 7 years of age), gelded, male llamas were purchased from commercial producers in Utah, Idaho, and Colorado. To minimize bias regarding individuals, llamas were kept separate from each other at various farms and ranches in the vicinity of the Research Facility prior to the study.

2.1.1. Phase I

Individual animals were randomly assigned to one of four groups (n = 5/group), and each group was brought to the study site 2 days prior to initiating data collection on each respective group. All animals were identified so they could be recognized from a distance. Llamas in each of the four groups wore colored halters with numbered plastic tags. Individual differences in coat color and markings were also used for identification. Llamas were categorized as light, dark, or mixed color. Animals were fed alfalfa daily in a trough located at one corner of the pen. Water was available ad lib. in another trough located close to the feeder. Since animals used these areas of the pen more intensively than others, proximity measures were not used to avoid bias associated with such fixtures. All llamas were individually weighed using a livestock scale. Physical characteristics (weight, age, and coloration) were recorded on prepared data sheets.

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' daily routine. Observations encompassed 4 h each day for 8 consecutive days. Two time blocks (08:00 to 12:00 h and 14:00 to 18:00 h) were used on alternate days. Since all animals were visible throughout the observation periods, focal-group sampling (Altmann, 1974) was used to assess interactions among individuals. Observations involved recording the frequencies with which animals initiated and responded to a series of behaviors (Table 1). Observation times for all samples were pooled and were sufficient to provide adequate measures for the least frequently occurring behavior studied (i.e., spitting).

All clear indications of dominance were recorded; mere replacement of one individual by another at the feeder or water was not. Dominance hierarchies within each group 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 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. Behaviors of interest recorded among llamas included threatening behaviors, defined in terms of specific movements and positions of head and ears and spitting. A threat was recorded if an animal exhibited at least one of the following behaviors: 1) lifted its head, 2) thrusted its ears back, 3) tilted its chin upward, or 4) spit.

Subordination/withdrawal was assessed separately from threats and was determined by a clear indication of retreating or turning away from a threat by another animal. Withdrawal was recorded if an animal displayed at least one of the following behaviors after a threat from another individual: 1) averted its head, 2) averted its body, 3) walked aside, or 4) walked away. 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. An animal was considered to be leading when it initiated a movement (a walk, a run, or a defecation) and was followed by another animal. Records were also kept regarding the frequency with which individuals were "followers." Frequencies with which llamas approached one another were recorded as a measure of social interest. An animal was considered to be interested in another whenever it approached another for no other apparent reason (i.e., to approach the feeder or water trough). Records of the responses displayed to each approach were also kept. Alert behavior of individual llamas was measured by examining ear positions and body postures. Llamas were considered to be alert when they displayed a frozen posture, with head raised high and ears erect and forward (Table 1).

2.1.2. Phase II

This phase of the study involved recording activity patterns of llamas and sheep. Each llama was placed in a 1-ha observation pen with a flock of five sheep, the minimum number necessary to form a stable group (Baldry in Anderson et al., 1987; Lynch et al., 1992). Sheep for this phase were obtained from a single flock belonging to the Animal, Dairy & Veterinary Sciences Department of Utah State University. Each sheep was clearly identifiable by bright 25-cm colored squares painted on its mid-sides. Each group was fed alfalfa at the same time every day. Water was available ad lib. Each group was given 5 days to establish social patterns before observations commenced. Then, for 5 consecutive days, observations were made within two 3-h time blocks (08:00 to 11:00 h and 14:00 to 17:00 h), alternating between blocks on consecutive days.

Activity patterns and cohesiveness between llama and sheep were assessed by recording each individual's location and

Table 1

Definition of behaviors recorded during phase I of study

Behavior	Description
Threatening behaviors:	
- Ear threats	Categorized as indirect aggression patterns, 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).

activity at preselected moments in time (i.e., instantaneous scan sampling at 15-min intervals) (Altmann, 1974). During each scan, every animal in the pen was identified, its activity recorded, and location within the pen mapped to estimate interspecific distances. Markers along fences and within the study arena were used to facilitate plotting individual locations and estimating distances between them. Several behaviors were recognized and recorded for each animal: sitting, walking, lying down, standing, grazing, drinking, alert, and feeding. Data were recorded on prepared data sheets.

2.1.3. Phase III

This phase examined interactions among llamas, sheep, and a dog. Interactions were observed from an observation building overlooking the same 1-ha pens used in phase II. Each llama-sheep group from phase II was exposed to two trials in which a dog, trained to herd sheep, was introduced into the pen. Once in the pen, the dog was directed, via hand signals from an experienced handler, to gather and move the sheep. Each trial lasted 10 minutes. Reactions of the llama to the dog were recorded on videotape for later analyses. Llamas were assigned an aggressiveness rank value based on the combination of two criteria: 1) their behavior toward the dog (whether they were afraid, curious, or aggressive), and 2) their affinity for sheep (whether or not they stayed close to sheep).

2.2. Data analysis

Information collected in phase I was pooled and frequencies of each behavior were tabulated for each llama. Throughout this thesis, "frequency" depicts the number of occurrences, in accord with convention in the statistical literature. Chi-square tests of independence were used to evaluate associations among physical characteristics of llamas (Agresti, 1990).

Within each group, frequencies with which each llama displayed each behavior were counted and rank orders were assigned based on total counts. Spearman rank-order correlation coefficients (Siegel and Castellan, 1988) were used to assess the associations among rankings for each recorded behavior. Spearman partial correlation coefficients were used when necessary to allow possible group effects to be eliminated.

Cohesiveness between llamas and sheep was assessed by the average distance among them. For each group, distances between the llama and each sheep were measured and an interspecific mean distance was calculated. Llamas were ranked from the most cohesive with the flock to the least cohesive based on these distances. Distribution of llama activity was determined by the percentage of time individual llamas spent at each activity, which was based on the fraction of scans in which that activity was recorded. Distribution of sheep activity was assessed the same way. The Cramér coefficient C was used to measure the degree of association between each individual llama's activities and that of their respective group of sheep (Siegel and

Castellan, 1988). This coefficient is particularly useful to measure the degree of association or relationship between two variables consisting only of categorical information (i.e., unordered series of categories). A contingency table was constructed for the activities of each llama and its respective group of sheep. The activities recorded for each group were pooled into three main categories (grazing, resting, and other) to avoid empty cells in the contingency tables. Since frequencies of sheep behavior in each group were not probabilistically independent, the chi-square statistic used to calculate Cramér coefficients was divided by the number of sheep (five) in each group (Wickens, 1989). Llamas were then ranked, according to Cramér coefficients, from the most to the least synchronized with the sheep. Spearman rank-order correlation coefficients (Siegel and Castellan, 1988) were used to determine whether there was a correlation between llama and sheep cohesiveness and the level of aggressiveness llamas displayed toward the dog, as well as between the "synchronicity of llama and sheep activity" and aggressiveness llamas displayed toward the dog. Spearman rank-order correlation coefficients (Siegel and Castellan, 1988) were used to assess the association between each behavioral or physical trait of llamas and the degree of aggressiveness llamas displayed toward dogs. A chi-square test of independence was used to evaluate the association between coloration of llamas and aggressiveness they displayed toward the dog (Agresti, 1990). Statistical analyses were computed using

SAS Release 6.11 (SAS Institute Inc., 1985, SAS Institute Inc., 1996).

CHAPTER3

RESULTS

3.1. Physical characteristics

Sixty percent of the llamas in this study 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 (Table 2). 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. Forty percent were dark colored (brown or black), 40% were light colored (cream or white), and 20% were mixed (Table 2). 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 between various behaviors (Table 4). Some of them are correlated. The negative correlation between "threats given" and "withdrawals" indicates the llamas that threatened others the most also withdrew from others the least, while the positive correlation between threatening and "withdrawn from" indicates these llamas were also "withdrawn from" the most. Animals that received the most threats withdrew most from other llamas. Llamas that are "withdrawn from"

Table 2

Physical characteristics of llamas used in this study

Group	Animal	Coloration	Age (mos.)	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

Table 3

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

Group	Llama	Threat[a]	Withdrawal[a]	Lead/Follow	Approach[a]	Alert
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	23
	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 0.983	-0.506 0.038[b]	0.644 0.005[b]	0.423 0.091[c]	-0.011 0.965	0.123 0.637	0.241 0.351	0.363 0.151
Threats received		0.595 0.012[b]	-0.173 0.506	-0.280 0.275	0.241 0.350	0.647 0.005[b]	-0.019 0.942	0.065 0.805
Withdrawal			-0.659 0.004[b]	-0.481 0.050[b]	-0.027 0.917	0.237 0.360	-0.093 0.723	-0.378 0.135
Withdrawn from				0.418 0.095[c]	0.038 0.883	0.091 0.727	0.165 0.526	0.126 0.629
Leading					-0.048 0.856	0.105 0.689	-0.092 0.726	0.274 0.288
Following						0.736 0.001[b]	-0.314 0.219	0.066 0.802
Approaches							-0.401 0.110	-0.029 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] $p < 0.10$.

the most are ones that withdrew from others the least. Llamas that approached other llamas more often received more threats but also followed other llamas more often. Based on these results, one could infer that llamas might not receive as many threats if they approached other llamas less often. From Table 4, it is obvious such ranking is not helpful for all behaviors. For example, alertness and following were not correlated with other behaviors recorded. Such variables may be independent of the dominance hierarchy.

Llamas were ranked according to both indices of dominance hierarchy within their respective groups (Table 5). Strong agreement between the two indices of social dominance is evident. All animals were ranked similarly, with the exception of llama #19, which is ranked second according to the dominance value and fourth according to the social-tension index. Dominant and aggressive individuals have large positive social-tension indices, whereas submissive individuals have large negative indices. The mean social-tension index within each group is zero, but the magnitude of variation, or range, differed 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 how close they tended to stay to the sheep (mean = 48.2 m ± 3., range = 46.8, SD = 15.54) (Table 6, Fig. 1).

The proportion of time allocated to various activities

Table 5

Dominance hierarchies determined within groups according to two indices

Group	Llama #	Dominance value[a]	Llama #	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).

Table 6

Mean interspecific distances and synchronicity between individual llamas and sheep during phase I

Llama #	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).

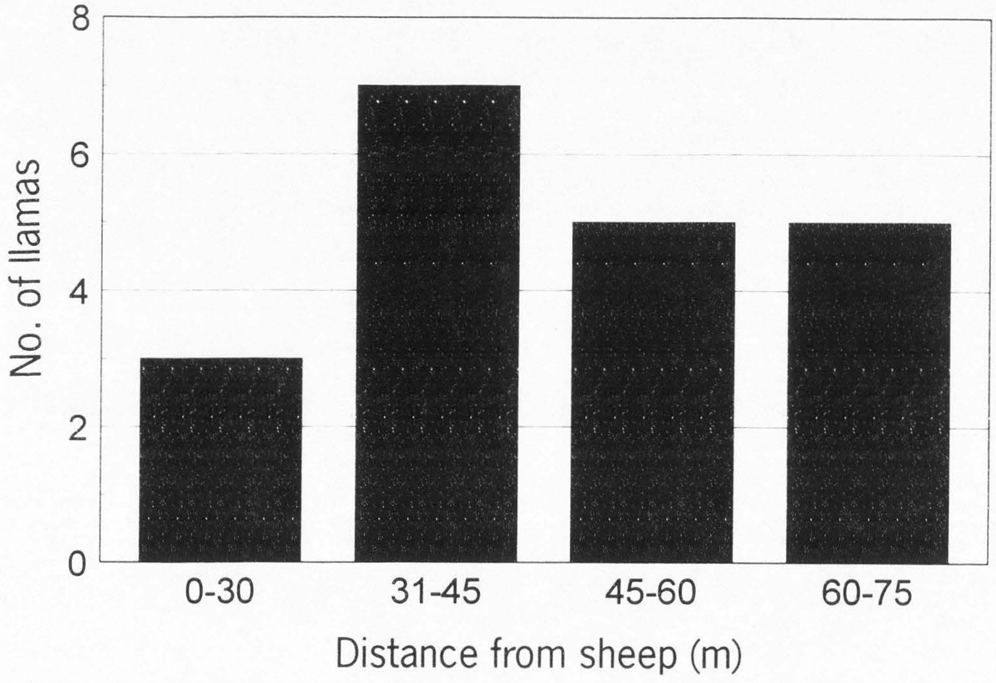

Fig. 1 Frequency distribution of llamas according to mean distances from sheep (mean no. of observations per llama = 435.35 ± 10.55).

varied among llamas (Fig. 2). Cramér coefficients (Table 6) provide a measure of synchronicity between the activities of each llama and flock 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

Individual llamas varied in the degree of aggressiveness displayed toward the dog. Some animals chased the dog, while others ran from it. Some stayed with the sheep, others did not. Almost all llamas were curious about the dog, whether they chased it or not, with the exception of llama #16, which stayed away and watched, but only got up from its resting position when the sheep ran 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 flock after chasing the dog, while bottom-ranked individuals ignored the sheep and ran from the dog instead of chasing it (Table 7).

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

There was a positive correlation between rankings of weight and aggressiveness ($r = 0.475$, $p = 0.039$) suggesting that larger, heavier llamas are more aggressive. Although age and weight were correlated, age and aggressiveness rank were not ($r = 0.337$, $p = 0.158$). Although llama coloration and aggressiveness rank were not independent ($\chi^2 = 6.003$, $df = 2$, $p = 0.049$), interpretation is speculative because color and weight were confounded. Among

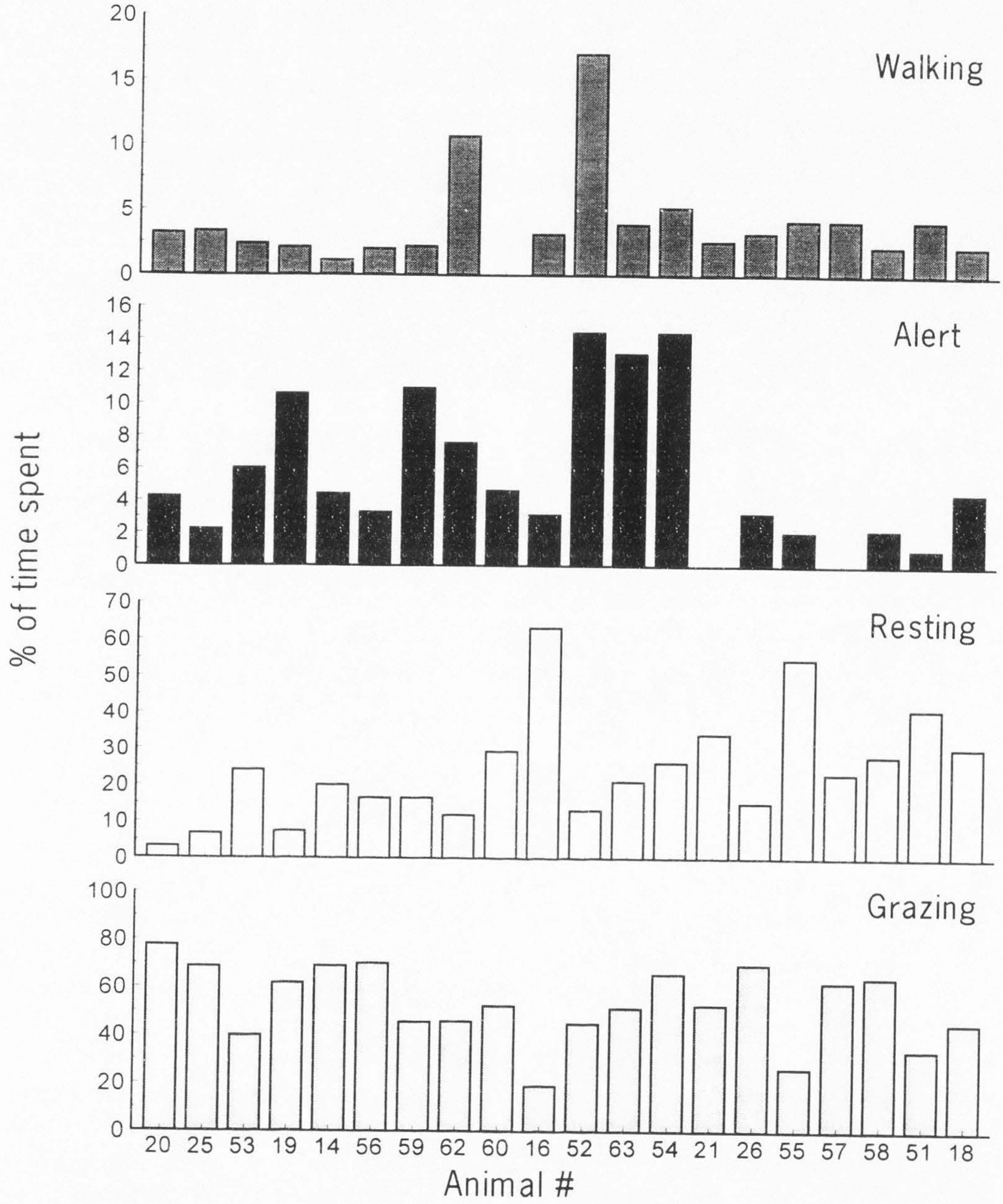

Fig. 2. Relative distribution of llama activity based on a mean of 435.3 scans per animal.

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 # 16 was not afraid, curious, or aggressive and the record for llama #57 lost due to video malfunction.

behaviors listed in Table 1, only leading and alertness were correlated with aggressiveness toward the dog (Table 8). Although there was a dominance hierarchy within each group of llamas, it was not reflected in the degree of aggressiveness llamas displayed toward the dog. Neither dominance values nor social-tension indices were correlated with aggressiveness rank ($r = 0.385$, $p = 0.141$ and $r = 0.265$, $p = 0.321$, respectively). Aggressiveness among llamas was correlated with age ($r = 0.544$, $p = 0.024$) and weight ($r = 0.441$, $p = 0.076$) but was not correlated with aggressiveness they displayed toward the dog ($r = 0.233$, $p = 0.385$). There was a positive correlation between the proportion of time llamas were alert in phase II and the degree of aggressiveness they displayed toward the dog (Table 8). This is consistent with results obtained in phase I. Llamas that were more alert were also more aggressive toward the dog. Mean interspecific distances between llamas and sheep were not correlated with the degree of aggressiveness individual llamas displayed toward the dog (r = 0.385, p = 0.141)(Table 8). Similarly, synchronicity of llama and sheep activity was not correlated with the aggressiveness llamas displayed toward the dog (r = -0.258, p = 0.286)(Table 8).

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)
<u>Physical attributes</u>:		
Age	0.337	0.158
Weight	0.475	0.039[a]
Color[c]	- -	0.049[a]
<u>Behavioral patterns among llamas (phase I)</u>:		
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[b]
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
<u>Llama-sheep relationships (phase II)</u>:		
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] $p < 0.10$
[c] $\chi^2 = 6.003$, df = 2.

CHAPTER 4

DISCUSSION

According to the National Agricultural Statistics Service (1995), predators accounted for 38.9% of the total sheep and lamb losses in United States in 1994. Among predatory losses, coyotes were the major cause, accounting for 66.2% (243,800 kills), with an estimated monetary loss of $11.5 million. Domestic dogs were second in importance, being responsible for 11% of predatory losses (40,325 kills), with an estimated monetary value of $2.2 million. Foxes accounted for 3.4% of predatory losses (12,350 kills), and an estimated monetary value of $507,250 (NASS 1995). In my study, a border collie trained to work with sheep was used as a surrogate for canid predators. Differences in the way a trained herding dog approached and interacted with the flock, compared to a wild or captive canid, are potential sources of bias. However, the use of a trained dog, which approached each group in a similar manner and with the same intensity, standardized this source of bias with a more consistent presentation of stimuli to each individual llama. Therefore, direct comparisons are reasonable.

This study identified physical and behavioral traits of llamas, some of which were correlated with aggressiveness llamas displayed toward the approaching border collie. There was considerable variation in the amount of aggression llamas displayed toward the dog. Some individuals actively protected the flock by unhesitatingly chasing the dog; others were "passive guards," simply standing between the sheep and the dog. This study 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, llamas were kept with a flock of five sheep. When placed with a sheep producer, a llama might be kept with a flock as large as 500 animals or more. In such situations, it might 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 and keeping it away from the flock.

One factor to consider is the background of study animals. Previous experiences could affect the responses observed in individual llamas. Llamas in this study were purchased from llama producers, and were raised in pastures with other llamas. None had extensive experience with sheep or dogs prior to this study and were assumed to be "random" acquisitions.

Traits correlated with llama aggressiveness toward dogs were alertness, leadership behavior, weight, and coloration. Remarkably, all these traits are easily recognized and sheep producers interested in buying a livestock-guarding llama could easily identify them among potential guardians. These are also some of the characteristics suggested by producers using guard llamas interviewed by Powell (1993).

The ability to detect approaching predators may be a key factor for a guard llama to successfully protect a flock of sheep. Detection of a predator is partially influenced by topography and vegetation cover. Alertness, however, is an important component of good guardian behavior. In a study with guard dogs, McGrew and Blakesley (1982) found the behavior of sheep increased the dogs' effectiveness by detecting and signaling approaching coyotes. Their dogs rarely detected the coyote before the sheep did. As opposed to dogs, most llamas in this study started approaching the dog before the sheep noticed it. Alert llamas may detect an approaching predator before it is too close to the flock, or before the sheep scatter. The tall stature of llamas, compared to dogs, would be an important asset in this regard.

Leadership behavior among llamas was correlated with the aggressiveness they displayed toward the approaching dog. I 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 an individual exhibiting leadership behavior might be more effective than others in providing protection to sheep against predators.

Larger and 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 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; in this study, color and weight of llamas appear to represent the same information. 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. This prevented a distinction between the importance of weight and color in predicting aggressiveness toward the dog. Future studies could test whether there is a difference in aggressiveness among light, mixed, or dark-colored llamas. Llamas possess two biochemical types of melanin (Sponenberg and Ito 1989) and through selective breeding it is possible to achieve a spectrum of colors for this species. Another factor deserving further investigation is a predator's ability to detect the presence of a llama in a flock. Dark llamas may be more easily detected than light-colored llamas. If predators with previous experience with guard llamas avoid flocks guarded by llamas, being conspicuous may be important.

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 be a result of: 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 a stronger hierarchy than groups 2 and 4. According to Beilharz and Zeeb (1982) and Beilharz and Cox (1967, p. 121), 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. In addition, "the animal with the highest dominance value submits in its actions to the fewest groupmates" (p.121). This animal is likely to suffer least from competition within its group.

Many studies of dominance rank have failed to discriminate between threats and withdrawals. Table 3 suggests there may be a relationship between the individuals that "threaten more than they are threatened" and the ones that are "withdrawn from" most frequently. However, because withdrawals occurred less frequently (mean = 0.7 withdrawals/group/hour) than threats (mean = 2.1 threats/group/hour), the hierarchy in these groups may not be as well formed or as rigid. According to McGlone (1986, p. 1132), the agonistic behavior shown after unfamiliar animals are grouped follows "the continuum from threat to aggression and submission" until a period of social stability is reached. During this period, only an occasional threat is necessary for an animal to maintain its dominance. If a great number of agonistic behaviors are seen, the group may have an unstable dominance order. Beilharz and Zeeb (1982) suggested that a dominant animal may have been aggressive in the past to obtain its dominant status, but it may not need to continue being aggressive, since stable relationships eliminate the need for it. This agrees with Rowell (1974), who suggested subordinate animals maintain the status by simply avoiding a dominant animal. Because threats occurred so often in this study, one might conclude that individuals were still working toward a more stable hierarchy. However, social dominance 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. This does not necessarily mean 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, it is common for territorial male guanacos to position themselves on hilltops or other elevated areas to detect invading animals and predators (Franklin 1983). Coppinger et al. (1983) suggested that attentiveness of guard dogs is a good indicator for predicting reduction in sheep losses to predators. According to them, attentiveness implies a social bond and constant contact between dog and sheep. An effective guard llama may not necessarily be one that stays in close proximity to sheep at all times, but one that maintains constant visual contact with the flock.

Sometimes a dedicated producer might successfully use a poor management practice. Likewise, a less dedicated producer incorrectly using a good management technique may find it ineffective. In recent years, use of livestock-guarding dogs has suffered some discredit due to lack of proper management. Some producers, primarily in open range operations, have developed guard dogs with nontraditional guarding breeds, resulting in dogs that are not attentive to the sheep or that wander off the property and chase and/or kill sheep and wildlife (Herb Mays, Animal Damage Control Specialist, Utah; pers. commun.). Refining the appropriate use of llamas as guard animals should be addressed before improper management procedures make this potentially good technique seem ineffective.

This study was conducted under an experimental condition 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. An appropriate next step might be to use the surrogate predator (i.e., border collie) to test individual llamas in various field situations. Ideally, the same llamas used in this study could be placed with sheep producers. After a period of acclimatization with larger areas and flocks, each llama could be retested with a dog to validate results of the current study.

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

This research identified traits associated with llama guarding behavior. The mechanism underlying aggressiveness llamas display is probably not entirely related to single physical or behavioral traits. Additional research is needed to dissociate weight and color and their respective roles in predicting the level of aggressiveness llamas exhibit toward canid predators. Future research could also determine if there is a difference in the level of aggression displayed by dark, mixed, and light-colored llamas.

Traits that appear correlated with llama aggressiveness are easily identifiable and sheep producers interested in acquiring a llama should consider them when selecting potential livestock guardians. Although selecting guarding llamas based on these traits may improve the likelihood of getting "better" guardians, sheep producers should keep in mind that no predator 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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