1977

Domestic sheep mortality during and after tests of several predator control methods

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DOMESTIC SHEEP MORTALITY DURING AND AFTER TESTS OF

SEVERAL PREDATOR CONTROL METHODS

By

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B.S., University of Utah, 1974

Presented in partial fulfillment of the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1977

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Date

Brawley, Kimber C., M.S., August 1977 Wildlife Biology

Domestic sheep mortality during and after tests of several predator control methods (69 pp.)

Director: Bart W. O'Gara

This was the third study conducted on the Cook Ranch in western Montana to document predator-caused livestock losses and the effectiveness of conventional and experimental predator control tests conducted by the Denver Wildlife Research Center. The first and second studies encompassed an entire year, the third 6½ months. The periods 15 March to 1 October for each study are referred to as: 1974, Part I (Henne 1975); 1975, Part II (Munoz 1976); and 1976, Part III (this study). Deaths of lambs (*Ovis aries*) not involving predation were comparable during Parts I and II but increased during III. Deaths of ewes not involving predation increased steadily from Part I to III. Ravens (*Corvus corax*), golden eagles (*Aquila chrysaetos*), and foxes (*Vulpes vulpes*) were not considered significant predators of sheep during the three studies. Dogs (*Canis familiaris*) from neighboring ranches killed one toxic-collared lamb and two of Cook's sheep and wounded at least six ewes during Part III. Coyotes (*Canis latrans*) killed 363 sheep (17.8% of the exposed herd) during Part I; 444 sheep (13.0% of an expanded herd) during II; and 227 sheep (8.7% of the exposed herd) during III. During Part III, coyotes killed 9 of 12 observed sick sheep. A major secondary effect of coyote predation was the deterioration of the health of the ewe herd, since replacement ewes were generally older, disease-prone animals. The health of sheep killed by coyotes declined steadily from Part I to III. Depredation controls reduced losses to coyotes during Part III. The direct effects of the various control methods tested and the possible influences of sheep management, availability of alternate prey, coyote population movements, and canid social interactions on the effectiveness of controls and fluctuations in kill levels were discussed. The various methods tested were ranked empirically according to their selectivity for sheep-killing coyotes and effectiveness in reducing depredations on the Cook Ranch. Controls appeared to be most effective when natural coyote population densities were at their lowest levels and replacement by immigrating coyotes was least likely. This mobility of coyotes makes damage control in an area like the Cook Ranch extremely difficult without widespread control efforts. The selection of control methods requires evaluation of the desirability of reducing overall coyote population levels and the effects of such reduction on other species.

ACKNOWLEDGMENTS

This project was funded under federal contract 14-16-008-1135 between the Montana Cooperative Wildlife Research Unit and the United States Fish and Wildlife Service (USFWS), Denver Wildlife Research Center (DWRC). I extend particular thanks to Don Balser for his interest and advice during all three studies.

I acknowledge my committee members, Drs. Bart W. O'Gara, Lee Metzgar, and Les Pengelly, for their interest and assistance in this research. Special thanks are due to Dr. O'Gara for his invaluable guidance and support throughout this project.

Bill and Greta Cook and Larry and Linda Pauly cooperated throughout the studies. I am grateful for their information about sheep production and for their hospitality.

The supervision of Guy Connolly, Roger Nass, and Sam Linhart of the USFWS during various aspects of the project is greatly appreciated. The following USFWS employees were responsible for most of the depredation control work: Rick Severson, Gary Dasch, Jerry Lewis, Roy McBride, Rick Griffith, Steve Montgomery, Tim Carrigan, and Dick Munoz.

Much of this work would not have been possible without my field assistants, Dallas Johannsen, Barbara Slott, and Carey Smith, and work-study students of the Wildlife Research Unit, Sewall Young and Jim Solomon.

Most of all, I thank my parents, Herbert and Kyoko Brawley of Takoma Park, Maryland, who long ago gave me the freedom to choose my own path -- and the self-discipline to choose wisely.

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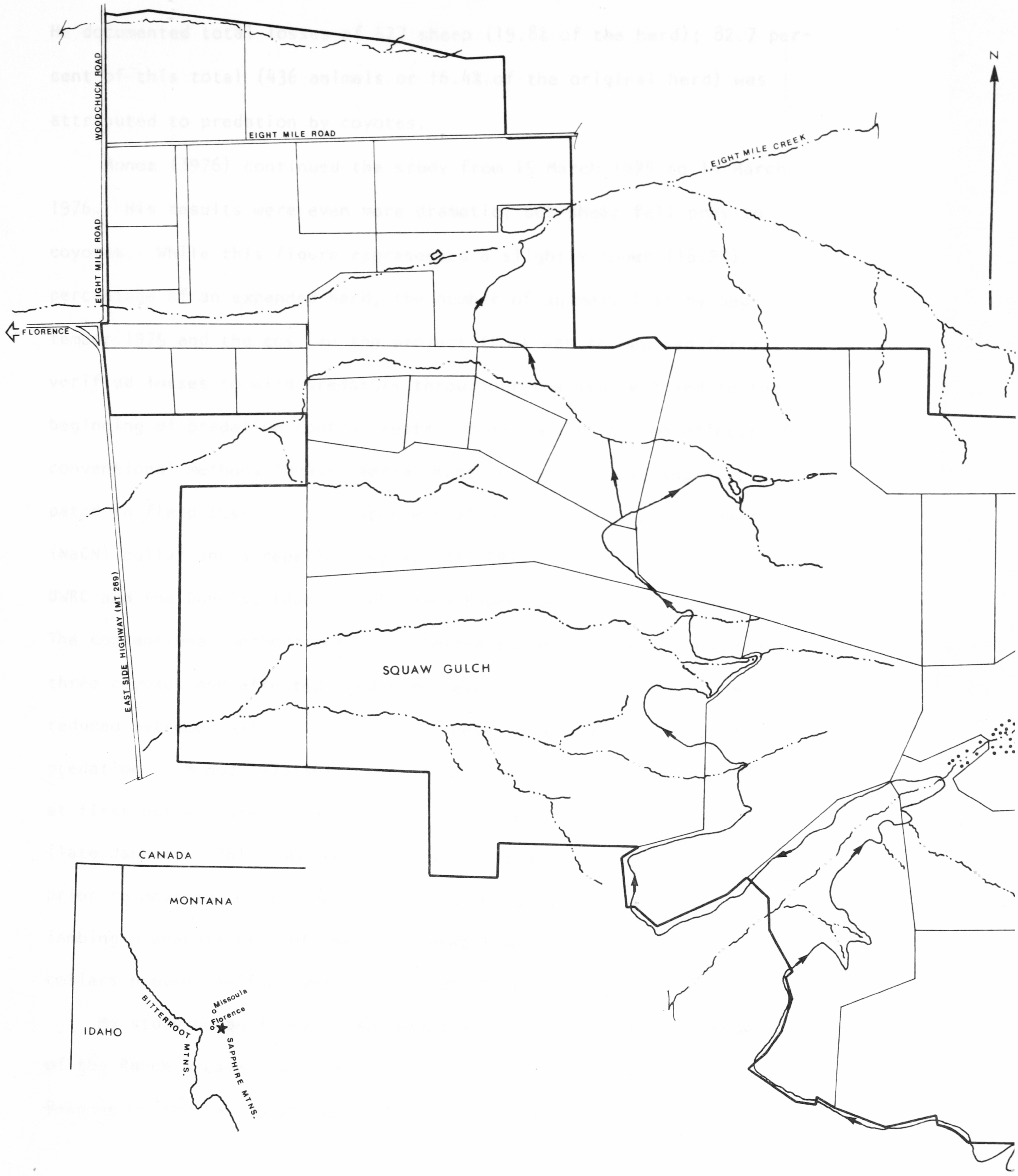
CHAPTER I

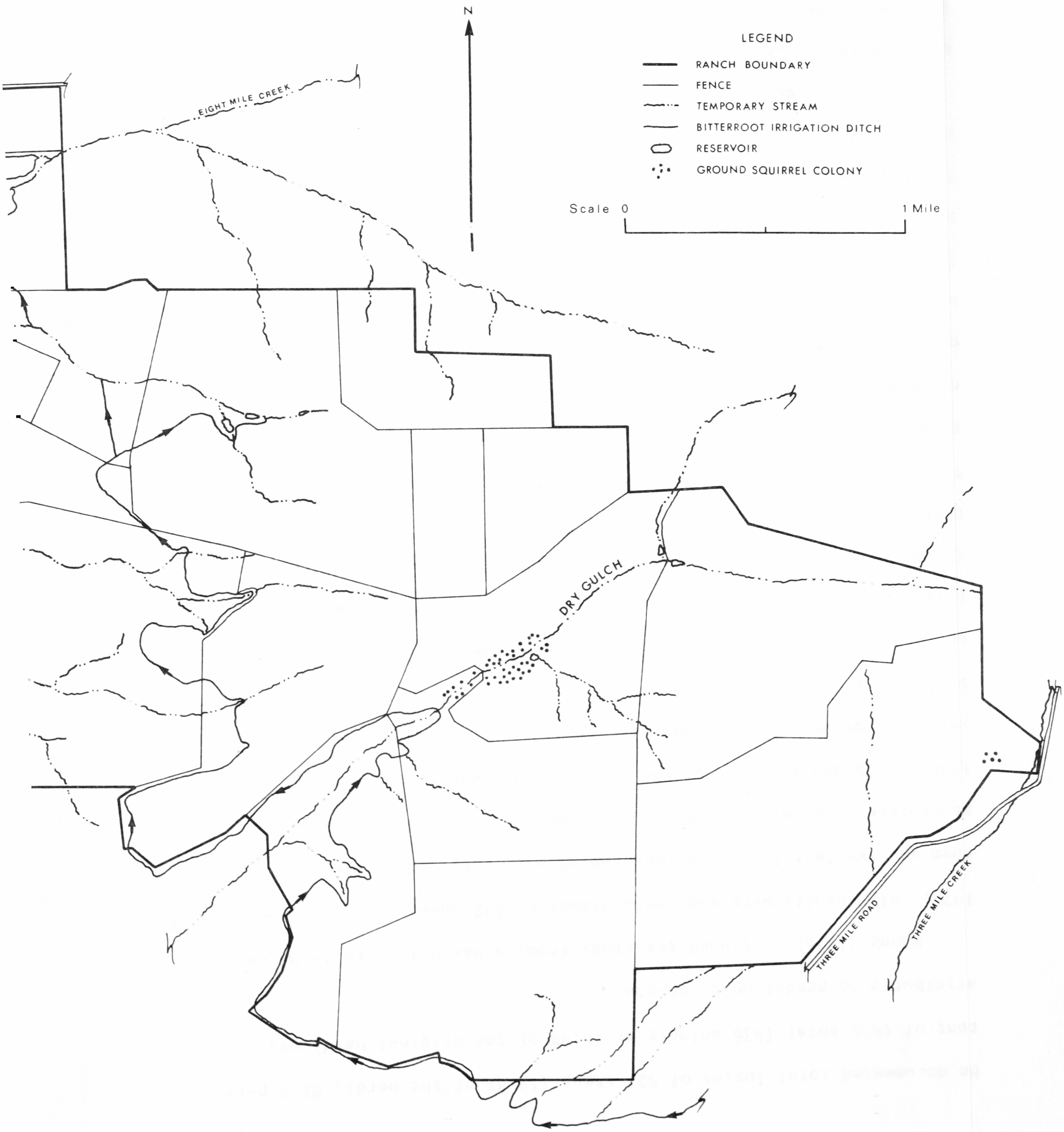
INTRODUCTION

The Cain Report (Cain et al. 1972) and the subsequent decisions of former President Nixon and the Environmental Protection Agency fell on a sheepmen's world ill-prepared to accept any curtailment of large-scale predator control. Little "hard" data existed at that time to substantiate the ensuing claims of extensive livestock losses to wild predators; little hard data existed to verify the effectiveness of widespread predator control, particularly the use of toxicants, in reducing those losses. The need therefore arose for research to: 1) document predator-caused livestock losses; 2) test the effectiveness of conventional depredation control methods; and 3) develop more selective (and hence, more effective) control methods. One such set of studies began on the Cook Ranch, located in the Bitterroot Valley of western Montana (Fig. 1), under the direction of Dr. O'Gara. The initial aim of the research was to document all domestic sheep mortality and verify losses to predators but evolved to encompass the two above areas of control methods.

Henne (1975) conducted the first study from 15 March 1974 to 14 March 1975. He was primarily concerned with sheep mortality in a shed lambing, unherded-fenced grazing management operation in the absence of all predator controls from docking until marketing of lambs. Limited private control consisting of trapping and hunting was allowed after marketing but had little or no influence on predation levels.

Fig. 1. Map of the Cook Ranch


N
WOODCHUCK ROAD
EIGHT MILE ROAD
EIGHT MILE CREEK
FLORENCE
EAST SIDE HIGHWAY (MT 269)
SQUAW GULCH
CANADA
MONTANA
IDAHO
BITTERROOT MTNS.
SAPPHIRE MTNS.
Missoula
Florence


N
LEGEND
RANCH BOUNDARY
FENCE
TEMPORARY STREAM
BITTERROOT IRRIGATION DITCH
RESERVOIR
GROUND SQUIRREL COLONY
Scale 0
1 Mile
EIGHT MILE CREEK
DRY GULCH
THREE MILE ROAD
THREE MILE CREEK

He documented total losses of 527 sheep (19.8% of the herd); 82.7 percent of this total (436 animals or 16.4% of the original herd) was attributed to predation by coyotes.

Munoz (1976) continued the study from 15 March 1975 to 14 March 1976. His results were even more dramatic; 602 sheep fell prey to coyotes. While this figure represented a slightly lower (16.2%) percentage of an expanded herd, the number of animals lost by September 1975 and the cost to the project (Cook was reimbursed for all verified losses to wild predators throughout the studies) led to the beginning of predation control tests. Munoz monitored the effects of conventional methods (M-44s, aerial hunting, and snares) and participated in field tests of two experimental methods, the sodium cyanide (NaCN) collar and a repellent spray (ARS-CR2), conducted by the DWRC and the Dubois, Idaho, USDA Sheep Experiment Station, respectively. The conventional methods met with limited success. Snares caught only three coyotes and affected predation levels little if at all. "M-44s reduced extreme daily kills . . . but never completely stopped predation." (Munoz 1976:36). Aerial hunting had much the same effect at first but appeared to have a lasting effect the last time used (late January 1976). However, the last hunt occurred immediately prior to movement of the herd to the Ranch building complex for lambing preparations. Of the experimental methods, sodium cyanide collars proved ineffective; the test of ARS-CR2 was inconclusive.

My study began 15 March and ended 30 September 1976 when sale of the Ranch became final and Cook went out of the sheep business. Because of the ban on predacides, he felt it was impossible to profitably raise sheep in the Bitterroot Valley. He and government agents had used every legal means of control with limited success. My objectives were to:

1) document sheep mortality during tests of conventional and experimental depredation control methods by the DWRC and compare sheep mortality with the data of Henne (1975) and Munoz (1976) for the same period (15 March through 30 September);

2) assist the DWRC in tests of control methods; and

3) determine the effects of controls on coyote movements and daily use patterns.

All numbers used in the sheep mortality tables were taken from the period 15 March to 30 September of the respective studies.

CHAPTER II

METHODS AND MATERIALS

Study Area

The Cook Ranch was situated in the foothills of the Sapphire Mountains 14 miles south of Missoula, Montana (Fig. 1), with vegetation and topography typical of the Palouse prairie type. Detailed description of the study area were contained in Henne (1975:4) and Munoz (1976:6).

Documentation of Sheep Mortality

With few modifications, the procedures used by Henne (1975:10) and Munoz (1976) were followed in this study.

Most searches were made from horseback, the rest from trucks. Searches on horseback were more time consuming than those from trucks but offered better visibility for detecting kills and coyote signs, better auditory and visual contact with scavanger birds, better olfactory contact with carcasses, and minimal damage to pastures. Early each morning, the pastures were quickly surveyed for the presence of ravens and golden eagles, good indicators of kill sites. Bedding grounds, frequently located on vantage points were the sites of most kills. Search patterns were concentrated around bedding grounds and adjacent draws in irregular terrain. Level pastures were traversed in a series of parallel lines.

Carcasses were examined and necropsied in the manner described by Henne (1975:13) and Munoz (1976:8), and data were recorded on a standard card (Fig. 2). Kill sites and kill and feeding patterns were noted; neck and throat areas, the primary coyote attack zone, were skinned and examined for wounds, as were any other suspicious-looking areas. Canid tracks in and around pastures where kills occurred were used to determine if sheep with unusual kill patterns were killed by inexperienced coyotes or experienced dogs. Subcutaneous hemmorhaging was taken as evidence that an attack had occurred prior to the sheep's death. Internal organs, if any remained, were examined for abnormalities. Carcasses (except those used in M-44 tests) were subsequently hauled to the Ranch dump.

Wounded sheep which could be caught were sacrificed by investigators; experience gained by Henne (1975) indicated that sheep that were wounded by predators soon died of infections and/or severe maggot infestations.

Data on sheep mortality were compared using the Chi-squared test of fit on the numbers in the Appendices.

Predation Controls

Four conventional predator control methods (snares, leghold traps, M-44s, and aerial hunting) and two experimental methods (the toxic collar and trained guard dogs) were monitored. Target lambs killed during toxic collar tests were not included in the mortality tables.

Snares [1/16 in. (1.59 mm) steel cable made at the Pocatello Supply Depot] and Victor No. 3 steel leghold traps were concealed on coyote travel paths. Lewis (local Animal Damage Control Agent) and

Fig. 2. Sheep carcass datum card.

SHEEP CARCASS DATA

Investigator(s)______________________________ Date__________

Time of Arrival__________ Location______________________________

Topography and vegetation: Level________ Sloping________ Gully________
Pasture (type)____________ Wooded____________ Open________

Weather Conditions______________________________

Animal Sign______________________________

No. of Photos______________ Animal No.__________ Sex__________

Age__________ Singlet__________ Twin__________ Triplet________

Cause of Death: Disease____________ Type______________________
Accident______ Cause______________________________
Predation_____ Predator__________________ Approx. Time of Kill______
Undetermined________ Other______________________________

Previous Anomalies

POST MORTEM EXAMINATION

When Performed______________________ Est. Time of Death__________

Mutilation: Remarks:______________________________
Wound Location____________ ______________________________
Ext. Bleeding____________ ______________________________
Subcut. Hemm____________ ______________________________

Tooth marks: 1 Surface________________ 2 Surfaces________________

Condition at Death:
Head______________________________
Throat______________________________
Thymus (if lamb): Normal________ Part Devel__________ Absent________
Undetermined____________

Heart______________________________
Lungs______________________________
Spleen______________________________
Liver______________________________
Kidneys______________________________
Intestines______________________________
Stomach system: Food Present______________ Absent________ Undet________
No. Fetuses (if Ewe): 0 1 2 3 Undet.

Date ____________ Examiner________________

Severson (biological technician with the DWRC) attached snares to fence bottoms in shallow scrapes dug by coyotes. Lewis set traps in or near scrapes with an attractant scent nearby. Study personnel checked traps and snares daily; traps were reset by Lewis if sprung.

M-44s, devices consisting of a sodium cyanide (NaCN)-filled capsule with a spring-loaded ejecting rod set in a metal tube driven into the ground, were set by Lewis along selected coyote travel routes and near sheep carcasses. A coyote tugging on the food-scented capsule holder would trip the spring and receive an oral dose of NaCN.

Aerial hunting involved early morning post-dawn flights in a three-man helicopter with the passenger door removed; the gunner used a 12-gauge shotgun loaded with BB or No. 4 buckshot to kill coyotes. Lewis was the gunner on 28 May and 1 and 11 June; McBride (Section of Predator Damage, DWRC) did the shooting on 30 May.

The toxic collar, described in detail by Connolly et al. (1976a), consisted of two or four plastic packets filled with Diphacinone (an anticoagulant) placed ventral to the ears of specially-marked lambs. Nylon cord was used to fasten the packets together during early tests, but was replaced with Velcro when the cord caused irritation and infections in rapidly-growing lambs. Collared lambs roamed free in selected pastures. These lambs were released in past and anticipated trouble areas from 23 March to 30 April while the main herd was at the Ranch complex for lambing. From 1 May to 30 June, collared lambs were placed in pastures separate from the main herds to intercept problem coyotes. The final collar test, 8 to 27

September, involved driving the sheep from the pasture each evening and replacing them with collared lambs on the bedding grounds.

The guard dogs, a pair of Hungarian Komondorok, were trained at the DWRC by handler Carrigan (Linhart et al. in prep.) under the supervision of Linhart and Sterner. All M-44s and snares, and all except one trap (an oversight), were removed 10 days prior to beginning the dog test. On 18 July, the dogs were placed in the pasture with Herd A and remained there with the sheep for 20 days. The handler assisted in morning searches of that pasture and returned each evening to feed the dogs. After the herd was moved to another pasture, radio collars were put on the dogs to trace their nightly movements in the test pasture.

Tissue samples were taken from 10 of the recovered coyotes; two others were badly decomposed. These samples were frozen and sent to the DWRC for Diphacinone analyses. A canine tooth from each coyote was sectioned and aged by Montana Microscopic according to the procedure outlined by Linhart and Knowlton (1967).

Coyote Movements and Daily Use Patterns

Daily records were kept of coyote signs. Whenever possible, study personnel determined direction and approximate time of travel and access points to pastures containing sheep. Coyote sightings and peculiar kill patterns were also noted. Carrigan (Linhart et al. in prep.) conducted a scent-post survey as part of the Komondorok test.

A crude minimum index of relative numbers of coyotes using the

Ranch (i.e., killing and/or feeding on sheep) per day was derived from daily kill figures and feeding patterns. On days with more than one kill per herd, the number of carcasses with feeding in the light, moderate, and extensive categories were used to estimate the number of coyotes attacking that herd (one carcass to one coyote). Light feeding was considered approximately the amount that one coyote could eat at one feeding. Coyotes that did not kill or feed on sheep would not be counted in this scheme. Thus, the estimated number of coyotes attacking a herd on a given day would frequently be lower than the number of sheep killed and/or wounded in that herd.

CHAPTER III

RESULTS

Since the sale of the Cook Ranch precluded continuing this study for a full year as in the two previous studies, comparison could only be made with Henne's and Munoz's data for the period 15 March through 30 September. Hereafter, this period for 1974 will be referred to as Part I; for 1975, Part II; and for 1976, Part III. Unless otherwise noted, data for Parts I and II were derived from the original (raw) data of Henne and Munoz, respectively.

Ranch Management Changes

Total numbers of docked lambs and adult ewes at lambing time in each study were: Part I, 2,084; Part II, 3,438; and Part III, 2,755. Management of sheep herds on the Ranch during Part III was similar to that in Parts I and II with a few exceptions. In Part I, Henne studied two herds; one contained twin lambs and the other contained single lambs. The herds in Parts II and III were mixed twins and singles, divided into two herds by age of the lambs.

During Parts I and II, both herds were moved from pasture to pasture away from the Ranch building complex (headquarters) starting in late March and early April, respectively. Beginning in late July and August, these movements were reversed, returning the sheep to headquarters by weaning time (early September). In Part III, the herds stayed near headquarters much later than during Parts I and II and remained away from headquarters until weaning time. The older flock (Herd A) was moved outwards from headquarters in early May. During late April, the younger flock (Herd B) was hauled by truck to the pasture farthest from headquarters. Herd B was moved progressively closer until the two herds met and intermingled late in August. A week later, the combined flock was herded to headquarters; the lambs and ewes were separated and released in nearby pastures. The ewes were sold and shipped in mid-September; lambs were shipped on 30 September, the day before the sale of the Cook Ranch became final.

Documentation of Sheep Mortality

Total Mortality

For adult ewes, total mortality included all deaths (not involving predators, predator-caused, and undetermined) from 15 March to 30 September and was synonymous with field mortality. For lambs, it only included deaths of docked lambs (i.e., lambs which survived long enough to be docked and tagged, generally 6 to 24 hours after birth) not involving predators (pre-exposure and field), involving predators, and from undetermined causes. Total mortalities (Table 1) differed significantly from Parts I to III ($X^2 = 143.5$, $p < .005$, 8 df).

Deaths of lambs not involving predation as a percentage of lambs docked were comparable during Parts I and II, but showed a marked increase during Part III. Natural deaths of ewes increased steadily from Parts I to III both in numbers and percentages of the total ewe herd. Numbers of predator-killed lambs increased from Part I to II but decreased during III (the percentage drop from Part I to Part II reflects an increased herd size). Numbers of sheep for which cause

Table 1. Total mortalities, in percentages, during Parts I, II, and III.[a]

		Original no. of animals	Natural deaths[b]	Predator kills	Undetermined	Unaccounted for	Total mortality
Lambs[c]	I	1,253	5.7	26.7	0.4	0.6	33.4
	II	2,006	5.5	19.9	0.3	1.1	26.8
	III	1,656	10.9	13.3	0.4	1.8	26.5[d]
Ewes	I	831	2.5	4.3	0	0	6.9[d]
	II	1,432	3.6	3.7	0	0	7.3
	III	1,099	5.3	1.5	0.1	0	6.8[d]
Lambs + Ewes	I	2,084	4.5	17.8	0.2	0.3	22.8
	II	3,438	4.7	13.1	0.2	0.6	18.7[d]
	III	2,755	8.7	8.6	0.3	1.1	18.7

[a] Original data in Appendix I.
[b] Pre-exposure and field deaths not involving predators.
[c] Docked lambs only.
[d] Adjusted for rounding error.

of death could not be determined remained fairly constant throughout all three parts. Numbers (and percentages) of lambs unaccounted for at the end of each Part increased steadily from I to III.

Mortality Not Involving Predators

Abortions/stillbirths and weak calf syndrome were the most common causes of lamb deaths before exposure to predation (Table 2). After lambs were moved from headquarters to pastures where they were exposed to coyotes, most of the non-predation deaths were caused by pneumonia and weak calf syndrome (Table 3). To eliminate apparent differences caused by predation controls during Part III and differences in release times between all Parts, pre-exposure and natural field deaths of lambs are summarized in Table 4. Mortalities for adult ewes not involving predation, due primarily to mastitis, old-age complications, and pneumonia, increased from Part I to III (Table 5).

Predator-caused Mortality

As in Parts I and II, the coyote was the most significant predator during Part III (Table 6). Coyotes killed only 227 sheep during Part III and this was only 63.9 and 47.6 percent of the coyote kills during Parts I and II, respectively. Eagle kills were noted only in Part I. Raven kills were not considered to be significant since ravens only killed sheep weakened from other causes. Foxes were insignificant predators since lambs quickly grew out of the size class [less than 20 lb. (9.1 kg)] in which we noted fox predation. Domestic dogs killed two sheep during Part I but none in Part II. A pair of

Table 2. Causes of lamb deaths prior to exposure during Parts I, II, and III, in percentages of total lamb crop.[a]

Cause	I[b]	II[c]	III
Abortion/Stillbirth	2.8	1.4	3.6
Miscellaneous[d]	4.0	0.7	8.3
Weak calf syndrome	2.0	0.3	1.8
Totals	8.8	2.4	13.7
Total lamb crop	1,327	2,044	1,911

[a] Includes deaths prior to docking. Original data in Appendix II.
[b] From Henne (1975)
[c] From Munoz (1976)
[d] Includes birth defects, accidents, too weak to feed, scours, exposure, bacterial infections, and unspecified deaths.

Table 3. Field deaths of lambs from causes other than predation during Parts I, II, and III, in percentages of exposed lamb crop.[a]

Cause	I	II	III
Accident	0.1	0.2	0.3
Bacterial infection	0	0.9	0
Bloat	0	0.1	0
Enterotoxemia	0.3	0.2	0
Intestinal blockage	0.1	0.1	0
Maggot infestation	0.1	0.1	0.1
Maternal neglect and starvation	0	0.7	0.1
Paralysis	0	0.1	0
Pneumonia	0.8	1.2	0.5
Pneumonia and liver infection	0.2	0	0
Prolapsed rectum	0	0	0.2
Unspecified	0.4	0.5	0.5
Urinary calculli	0.1	0	0
Weak calf syndrome	0.2	1.2	0.2
Totals	2.4[b]	5.0[b]	1.9[b]
Total exposed lamb crop	1,210	1,995	1,503

[a] Original data in Appendix III.
[b] Adjusted for rounding errors.

Table 4. Mortality of all docked lambs from causes other than predation during Parts I, II, and III, in percentages of lambs docked.[a]

	I	II	III
No. docked	1,253	2,006	1,656
Pre-exposure deaths	3.4	0.5	9.2
Field deaths	2.3	5.0	1.7
Totals	5.7	5.5	10.9

[a] Original data in Appendix IV.

Table 5. Mortality for adult ewes from causes other than predation during Parts I, II, and III, in percentages of ewe herd.[a]

Cause	I	II	III
Accident	0.1	0.1	0.2
Blindness	0.1	0	0
Bloat	0.5	0.1	0.3
Enterotoxemia	0.2	0.1	0
Intestinal blockage	0.1	0.1	0
Lambing complications	0.1	0.1	0.3
Maggot infestation	0	0.3	0.1
Mastitis	0.1	0.4	1.2
Old age complications	0.7	1.3	2.4
Pneumonia	0.2	1.0	0.4
Pneumonia and liver infection	0	0	0.1
Unspecified	0.2	0.1	0.5
Total	2.5[b]	3.6[b]	5.3[b]
Original ewe herd	831	1,432	1,099

[a] Original data in Appendix V.
[b] Adjusted for rounding errors.

Table 6. Numbers of sheep killed by predators during Parts I, II, and III.

Part I. Exposed herd: 2,041 sheep (1,210 lambs and 831 ewes)

	Lambs	Ewes	Total	% All Predation	% Exposed Herd
Coyotes	330	33	363	97.8	17.8
Dogs	0	2	2	0.5	0.1
Foxes	3	0	3	0.8	0.1
Eagles	2	0	2	0.5	<0.1
Ravens	0	1	1	0.3	<0.1
Totals	335	36	371	100[a]	18.2

Part II. Exposed herd: 3,427 sheep (1,995 lambs and 1,432 ewes)

	Lambs	Ewes	Total	% All Predation	% Exposed Herd
Coyotes	394	50	444	98.2	13.0
Foxes	1	0	1	0.2	<0.1
Ravens	0	3	3	0.7	<0.1
Undet. pred.	4	0	4	0.9	0.1
Totals	399	53	452	100	13.2

Part III. Exposed herd: 2,602 sheep (1,503 lambs and 1,099 ewes)

	Lambs	Ewes	Total	% All Predation	% Exposed Herd
Coyotes	214	13	227	95.8	8.7
Dogs	1	2	3	1.3	0.1
Foxes	3	0	3	1.3	0.1
Undet. canid	1	1	2	0.8	<0.1
Ravens	1	0	1	0.4	<0.1
Undet. pred.	1	0	1	0.4	<0.1
Totals	221	16	237	100	9.1

[a] Adjusted for rounding error.

dogs from a neighboring ranch repeatedly harrassed sheep during Part III. At least six ewes received minor wounds from these dogs; a lamb and ewe were wounded severely and had to be destroyed. Three other dogs (1 single, 1 pair) were sighted but were not known to have harassed sheep. An additional pair visited the Ranch; one killed a collared target lamb and subsequently died of Diphacinone poisoning.

Health of sheep killed by coyotes. The results of necropsies performed on intact carcasses of sheep killed or wounded by coyotes in Parts I, II, and III are shown in Table 7. Animals with abnormalities present (such as a minor case of pneumonia or enteritis) could not be distinguished visually or behaviorally from healthy animals. Animals with severe disorders (such as severe infections or physical anomalies) were visibly handicapped. Henne (1975:26) randomly selected 15 lambs for comparison to predator kills: 73.3 percent were healthy, 20 percent had abnormalities present, and 6.7 percent exhibited severe disorders. Data for Part I showed similar patterns of health for lambs selected by predators. Since this sampling was not repeated during Parts II and III, comparisons could not be made between health of animals killed by coyotes and health of the total herd.

Selection for handicapped (sick or crippled) sheep during Parts I and II could not be evaluated without the personal field notes of the respective investigators. During Part III, handicapped sheep were killed when they were readily visible. Of twelve sheep which were visibly handicapped, nine were capable of keeping up with the herd or were immobile on bedding grounds without cover and were

Table 7. Health at time of death of sheep killed by coyotes during Parts I, II, and III, in percentages of sheep examined.[a]

	Part	Lambs	Ewes	Totals
Numbers examined	I	140	26	166
	II	207	30	237
	III	58	10	68
Healthy	I	75.0	69.2	74.1
	II	71.5	53.3	69.2
	III	55.2	30.0	51.5
Abnormalities present	I	19.3	23.1	19.9
	II	19.3	40.0	21.9
	III	31.0	60.0	35.3
Severe disorders present	I	5.7	7.7	6.0
	II	9.2	6.7	8.9
	III	13.8	10.0	13.2
Health undetermined[b]	I	190	7	197
	II	187	20	207
	III	156	3	159

[a] Original data in Appendix VI.

[b] Numbers of sheep for which health could not be determined.

killed by coyotes, usually before healthy sheep were taken. The remaining three handicapped sheep were immobile in heavy cover for several days and were not killed by coyotes.

Feeding on kills. Coyote feeding patterns (Table 8) were classified as follows:

1) wounded - animal still alive at time of discovery;

2) no consumption - carcass found intact;

3) very light feeding - little feeding, usually involving the fatty greater omentum (1 to 5% of a carcass);

4) light feeding - a small area consumed, such as the neck, a leg, the sternum, portions of the viscera, or the outer edge of the rib cage (5 to 25% of a carcass);

5) moderate feeding - all of the viscera, or the fore- or hind-quarters consumed (25 to 75% of a carcass); and

6) extensive feeding - most of the flesh consumed, little remaining other than fleece and bones.

The feeding patterns on lambs changed from Part I to III (X^2 = 34.6, $p < .005$, 10 df). Patterns during Part III closely followed those of Part II; feeding was generally lighter during II and III than during I.

Characteristics of coyote kills. The locations of bites used by coyotes to kill sheep (Table 9) were similar during all studies. Coyotes during Part III inflicted a slightly higher percentage of bites to the torso or legs than during I or II. Sheep which we knew were attacked by domestic dogs (because of sightings and tracks) during Part III, except for the target lamb attacked by the German

Table 8. Degree of feeding on carcasses by coyotes during Parts I, II, and III, in percentages of sheep examined.[a]

	Part	Lambs	Ewes	Totals
Numbers examined	I	317	33	350
	II	363	38	401
	III	206	12	218
Wounded	I	7.3	12.1	7.7
	II	12.1	10.5	12.0
	III	13.6	8.3	13.3
No comsumption	I	9.8	6.1	9.4
	II	17.1	7.9	16.2
	III	9.7	0	9.2
Very light	I	11.0	9.1	10.9
	II	8.5	5.3	8.2
	III	5.3	16.7	6.0
Light	I	24.0	33.3	24.9
	II	26.2	34.2	26.9
	III	35.9	16.7	34.9
Moderate	I	33.4	33.3	33.4
	II	26.4	36.8	27.4
	III	26.2	50.0	27.5
Extensive	I	14.5	6.1	13.7
	II	9.6	5.3	9.2
	III	9.2	8.3	9.2

[a] Original data in Appendix VII.

Table 9. Location of coyote-inflicted wounds during Parts I, II, and III, in percentages of numbers examined.[a]

	Part	Numbers examined	Neck-throat only	Other anterior to shoulders[b]	Torso or legs
Lambs	I	321	66.4	29.6	4.0
	II	391	70.1	26.1	3.8
	III	205	69.3	24.4	6.3
Ewes	I	33	87.9	6.1	6.1
	II	45	77.8	11.1	11.1
	III	13	92.3	7.7	0
% of total selected	I	354	68.4	27.4	4.2
	II	436	70.9	24.5	4.6
	III	228	70.6	23.4	6.0

[a] Original data in Appendix VIII.
[b] Involving bites to the face or head, or decapitation.

shorthaired pointer, received wounds in the neck-throat area and few wounds to the torso or legs, characteristics neater than is considered typical of dog attacks but less neat than is considered typical of coyote attacks. Two lambs received wounds similar to those inflicted by the two off-Ranch dogs and the guard dogs but no dogs were seen or tracked in the pastures where those kills occurred.

Predation on adult ewes during summer months (Fig. 3) began earliest (mid-June) during Part II, later during Part I (mid-July), and latest during Part III (mid-August). Coyotes killed 23 and 21 ewes from 14 June to 20 September during Parts I and II, respectively. Only two ewes were killed by coyotes in the same period during Part III.

Lamb-killing coyotes (Table 10) showed a decreasing tendency to chase lambs to low areas (gullies, washes, draws, or creeks) from Parts I to III. Ewe-killing coyotes chased ewes to low areas more frequently during Part II than during Part I and less frequently during Part III than during Parts I or II.

Coyote Use Patterns and Predation Controls

Coyote Use Patterns

My assistant and I identified the major coyote travel routes on the Cook Ranch from coyote signs (tracks and digs) and locations of sheep carcasses. A few coyotes attacked sheep in pastures north of Eight Mile Road (Fig. 1) but did not appear to use well-defined routes. Most coyotes entered the Ranch from the north and east via

Fig. 3. Numbers of ewes killed per day (averaged weekly), 14 June to 20 September, during Parts I, II, and III.

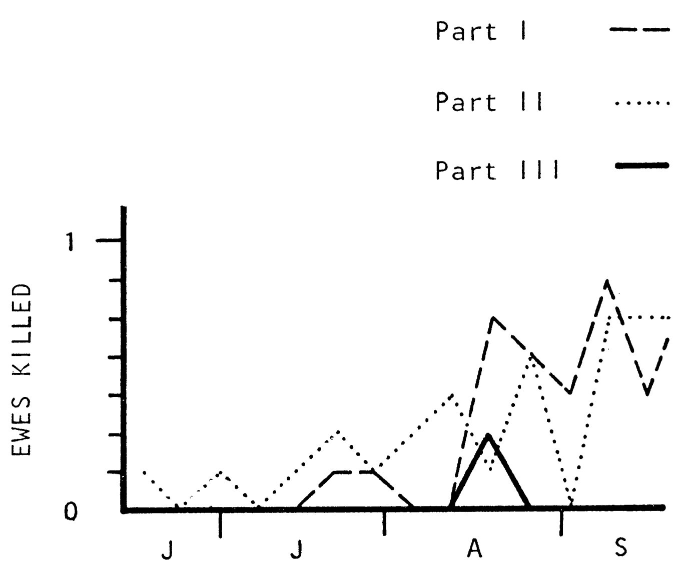

Part I
Part II
Part III
EWES KILLED
1
0
J
J
A
S

Table 10. Kill sites in pastures with low areas, in percentages of numbers examined.[a]

		Numbers examined	Killed in low area	Not killed in low area
Lambs	I	194	40.7	59.3
	II	295	27.8	72.2
	III	129	20.2	79.8
Ewes	I	24	33.3	66.7
	II	41	61.0	39.0
	III	12	25.0	75.0

[a] Original data in Appendix IX.

the Dry Gulch drainage system. The Eight Mile Creek drainage system appeared to be less travelled than the routes from the north and east. The north draw in Squaw Gulch pasture and Three Mile Creek served as minor travel routes from the west and east, respectively. Routes other than Dry Gulch usually bore tracks of one or fewer coyotes per day; Dry Gulch usually bore tracks of two to four coyotes per day. Our route identifications were verified by USFWS trappers and biologists.

The numbers of coyote kills per day during Parts I, II, and III are shown in Fig. 4. Major surges in kills per day were noted in all studies during early to mid-May, early June, and early September. Additional surges were noted during Part II in mid-June and mid-September. A general slump occurred during July and August of all Parts.

Estimated minimum numbers of coyotes using the Ranch (i.e., killing and/or eating sheep) per day are shown in Table 11. Coyote use changed significantly from Part I to Part III ($X^2 = 55.7$, $p < .005$, 8 df). More days passed without kills during Part III than during either I or II. On days with kills, more coyotes used the Ranch during Part II than I; use (as percentages of days with kills) decreased from Part II to III. The maximum number of coyotes killing sheep during most days appeared to be four; this number was exceeded only once in Part I, twice in II, and not at all in III.

Coyote Sightings and Times of Kills

During Part III, coyotes were sighted 12 times. Four of these

Fig. 4. Numbers of coyote kills per day (averaged weekly) during Parts I, II, and III.

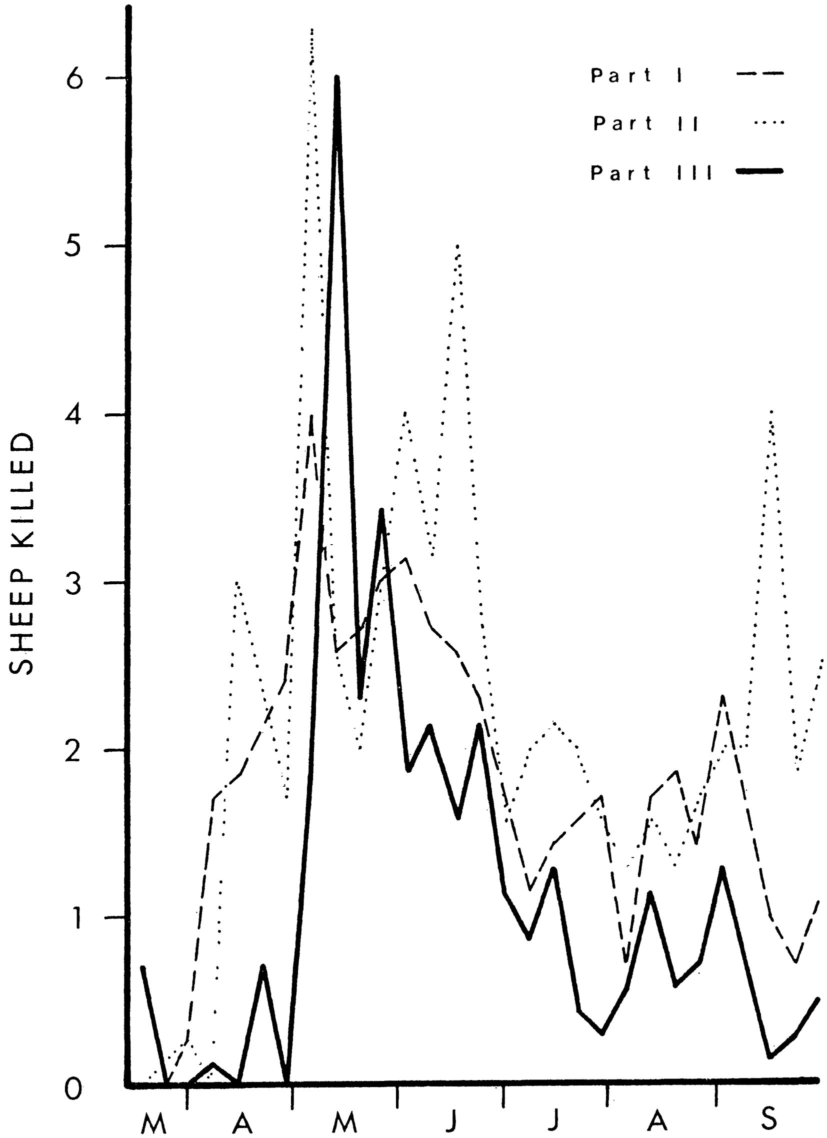

SHEEP KILLED
0
1
2
3
4
5
6
M
A
M
J
J
A
S
Part I
Part II
Part III

Table 11. Estimated minimum coyote use during Parts I, II, and III, in percentages of total days.[a]

Est. no. of coyotes per day	Percentage of total days I	II	III
0	20.5	21.0	44.0
1	46.5	35.0	37.0
2	22.5	23.0	13.0
3	7.5	14.5	3.0
>3	3.0	6.5	3.0
Total days	200	200	200
Total coyote-use days[b]	253	303	168

[a] Original data in Appendix X.
[b] Σ(Est. no. of coyotes per day X no. of days).

sightings involved coyotes feeding on carcasses; coyotes were not seen in the act of killing sheep. The latest sightings occurred at 1100 hours; all but three occurred between 0700 and 0900.

Kills usually occurred during the early morning hours before searches. Griffith (pers. comm.) reported a series of kills and sightings in Herd B around 0730 during mid-May.

Kill times and coyote sightings could not be compared to those of Parts I and II without the original field notes of the respective investigators.

Coyotes Taken During Predation Control Tests

Data on coyotes recovered during control activities in Part III are shown in Table 12. Two canids killed during Part III are not shown: a coyote, shot from a helicopter on 29 May in an area where the helicopter could not land; and a 60 lb. (27.3 kg) German short-haired pointer which killed a collared target lamb on the night of 9-10 April and died of Diphacinone poisoning on 17 April.

Carcasses of 12 coyotes killed during Part III were recovered: one each by leghold traps, snares, and Diphacinone; eight by aerial hunting; and one apparently by the guard dogs. One M-44 was pulled but no coyote was recovered. Thirteen toxic collars were punctured by coyotes; assuming 20 percent of those coyotes received sub-lethal doses (calculated from data in Connolly et al. 1976a), and excluding pups which may have been fed Dephacinone-smeared meat by adults, as many as 10 coyotes may have died from Diphacinone poisoning in addition to the one recovered.

Table 12. Coyotes recovered during Part III.

Date	Animal #	Method	Weight lb./kg	Sex	Age (yrs.)	Stomach Contents
4/3	1	Snare	16.0/7.3	F	1	Mice + calf hair[a]
4/24	2	Diphacinone	28.5/13.0	M	1	Wool
5/28	3	Aerial hunt	27.0/12.3	M	1.3	Wool
5/28	4	Aerial hunt	28.0/12.7	F	1.3	Wool
5/29	5	Aerial hunt	23.0/10.5	M	1.3	Cow hair[a]
5/29	6	Aerial hunt	32.0/25.0	M	1.3	Wool
5/29	7	Aerial hunt	16.0/7.3	F	1.3	Mice
6/1	8	Aerial hunt	25.0/11.4	M	1.3	Mice
6/1	9	Aerial hunt	30.5/13.9	M	2.3	Lamb
6/11	10	Aerial hunt	28.0/12.7	M	2.3	Mice
7/23	11	Trap	---	F	3.4	---
8/13	12	Dogs?	---	---	3.4	---

--- = undetermined
[a] Believed to be carrion.

Munoz (1976) examined 43 coyotes between 9 October 1975 and 29 January 1976: 3 were taken in snares, 25 by aerial and sport hunting, 18 by M-44s, and 2 pups were found dead. Of the 10 coyotes stomachs examined during Part III, 5 (50%) contained sheep parts; of the 33 coyotes stomachs examined by Munoz, 11 (33%) contained sheep parts.

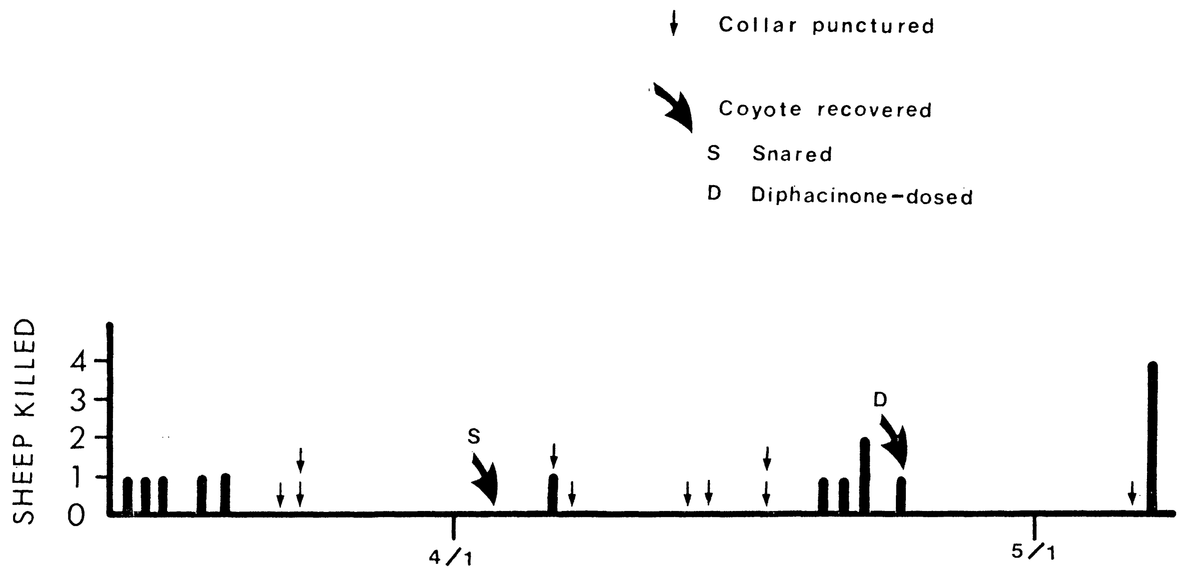
Effects of Predation Controls on Daily Kills

Toxic collar tests. The effects of the Diphacinone collar tests of Part III on daily kills are shown in Figs. 5 and 6. The kill level during the early test (23 March through 5 May) averaged 0.2 sheep per day compared to 1.6 and 1.7 sheep per day for this period during Parts I and II, respectively. The kill level during the middle test (5 May through 1 June) showed no appreciable drop compared to the levels of Parts I and II. The kill level during the last test (9 through 29 September) averaged 0.3 sheep per day compared to 1.4 and 2.5 sheep per day during Parts I and II, respectively.

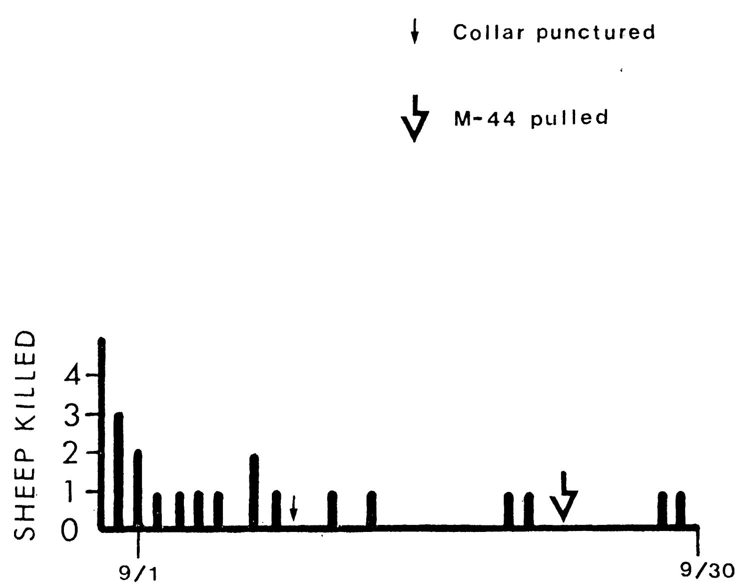
From pen tests (Connolly et al. 1976a:90-91), a 4- to 16-day delay was expected between the puncture of a collar and the cessation of kills. This delay appeared to occur once in each test. Six days after the rupture of collar 8 (23 April), coyote 2 was recovered (dead of Diphacinone poisoning) and killing ceased. Three days after the rupture of collar 11 (8 May), killing ceased for 2 days in Herd B; collars 10 (6 May) and 11 were probably ruptured by the same coyote and the temporary halt in killing was compatible with the expected lag time. Killing ceased 5 days after the rupture of

Fig. 5. Daily kills before and during early toxic collar test (15 March through 7 May).

Fig. 6. Daily kills before, during, and after last toxic collar test.



Collar punctured
Coyote recovered
S Snared
D Diphacinone-dosed
SHEEP KILLED
4
3
2
1
0
S
D
4/1
5/1



Collar punctured
M-44 pulled
SHEEP KILLED
4
3
2
1
0
9/1
9/30

collar 13 (9 September).

Aerial hunting. The effects of aerial hunting on daily kills are shown in Fig. 7. Coyotes killed an average of 2.2 sheep per day for the 18 days after the first hunt. During the same period in Parts I and II, respectively, kills averaged 2.9 and 3.5 per day.

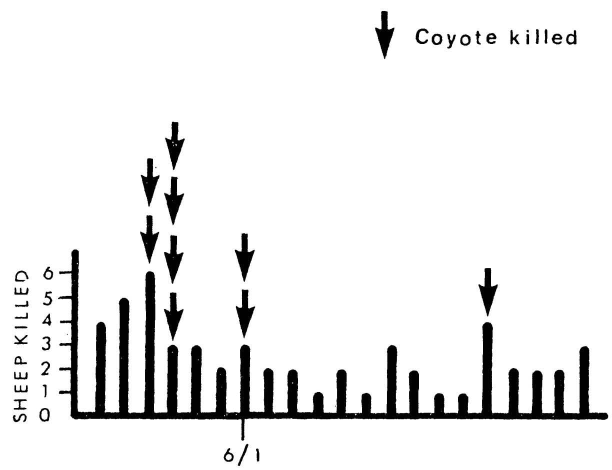
Snares, traps, and M-44s. The possible effects of snares, leghold traps, and M-44s on daily kills during Part III are shown in Figs. 5, 8, and 6, respectively. Coyote 1 (snared) was recovered during the early toxic collar test, but wool or residues of Diphacinone were not found in its carcass. Coyote 11 (trapped) was recovered during, but died prior to, the Komondorok test; this coyote did not possess any canine or incisor teeth with which to kill sheep. One M-44, pulled on 23 September (2 weeks after collar 13 was punctured), appeared to eliminate the coyote that killed lambs on 20 and 21 September. However, a coyote carcass was not found; this coyote may have died in dense cover close to the M-44.

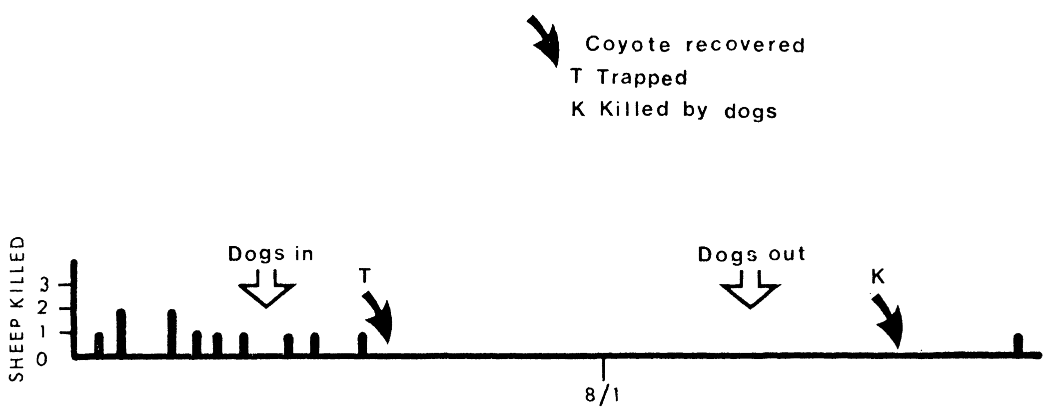
Guard dogs. The effects of the Komondorok on daily kills in Herd A are shown in Fig. 8. Kills ceased 5 days after the dogs were placed in the pasture with Herd A, and resumed 11 days after the dogs were removed from that pasture. Coyotes killed 0.5 sheep per day in Herd B and 1.5 sheep per day in Parts I and II during this period (19 July through 17 August).

Coyote 12 was recovered in that pasture after the test ended but appeared to have died about 2 weeks earlier during the dog test. While the exact cause of death could not be determined, canid rending

Fig. 7. Daily kills before, during, and after aerial hunting.

Fig. 8. Daily kills in Herd A before, during, and after dog test.


Coyote killed
SHEEP KILLED
0
1
2
3
4
5
6
6/1


Coyote recovered
T Trapped
K Killed by dogs
SHEEP KILLED
0
1
2
3
Dogs in
T
Dogs out
K
8/1

of the carcass and dog movements within the pasture (Linhart et al. in prep.) indicated the dogs may have killed coyote 12.

Effects of Predation Controls on Coyote Movements and Daily Use Patterns

Discernible shifts in coyote movements and use patterns in apparent response to control activities were detected three times during Part III. Dasch (pers. comm.) noted a lack of coyote activity in the vicinity of Herd B during its first 6 days after leaving headquarters. On the seventh day (5 May), he noted coyote tracks and a fresh "dig" (access point to a pasture): the following day, a toxic-collared lamb (collar 10) was killed near the dig, and another (collar 11) was killed there on 8 May. On 7, 9, and 10 May, sheep were killed in Herd B apparently by the coyote responsible for the tracks and dig and the two dead collared lambs. When killing resumed on 13 May, Griffith (pers. comm.) noted a 1-mile (1.6 km) shift in the coyote access point, presumably due to a new coyote.

A shift in daily use patterns was noted after the first aerial hunt. For 3 days prior to that hunt, when coyotes resumed killing sheep in Herd A after the herd was moved 2 miles (3.2 km), 11 of 15 coyote kills (73%) occurred during early morning hours (0400 to 0700). In contrast, during the 13 days following the first hunt, 18 of 23 kills (78%) occurred during evening hours (1800 to 2300).

Shift in movements occurred during the guard dog test. The pasture where the test was conducted (Squaw Gulch - Fig. 1) contained two east-west draws. The sheep bedded down each evening in the north-east corner of the pasture, and coyote sightings and Carrigan's scent-post survey (Linhart et al. in prep.) indicated the coyote entered near the northwest corner of the pasture, using the north draw for travel. After killing ceased, coyote use shifted to the southeast corner, with the south draw serving as the travel route.

Minor shifts in movements and daily use patterns were noted whenever coyotes were killed. Temporary lulls (1 to 2 days during March through June and 1 to 2 weeks during July through September) followed by surges in numbers of kills per day and changes in kill patterns and sheep carcass locations suggested that coyotes eliminated by predation controls were replaced by new, immigrating coyotes.

CHAPTER IV

DISCUSSION

Ranch Management Changes

Two changes in sheep management during Part III influenced coyote predation on lambs compared to Parts I and II: 1) the late release of lambs into pastures where coyotes would kill them; and 2) the release of Herd B into the pasture farthest from headquarters. The first change delayed the onset of predation on lambs. Coyotes were apparently reluctant to kill lambs in pastures close to the lambing sheds during all Parts, probably because of human activity associated with a shed lambing operation or because the Ranch dogs had established territories in that area which coyotes respected. The timing and location of 2) probably increased predation on Herd B beyond the level which would have occurred had the herd moved slowly outward from headquarters as in Parts I and II. The lambs were small and vulnerable at that time, and the pasture was close to the Sapphire Mountains (the apparent source of most coyotes) and adjacent to Dry Gulch (Fig. 1), the major coyote travel route of the Ranch. Therefore, that pasture could have more coyote activity than any other pasture on the Ranch and the quickest replacement of coyotes killed during control activities. This move also increased the difficulty of finding all lamb carcasses, increasing the number of lambs unaccounted for. Small lambs were easily carried away or dismembered by coyotes and thoroughly scavenged by the large numbers of ravens. Montgomery (pers. comm.) observed a coyote carrying a section of a carcass. On another occasion, all parts of a small toxic-collared lamb except the backbone disappeared from the pasture, presumably carried away by a coyote; the collar was recovered in an adjacent pasture.

Sheep Mortality

Mortality Not Involving Predators

One of the subtle effects of long-term coyote depredation was the disruption of Cook's selective breeding program. He preferred to develop his own breeding stock (Henne 1975:8), but losses of ewes and ewe lambs suitable for breeding forced him to purchase replacement ewes. Due to market conditions at those times, commercially available breeders were older, less healthy animals than those raised on the Ranch. The steady increase in natural deaths of adult ewes noted during the studies resulted, probably predisposing many lambs to diseases through poor pre- and postnatal nutrition.

The total lamb losses for Parts II and III were virtually identical, apparently supporting Wagner's (1972:37) contention that "predatory and non-predatory losses are somewhat compensatory." However, the increased natural lamb deaths during Part III were apparently a consequence of the predisposing influences mentioned above coupled with bad weather and crowding at lambing time. Pauly (pers. comm.) remarked on several occasions that the weather was colder and the lambing was better synchronized than in previous years. Thus, conditions (climate and crowding) in the lambing sheds were conducive to diseases and accidents, and the results of this study do not bear out Wagner's contention that a certain percentage of a herd will die regardless of the causes.

Predator-caused Mortality

Coyotes were the chief predators during Part III. Domestic dog problems increased markedly, however. This increase could have been coincidental to control activities, but the dogs may have recognized and respected coyote territories during the previous studies. Control activities during Part III probably disrupted established territories and prevented the establishment of new ones. If coyote 12 was not killed by the guard dogs, the decreased depredation and shifts in coyote movement patterns noted during the dog test could have resulted from territorial recognition between coyotes and dogs, since no other evidence exists to suggest that the dogs actively defended sheep from coyotes (Linhart et al. in prep.).

Health of sheep killed by coyotes. Lambs killed by coyotes during Part III appeared to be less healthy than those killed during Parts I and II. Sampling error could have caused this difference, since most carcasses (73%) had been eviscerated by coyotes and/or scavenging birds prior to necropsy. The difference could also reflect generally poorer health of the lamb crop due to weather conditions during lambing and the greater age and poorer condition of the dams.

During Part III, 9 of 12 handicapped sheep were killed by coyotes. It appeared that coyotes attacked sheep as they were encountered; thus, the slower handicapped sheep were more likely to be encountered and killed before healthy ones.

Characteristics of coyote kills. Coyote control was exercised prior to Part I (Henne 1975), withheld during Parts I and II, and exercised frequently after Part II. With the evidence of immigration noted on the Cook Ranch, the local coyote population should have stabilized during Part I, remained stable through Part II, and turned over constantly during Part III. Three assumptions are made: 1) coyotes, being opportunists, were attracted to and remained near an abundant, constantly available, and easily captured food supply such as sheep; 2) many coyotes in a population without systematic predator control live for several years; and 3) experience improves proficiency, the coyotes during Part II should have been the most proficient at killing sheep, less proficient during I, and least proficient during III. Two characteristics of coyote kills, the onset of predation on adult ewes when lambs were available and the selection of sites for killing adult ewes in pastures with low areas, were used to establish the relative proficiencies of coyotes during the three studies.

During Part I, coyotes which had presumably been killing lambs since March started killing adult ewes in mid-July and killed 23 ewes by 20 September 1974. During Part II, lamb-killing coyotes began killing ewes in mid-June and killed 21 ewes by 20 September 1975. Aerial hunting and toxic collar tests from late January to early June 1976 appeared to eliminate the experienced coyotes remaining on the Ranch after Part II, since coyotes did not again kill ewes until mid-August during Part III and then only killed two. Thus, immigrating coyotes appeared to be limited to killing lambs during summer months.

While catching sheep which were wounded or used in toxic collar tests, my field assistants and I noticed that lambs were easier to catch than ewes, and lambs were progressively harder to catch as they grew older and larger. Munoz (1976:26) noted that sheep slowed down when approaching the bottoms of draws. Presumably, coyotes could also detect these behavioral differences and, with experience, could learn to use low areas to their advantage in catching ewes. Experienced coyotes would, therefore, be less limited to taking lambs and would take ewes earlier in the summer than would inexperienced coyotes.

Based on the above argument, coyotes were most proficient during Part II, less proficient during I, and least proficient during III.

Further support for the concept of improved efficiency through experience is revealed by an analysis of the locations of wounds inflicted by domestic dogs and the two undetermined canids. The wounds inflicted by the German shorthaired pointer were typical of dog attacks, involving a large number of bites to extensive areas of the target lamb's body, neck, and legs. Two off-Ranch dogs and the guard dogs attacked sheep repeatedly; attacks involved few bites to the bodies of sheep and none to the legs, with most bites concentrated in the neck area. Wounds on the two kills attributed to undetermined canids were similar to those on sheep attacked by these dogs, yet we never sighted dogs or found dog signs in or near the pastures where the kills occurred. These two kills could have been committed by inexperienced coyotes. Thus the characteristics used to define coyote kills were only considered 99 percent certain during Part III.

The decrease in numbers of adult ewes killed during summer months by the less adept coyotes of Part III, resulting from predator controls, would, in the long run, preserve existing breeding stock, thereby partially alleviating the need for supplemental breeding stock and the health problems associated with those animals.

Coyote Use Patterns and Predation Controls

Coyote Use Patterns

Similar trends in numbers of kills per day were noted during all three studies. The first and most intense surge in killing (early May) coincides with the coyote pup weaning period and may reflect the increased food requirements of that period, though aerial hunts shortly after that period yielded no lactating bitches (the assumption is made that lactating bitches are as vulnerable as other coyotes to aerial hunting). Whatever the reason, coyotes were evidently willing to travel many miles to take advantage of the prey concentration on the Ranch during that period. Since conventional and experimental controls from 9 October to that time were ineffective in preventing this surge during Part III, intensive sheep management (herding or corralling at night) during this period may be the only solution to prevent extensive losses on ranches experiencing a similar surge. However, increased range damage and expenses and orphaning of lambs resulting from intensive management could outweigh the benefits, and coyotes might shift daily hunting periods to compensate for those changes in sheep management.

The surge noted during early September was probably a consequence of the lamb weaning process in which lambs were forcibly separated from ewes, disrupting the existing social structure and cohesiveness of the herd. My assistants and I noticed that the lambs were more difficult to herd after weaning than before; Pauly had informed us that this was to be expected, and the lambs would be easily excited for several days after weaning until new social bonds were formed and the cohesiveness of the herd was partially restored. Connolly et al. (1976b) found that escape behavior of sheep (fleeing) rather than hunger stimulated coyotes to attack. Therefore, the increased excitability of lambs after weaning probably influenced the number of lambs attacked by coyotes. Intensive management of lambs after weaning until new social bonds formed should reduce losses to coyotes.

The mid-September surge noted during Part II may have been caused by coyote pups learning to kill sheep, since some of the 12 pups taken shortly thereafter had fed on (and presumably killed) sheep.

A general decrease in daily kills occurred during July and August, presumably because of the availability of alternate prey such as Columbian ground squirrels (Spermophilus columbianus) and white-tailed jackrabbits (Lepus townsendii). The observed differences in kill levels between Parts II and III could have resulted from differences in abundance of alternate prey as much as predator control activities; ground squirrels and jackrabbits appeared to be more abundant during Part III than II (Johannsen and Munoz pers. comm.). Both control activities and alternate prey were probably factors since most coyotes moving onto the Ranch traveled through the area

(Dry Gulch) where ground squirrels and jackrabbits were most abundant.

As expected, the numbers of kills per day decreased during Part III. Apparently, coyote use of the Ranch also decreased. The reliability of the coyote-use index (estimated numbers of coyotes killing sheep per day) is based on Severson's (pers. comm.) observations on 11 May 1976, when seven lambs were killed and seven were wounded. Severson tracked two coyotes and one fox in and around the pasture where those attacks occurred. Analysis of the datum cards for that day indicates that one lamb was killed and fed on by a fox, and two were killed and fed on by coyotes. No other carcasses were fed on significantly. Also, during all three Parts, there were periods when the number of carcasses fed on was consistent from day to day, even though the number of kills varied.

Coyote use of the Ranch appeared to increase from Part I to II. Gier (1975:251) stated that "the general concentration of coyotes is naturally limited by (1) adequacy of food supply, (2) denning territory, (3) intraspecific strife dependent on the frequency of contact and competition for food, and (4) adequate space devoid of interspecific rivalry with other carnivores." Factors (1) and (4) were apparently not limiting on the Cook Ranch since sheep were abundant and other carnivores were not present in significant numbers. Factor (2) presumably remained constant in the absence of any major change in land use practices on or around the Ranch. The increase in coyote use, then, would appear to be a function of (3). With the apparently heavy influx of coyotes noted on the Cook Ranch, the local coyote population should have stabilized during Part I and remained stable through Part II in the absence of predator controls in the area. The increase in coyote use from Part I to Part II might indicate increased social tolerance among coyotes.

Observations by Severson (pers. comm.) in late January 1976 suggest a possible mechanism. Through careful tracking, he discovered that all kills at that time were committed by coyotes occupying two dens close to the Ranch. During aerial hunts on 28 and 29 January, he killed 10 coyotes at those dens, 4 adults and 6 "short-yearlings" (9 to 10 months old). Coyote pup dispersal normally begins during November and ends around the end of January (Knowlton 1972; Gier 1975:257). The presence of short-yearlings in dens indicates that, in the presence of an abundant, concentrated food source such as domestic sheep, social tolerance could increase, leading to the retention of short-yearlings and the formation of clan-groups or packs. Camenzind (in prep.) observed the formation of similar aggregations among carrion-feeding coyotes on the National Elk Refuge, Jackson, Wyoming.

<u>Coyotes Taken and the Effectiveness of Predation Controls</u>

Fewer coyote carcasses were recovered during Part III than were recovered by Munoz (1976) from 10 October 1975 to 31 January 1976. Excluding his 32 pups and 5 unknown-age coyotes to eliminate seasonal differences between the two predator control periods, the numbers were nearly equal (11 for the first period, 12 for Part III). His coyotes averaged 1.5 years old (adjusted for seasonal differences), while those recovered during Part III averaged 1.7 years old. Recovery of the Diphacinone-killed coyotes would have been expected to raise the figure for Part III because the toxic collar is theoretically most effective against older, more wary coyotes who elude other methods of control (Connolly et al. 1976a). The most effective control methods used during Part III (toxic collars and aerial hunting), therefore, were probably more selective for older coyotes than the most effective methods (aerial hunting and M-44s) used from 10 October 1975 to 31 January 1976.

The number of coyotes recovered during Part III was a conservative estimate of the number of coyotes killed. The slow-acting nature of Diphacinone increased the probability that coyotes died off-Ranch, whereas Munoz's (1976) methods killed quickly and therefore insured recovery of coyote carcasses. The low recovery rate of Diphacinone-dosed coyotes was expected, since McBride (pers. comm.) only recovered one coyote during his toxic collar work with a faster-acting toxicant on 14 ranches in Texas.

The methods used during Part III were probably more selective for sheep-killing coyotes than those used by Munoz (1976). Only 33 percent of the coyote stomachs he examined contained wool while 50 percent of those examined during Part III contained wool. Again, this 50 percent is conservative due to the nature of Diphacinone.

The samples of coyotes killed by some control methods were small and variables such as weather, habitat, alternate prey, skill of damage control personnel, and many other factors appeared to affect the efficacy of each control method on this Ranch during this period. However, based on data from coyotes killed between 9 October 1975 and

30 September 1976, I derived the following empirical ranking for the effectiveness of the various methods devised for killing depredating coyotes on the Cook Ranch:

1) the toxic collar - selective for sheep-killing coyotes, their companions, and their pups;

2) aerial hunting - more selective for older coyotes and sheep-killers than traps, snares, and M-44s; and

3) traps, snares, and M-44s - selective for young coyotes, probably few sheep-killers.

There are problems inherent in the two most selective methods. Aerial hunting is limited to daylight hours. Coyotes during Part III shifted their sheep-killing activities in response to early morning hunts, either through avoidance or through the elimination of morning-hunting coyotes.

The major problem with the toxic collar was the slow-acting toxicant. The results obtained on the Cook Ranch and during other filed tests "indicate that a non-repellent, fast acting (within 24 hr.) toxicant is essential to successful use of the toxic collar concept. One such toxicant is sodium fluoroacetate (Compound 1080). However this compound has not been approved for experimental use in the toxic collar because of its controversial background. Given 1080 or another suitable toxicant the collar will work . . ." (Connolly et al. 1976a:3).

The slow-acting nature of Diphacinone precluded accurate comparison of the effectiveness of the toxic collar in its three possible applications (pre-release, interception along coyote travel routes, and replacement of regular herds on bedding grounds). Collars were punctured during each application, and the collar would probably work well in each instance with a faster-acting toxicant.

The toxic collar has ramifications for population control as well as depredation control. If all coyotes are latent sheep killers as Connolly et al. (1976b) suggested, then long-term use of the toxic collar could substantially reduce coyote populations in sheep-producing areas. However, the cost, time, and manpower required for toxic collar work would be prohibitive for use in large-scale control, making this method more desirable as a "last-ditch" effort to control coyotes which escape other methods of control (Connolly et al. 1976a).

The effectiveness of the controls tested between 9 October 1975 and 30 September 1976 appeared to be inversely related to the yearly coyote density fluctuations noted by Knowlton (1972); that is, controls appeared to be most effective when natural coyote population densities were at their lowest levels (February through March and July through October) and replacement by immigrating coyotes was least likely. The difficulty in controlling coyote damage on the Cook Ranch before Henne's (1975) study and after 9 October 1975 appeared to be caused by this mobility (i.e., immigration) of coyotes onto the Ranch, and therefore controls would be necessary over an area larger than the Ranch to substantially reduce losses.

The guard dogs were the most effective method tested in eliminating losses to coyotes. Low coyote replacement rates and the availability of alternate prey during summer months may have influenced the results. Damage by coyotes, however, was replaced by harassment of the sheep by the guard dogs, which may have been a consequence of the dogs' rearing and training (Linhart et al. in prep.). Further refinements in rearing and training are necessary before guard dogs can be properly evaluated. The dogs did show great potential for reducing coyote damage.

Management Implications

The controls tested during Part III reduced losses of sheep to coyotes. Further reductions should be possible through refinements in sheep management (e.g., corralling sheep at night during peak loss periods) and proper application of control methods. However, coyote mobility makes the elimination of coyote damage in an area like the Cook Ranch, where loss levels were a function of coyote population movements and density, impossible without reduction over a larger area than a single ranch. The potential impact of large-scale reduction on other species must be considered in selecting lethal (such as toxic collars, aerial hunting, and M-44s, which actively kill coyotes) or non-lethal (such as guard dogs or aversive agents, which cause coyotes to avoid sheep) control methods.

Predator control may benefit certain wildlife species in addition to livestock. Studies (Cook et al. 1971, Trainer 1975, Reichel 1976) have documented coyote predation as the greatest single factor influencing fawn survival of white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), and pronghorn antelope (*Antilocapra americana*), respectively, in certain areas. Coyote reduction sometimes increases fawn survival (Horn 1941, Arrington and Edwards 1951, Beasom 1974a and b). While coyote predation is often the major mortality factor affecting jackrabbits and rodents (Horn 1941, Clark 1972, Wagner and Stoddart 1972), coyote control can result in reduced rodent and lagomorph densities (Horn 1941). Coyote densities have been observed to fluctuate inversely with the densities of some medium-to-small carnivores (Robinson 1961, Linhart and Robinson 1972), implying that coyotes may limit those species in some areas. These studies indicate that large-scale coyote population reduction would have little effect on rodents and would benefit deer, bobcats (Lynx rufus), and other medium-to-small carnivores if the habitat could support population increases of those species.

CHAPTER V

SUMMARY

Three studies on the Cook Ranch in western Montana documented predator-caused livestock losses and tested the effectiveness of conventional and experimental predator control methods in reducing those losses. Henne (1975) conducted the first study from 15 March 1974 to 14 March 1975 and was concerned primarily with sheep mortality. Munoz (1976) directed the second study from 15 March 1975 to 14 March 1976. He also documented causes of sheep mortality, but control efforts were begun when losses threatened to outstrip the funds budgeted to reimburse Cook for confirmed losses to wild predators.

My study began 15 March and ended 30 September 1976 when Cook sold the Ranch because he felt he could not profitably raise sheep in the Bitterroot Valley due to coyote predation. My objectives were to measure the efficacy of conventional and experimental depredation control methods, tested by the Denver Wildlife Research Center, by comparing kill levels in the presence of various control methods to the levels recorded by Henne and Munoz in the absence of control, and to determine the effects of those controls on coyote movements. Since this study did not cover a full year, comparisons could only be made with Henne's and Munoz's data for the period 15 March through 30 September. That period for 1974 is referred to as Part I; for 1975, Part II; and for 1976, Part III.

Lamb deaths not involving predation were comparable during Part I and II (5.7 and 5.5% of the lamb crop, respectively), but increased during Part III (10.9% of the lamb crop) as a result of crowding and inclement weather during lambing and the age and condition of the ewes. Ewe deaths not involving predation increased steadily from Part I to III (2.5, 3.6, and 5.3% of the ewe herd, respectively).

Ravens, golden eagles, and foxes were not considered significant predators of sheep during the three studies. Dogs killed two sheep during Part I and killed or wounded at least nine during Part III. Dog harassment was not noted during Part II. The increase might have resulted from disruption of coyote territories caused by predator controls.

Coyotes killed 330 lambs and 33 ewes during Part I (17.8% of the exposed herd); 394 lambs and 50 ewes during II (13.9% of an expanded herd); and 214 lambs and 13 ewes during III (8.7% of the exposed herd) in spite of predator controls. A major secondary effect of coyote predation was deterioration of the health of the ewe herd, since commercially available replacement ewes were generally older and more disease-prone than those raised on the Ranch. The health of sheep killed by coyotes declined steadily from Part I to III. Percentages of sheep in each category (healthy/abnormalities present/severe disorders present) were: Part I, 74.1/19.9/6.0; Part II, 69.2/21.9/8.9; and Part III, 51.5/35.3/13.2. During Part III, 9 of 12 handicapped sheep were killed by coyotes. It appeared that coyotes attacked sheep as they were encountered; thus, the slower handicapped sheep were more likely to be encountered and killed before healthy ones.

Carcasses were generally fed on more extensively during Part I than during Parts II and III. Sheep were frequently found wounded or killed with no feeding on the carcasses on days with multiple kills. Coyotes used similar bite patterns to kill sheep during the three studies. Coyotes during Part III inflicted proportionately more bites to the body or legs than during Parts I or II, possibly because inexperienced coyotes were replacing experienced coyotes killed during the tests of control methods. Most sheep attacked by dogs received fewer, neater bites than is considered typical of dog attacks. Two additional lambs received wounds similar to the ones inflicted by these dogs but may have been killed by inexperienced coyotes. Thus, the characteristics used to define coyote kills were only considered 99 percent accurate during Part III.

Trends in the onset of predation on adult ewes when lambs were available and the selection of sites for killing ewes in pastures with low areas supported the hypothesis that coyotes were most proficient during II, less during I, and least during III. Coyotes began killing ewes earliest during II (mid-June), later during I (mid-July), and latest during III (mid-August). Coyotes killed most (61%) ewes in low areas during II, fewer (33%) during I, and fewest (25%) during III.

Major surges in kills per day occurred during early- to mid-May (4.0 kills per day during I, 6.3 per day during II, and 6.0 per day during III) and early September (2.3 per day during I, 2.0 per day during II, and 1.3 per day during III). The first surge coincided with the coyote pup weaning period. The second apparently resulted from disruption of the herd's social structure and the resulting increase in excitability of lambs caused by the weaning process. A general decline in average numbers of kills per day occurred during summer months, possibly due to the increased abundance of alternate prey as young ground squirrels and lagomorphs became available.

Estimated minimum coyote use of the Ranch increased from Part I to II and decreased during III (253, 303, and 168 coyote-use days, respectively). The increase from I to II may reflect increased social tolerance among the local coyotes, or simply a buildup in coyote numbers without controls.

At least 13 coyotes were killed during Part III: nine by aerial hunting and one each by traps, snares, and toxic collars. One coyote may have been killed by the guard dogs. In addition, one dog died after puncturing a toxic collar. Coyotes ruptured 13 collars; excluding pups and hunting companions (i.e., coyotes which did not directly attack collared sheep), as many as 10 coyotes may have died from Diphacinone poisoning. One M-44 was pulled and apparently killed a coyote but no carcass was found.

Of the 10 coyote stomachs examined during Part III, 5 (50%) contained wool; of the 33 coyote stomachs examined by Munoz between 9 October 1975 and 29 January 1976, 11 (33%) contained wool.

The early toxic collar test appeared to reduce losses; 0.2 sheep per day were killed during this period in Part III compared to 1.6 and 1.7 during Parts I and II, respectively. Kills during the last collar test were 0.3 sheep per day during Part III compared to 1.4 and 2.5 per day, respectively, during Parts I and II.

Aerial hunting appeared to reduce losses slightly; 2.2 sheep were killed per day during Part III, while losses for the same period during Parts I and II averaged 2.9 and 3.5 sheep per day, respectively. Coyotes shifted from killing during early morning hours (11 of 15 kills or 73% of the total) to killing during evening hours (18 of 23 kills or 78% of the total) in apparent response to aerial hunting. Alternatively, the morning killers may have been removed, only to be replaced by coyotes that killed in the evening.

Killing ceased in the test Herd (A) 5 days after beginning the dog test and resumed 11 days after it ended. Coyotes killed 0.5 sheep per day in Herd B and 1.5 per day in Parts I and II during the same period. The mechanism for this reduction may have been active (chasing or killing coyotes) or passive (leaving territorial marks which coyotes respected). Increased availability of alternate prey was probably an additional factor in this reduction.

The effectiveness of control methods appeared to be inversely related to coyote population movements and density; that is, controls were most effective when replacement by immigrating coyotes was least likely.

Of the coyote control methods tested between 9 October 1975 and 30 September 1976, the toxic collar appeared to be the most selective, aerial hunting less selective, and traps, snares, and M-44s least selective for killing depredating coyotes on the Cook Ranch. The guard dogs appeared to be the most effective method for reducing losses to coyotes.

The mobility of coyotes makes the elimination of coyotes damage in an area like the Cook Ranch impossible without control over an area larger than a single ranch. The selection of control methods (lethal, as with killing, or non-lethal, as with guard dogs), therefore, requires evaluation of the desirability of reducing overall coyote population levels and the effects of such reduction on other species.

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APPENDIX I

TOTAL MORTALITIES DURING PARTS I, II, AND III
(Numbers used to calculate Table 1)

		Original no. of animals	Natural deaths[a]	Predator kills	Undetermined	Unaccounted for	Total mortality
Lambs[b]	I	1,253	72	335	5	7	419
	II	2,006	111	339	6	22	538
	III	1,656	181	221	7	30	439
Ewes	I	831	21	36	0	0	57
	II	1,432	52	53	0	0	105
	III	1,099	58	16	1	0	75
Lambs + Ewes	I	2,084	93	371	5	7	476
	II	3,438	163	452	6	22	643
	III	2,755	239	237	8	30	514

[a] Pre-exposure and field deaths not involving predators.
[b] Docked lambs only.

APPENDIX II

CAUSES OF LAMB DEATHS[a] PRIOR TO EXPOSURE DURING PARTS I, II, AND III
(Numbers used to calculate Table 2)

Cause	I[b]	II[c]	III
Abortion/Stillbirth	37	29	68
Miscellaneous[d]	53	14	158
Weak calf syndrome	27	6	35
Totals	117	49	261
Total lamb crop	1,327	2,044	1,911

[a] Includes docked and undocked lambs.
[b] From Henne (1975)
[c] From Munoz (1976)
[d] Includes birth defects, accidents, too weak to feed, scours, exposure, bacterial infections, and unspecified deaths.

APPENDIX III

FIELD DEATHS OF LAMBS FROM CAUSES OTHER THAN PREDATION DURING PARTS I, II, AND III
(Numbers used to calculate Table 3)

Cause	I	II	III
Accident	1	3	4
Bacterial infection	0	18	0
Bloat	0	2	0
Enterotoxemia	4	4	0
Intestinal blockage	1	1	0
Maggot infestation	1	1	2
Maternal neglect and starvation	0	13	1
Paralysis	0	1	0
Pneumonia	10	23	7
Pneumonia and liver infection	3	0	0
Prolapsed rectum	0	0	3
Unspecified	5	10	8
Urinary calculli	1	0	0
Weak calf syndrome	3	24	3
Totals	29	100	28
Total exposed lamb crop	1,210	1,995	1,503

APPENDIX IV

MORTALITY OF ALL DOCKED LAMBS FROM CAUSES OTHER THAN PREDATION DURING PARTS I, II, AND III
(Numbers used to calculate Table 4)

	I	II	III
No. docked	1,253	2,006	1,656
Pre-exposure deaths	43	11	153
Field deaths	29	100	28
Totals	72	111	181

APPENDIX V

MORTALITY FOR ADULT EWES FROM CAUSES OTHER THAN PREDATION DURING PARTS I, II, AND III
(Numbers used to calculate Table 5)

Cause	I	II	III
Accident	1	1	2
Blindness	1	0	0
Bloat	4	2	3
Enterotoxemia	2	2	0
Intestinal blockage	1	1	0
Lambing complications	1	2	3
Maggot infestation	0	4	1
Mastitis	1	6	13
Old age complications	6	18	26
Pneumonia	2	14	4
Pneumonia and liver infection	0	0	1
Unspecified	2	2	5
Totals	21	52	58
Original ewe herd	831	1,432	1,099

APPENDIX VI

HEALTH AT TIME OF DEATH OF SHEEP KILLED BY COYOTES DURING PARTS I, II, AND III
(Numbers used to calculate Table 7)

	Part	Lambs	Ewes	Totals
Numbers examined	I	140	26	166
	II	207	30	237
	III	58	10	68
Healthy	I	105	18	123
	II	148	16	164
	III	32	3	35
Abnormalities present	I	27	6	33
	II	40	12	52
	III	18	6	24
Severe disorders present	I	8	2	10
	II	19	2	21
	III	8	1	9
Health undetermined	I	190	7	197
	II	187	20	207
	III	156	3	159

APPENDIX VII

DEGREE OF FEEDING ON CARCASSES BY COYOTES DURING PARTS I, II, AND III
(Numbers used to calculate Table 8)

	Part	Lambs	Ewes	Totals
Numbers examined	I	317	33	350
	II	363	38	401
	III	206	12	218
Wounded	I	23	4	27
	II	44	4	48
	III	28	1	29
No consumption	I	31	2	33
	II	62	3	65
	III	20	0	20
Very light	I	35	3	38
	II	31	2	33
	III	11	2	13
Light	I	76	11	87
	II	95	13	108
	III	74	2	76
Moderate	I	106	11	117
	II	96	14	110
	III	54	6	60
Extensive	I	46	2	48
	II	35	2	37
	III	19	1	20

APPENDIX VIII

LOCATION OF COYOTE-INFLICTED WOUNDS DURING PARTS I, II, AND III
(Numbers used to calculate Table 9)

	Part	Numbers examined	Neck-throat only	Other anterior to shoulders	Torso or legs
Lambs	I	321	213	95	13
	II	391	274	102	15
	III	205	142	50	13
Ewes	I	33	29	2	2
	II	45	35	5	5
	III	13	12	1	0

APPENDIX IX

KILL SITES IN PASTURES WITH LOW AREAS
(Numbers used to calculate Table 10)

		Numbers examined	Killed in low area	Not killed in low area
Lambs	I	194	79	115
	II	295	82	213
	III	129	26	103
Ewes	I	24	8	16
	II	41	25	16
	III	12	3	9

APPENDIX X

ESTIMATED MINIMUM COYOTE USE DURING PARTS I, II, AND III
(Numbers used to calculate Table 11)

Est. no. of coyotes per day	Number of days I	II	III
0	41	42	88
1	93	70	74
2	45	46	26
3	15	29	6
>3	6	13	6
Total days	200	200	200
Total coyote-use days	253	303	168