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Causes of sheep mortality at the Cook Ranch, Florence, Montana, 1975-76

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CAUSES OF SHEEP MORTALITY AT THE COOK RANCH, FLORENCE, MONTANA, 1975-76

By

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Director: Bart W. O'Gara

Two studies of sheep (Ovis aries) mortality on the Cook Ranch, Florence, Montana, were conducted during 2 consecutive production years, 15 March 1974 to 14 March 1976. Coyote (Canis latrans) predation was the primary cause of sheep losses, and predators killed more than 16 percent of the flock each year for a total of 1,027 sheep. In the first study, Henne (1975) reported 0.6 percent undetermined deaths, compared to 0.8 percent for the second study. Coyotes were responsible for 97.1 (first study) and 99.3 percent (second study) of all predation. During the second study, 80.7 percent of the sheep taken by coyotes were killed by neck and throat wounds. Coyotes were sighted 61 times, dogs (Canis familiaris) three times, and foxes (Vulpes vulpes) twice during the second period. Of the 602 sheep killed by coyotes during the second study, scavenging birds fed so extensively on 83 carcasses that the amount of feeding by coyotes could not be determined. Feeding was light to moderate on 401 of the other 519 carcasses and return feeding was insignificant during both studies.

Secondary losses, resulting from harassment by coyotes, included reduced lambing success, increased excitability of flocks, reduced growth rates and difficulty in fattening lambs, and loss of unborn lambs.

Pneumonia, weak-calf syndrome, and old age complications were the primary causes of natural deaths. Health of the sheep killed by coyotes was similar to that of the rest of the herd.

Success of M-44s, shooting from a helicopter, and snares, as well as experimental sodium cyanide collars and a spray-on adversive agent, were monitored. Conventional predator controls killed 44 coyotes; 18 by M-44s, 23 by shooting from a helicopter, and 3 by snares. Predation was reduced but not stopped by conventional controls; as used, the two experimental methods did not reduce predation.

Three coyotes, radiocollared and tracked during the second study, were seldom found among the sheep.

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CHAPTER I

INTRODUCTION

In 1971, the Cain Committee on predator control published a report that concluded, "Today's society places as high a value on prairie dogs, eagles and coyotes as does the grazing lessee on public lands or owners of a ranch on his flock of sheep." The report recommended the modification of predator control, which until 1971 had been based on the concept of eradication of predators as a solution to livestock depredation. Cain et al. (1972) felt that instead of eradication, predator controls should be selective for individual predators causing livestock depredation. A combination of public pressure and the Cain Report influenced President Nixon, in 1972, to ban the use of poisons on federal lands and the Environmental Protection Agency to halt interstate shipment of chemical toxicants.

These initiatives were followed by complaints from stockmen, especially sheep ranchers. Where politicians had felt pressure to protect predators because they were deemed ecologically beneficial, sheepmen maintained that predators

had little value in sheep grazing areas and should be controlled. In an effort to clarify an emotional and economic controversy, legislators authorized extensive funding for research in the field of livestock predation. The agency most directly responsible for this research was the U.S. Fish and Wildlife Service, Department of the Interior. Donald Balser, Chief, Section of Predator Damage, Denver Wildlife Research Center, was charged with determining what studies were needed. Different types of sheep operations exist in the Western States; therefore, Balser initiated five independent studies of sheep mortality at sites utilizing different operations, which ranged from herded shed lambing to herded range lambing, from unherded fenced grazing to herded open grazing and from areas with extensive predator control programs to areas with no predator control programs.

In Idaho and Wyoming, documentation of sheep mortality in herded shed lambing and herded range lambing operations, respectively, was begun in 1973 by personnel of the Denver Wildlife Research Center. In these study areas, predator control programs were well established, and the data collected will be compared with findings from three studies contracted with universities in areas with no control programs or modified control programs.

Samuel Beasom, funded by contract money from the U.S. Fish and Wildlife Service and the Environmental Protection Agency, is currently in the third year of a 6-year study of modified predator control on three different sheep herds in an area of Texas where no major sheep ranches remain in operation. Predator control is limited so Beasom is studying three herds with minimal outside factors to influence results. He is testing three phases of predator controls rotating each phase yearly through the three herds. The first herd was tested with no controls, the second with M-44s, and the third with a combination of M-44s, helicopter gunning, snares, and live-trapping. The following year, the first herd was studied with M-44s only; the second, with the combination of four predator controls; and the third, with no controls. By 1980, this rotation will have progressed through two cycles. Besides predator control tests, Beasom is studying alternate food sources for predators and plans to correlate his findings with percentages of sheep killed in each herd.

Two other studies funded by the U.S. Fish and Wildlife Service to document sheep mortality in areas without predator controls were initiated in 1974 on private ranches in New Mexico and Montana. In New Mexico, V. W. Howard and his students documented sheep mortality from 14 April 1974 to 31 January 1976. No predator controls

were used on the ranch during the study, but extensive predator controls were used on adjacent ranches. Approximately 15 percent of the lamb crop was lost to predators during the first year of the study (DeLorenzo and Howard 1975).

The Montana study on the Cook Ranch was organized by Bart O'Gara and consisted of two segments. The first segment was conducted by Henne (1975) from 15 March 1974 to 14 March 1975. He documented sheep mortality on an unherded, shed-lambing operation with predator control excluded from docking to marketing. On 15 March 1975, I began a yearlong study, again documenting sheep mortality with no predator controls until 9 September. In addition, I collared and radiotracked coyotes and, after lambs were marketable, monitored the effects of M-44s, shooting from a helicopter, and snares. My objectives were to compare sheep mortality with that from Segment A, to determine coyote movements in and around sheep herds, and to evaluate effectiveness of the controls used on a fenced grazing operation. I also participated in field tests of an experimental control device, the sodium cyanide (NaCN) collar during September and October 1975, and assisted in a preliminary test of ARS-CR2, a coyote repellent sprayed on both lambs and ewes. The latter test was conducted from 19 November to 2 December 1975 by Dr. N. Gates and other personnel of the U.S. Sheep Experiment Station

(U.S.D.A.), Dubois, Idaho.

The Cook Ranch is located 22 miles (35.2 km) south of Missoula just east of the Bitterroot River and west of the Lolo National Forest (Fig. 1). The ranch consists of 6,064 acres (2,454 ha) owned by the Cooks plus 2,000 leased acres (809.4 ha). It is divided into 28 pastures ranging from 3 acres (1.2 ha) to 816 acres (330.2 ha). To the north and south, the ranch borders on cattle and wheat ranches. Predators were hunted and trapped extensively prior to 1974, yet Cook reported approximately 12 percent (300 sheep) mortality to predators during 1973.

Much of the ranch has been recently cultivated or reseeded. The predominant vegetation in the uncultivated areas consisted of bluebunch wheatgrass (Agropyron spicatum), sagebrush (Artemesia spp.), spotted knapweed (Centaurea maculosa), with ponderosa pine (Pinus ponderosa), and black cottonwood (Populus tricocarpa) the major tree species. Cultivated pastures were planted with crested wheatgrass (Agropyron cristatum), intermediate wheat (A. intermedium), dry land alfalfa (Medicago sp.) and sainfoin alfalfa (Onobrychis viciaefolia). Four fields were planted with barley (Hordeum sp.) and winter wheat (Triticum sp.). Most of the fences consisted of three strands of barbed wire above 24 in. (61 cm) of woven wire.

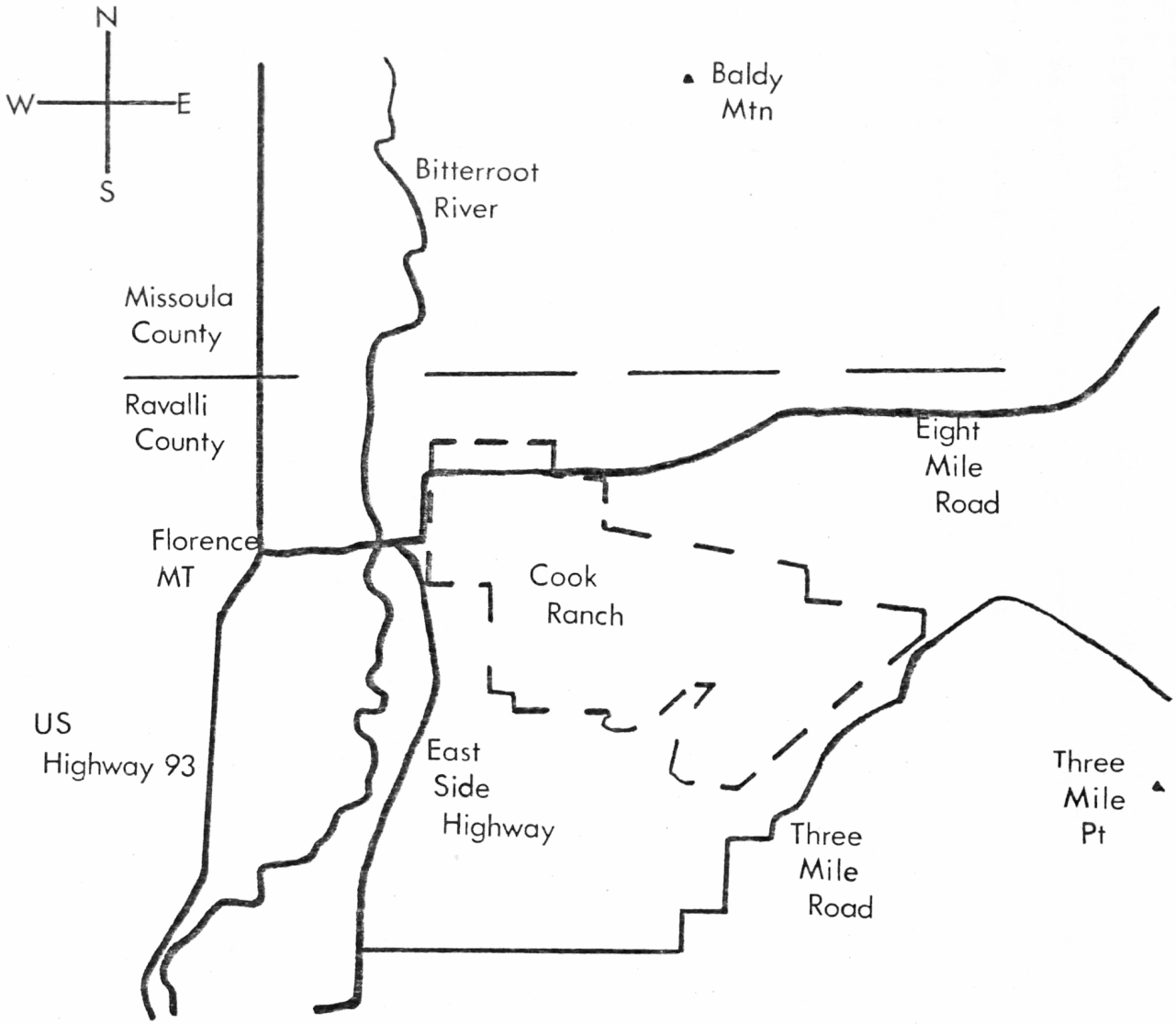

Fig. 1. Map of Study Area (2.4 in.=1 mi. or 6.1 cm=1.6 km.).

Since my documentation of sheep mortality on the ranch from 15 March 1975 to 14 March 1976 was a continuation of the study conducted by Henne (1975) from 15 March 1974 to 14 March 1975, this report compares the results from both studies. Hereafter, data collected by Henne and me will be referred to as Segments A and B, respectively. Each segment encompasses one production year from lambing to lambing.

CHAPTER II

METHODS AND MATERIALS

Documentation of Sheep Mortality

Management of sheep herds on the Cook Ranch was consistent during Segments A and B, except that Henne studied two herds containing single lambs in one herd and twins in the other. In Segment B, both herds were mixtures of twins and singles. The number of sheep on the ranch increased from 2,041 early in Segment A to 3,712 in Segment B. During spring and early summer, the herds were moved progressively from pasture to pasture further from the ranch headquarters with the process reversed during late July and August, so that by marketing time, sheep were again close to headquarters. The sheep were mostly unattended, although the ranch foreman checked the herds each morning.

The same methods and materials were used to document sheep mortality during both years of the study. Searches were started just after sunrise so as to ". . . arrive after predators finished killing but before scavenging birds and autolysis destroyed evidence" (Henne 1975).

Usually 10 to 15 ravens (Corvus corax) congregated on fresh kills. Exposed internal organs and flesh were quickly consumed and, if left alone, scavengers cleaned up exposed organs within 6 hours. When vegetation was abundant, searches were made on horseback, but when vegetation died back during winter, searches were made by truck. The advantages of searches on horseback were better visibility in tall vegetation, better contact with scavenger birds both visually and audibly, and minimal effect on pastures. The major disadvantage was that more time was required to conduct searches on horseback. In undulating pastures searches were concentrated near sheep bedding grounds, ravines, and draws; whereas, on flat terrain, a series of parallel lines was traversed. The width between lines was a function of visibility. Ravens, magpies (Pica pica), and golden eagles (Aquila chrysaetos) were good indicators of kill sites but were not reliable. Ravens left the ranch during late July and early August 1975, just as they did in Segment A.

When carcasses were found, necropsies were performed in the field after photographs had been taken and descriptions of kill patterns were recorded. Initially, carcasses were examined for wounds, especially in the neck and throat area, where coyotes generally attack sheep. After preliminary examinations, the skin was removed from neck and throat areas, and wound patterns, if any, were

noted. Wounds with subcutaneous hemorrhaging indicated that sheep were alive when attacked. Following examination of necks and throats, carcasses were opened on the ventral side from the abdomen to the proximal end of the sternum. Rib cages of lambs were cut through cartilage located just to one side of the sternum. Adults did not retain this cartilage, so a bone saw was required to open their rib cages. Once exposed, internal organs were examined and general health was recorded. Ear tags were saved for cross reference after marketing of lambs in the fall, and except for 4 weeks in July and August, carcasses were hauled to a dump located near the ranch headquarters.

Ear tag numbers of wounded sheep observed in the herds were recorded and, if wounded sheep were easily caught, they were killed by investigators. Once wounded, sheep readily developed infections that impaired feeding and/or breathing, and attempts by ranch personnel to treat wounded sheep resulted in limited success. During summer months, infestations of open wounds by maggots further complicated recovery. Because these lambs rarely recovered and for humane reasons, wounded sheep that could be easily caught were killed. Wounded sheep were generally caught within 1 week after first being observed.

Radiocollaring and Tracking Coyotes

Two methods were used to radiocollar coyotes, tranquilizing from a helicopter and live-trapping with Number 3 steel traps. From 17 to 20 May 1975, Rick Severson, Biological Technician, Denver Wildlife Research Center, flew during early morning and evening hours to tranquilize coyotes. Shooting from a two-man helicopter with the door removed, he used a Palmer long-range projector and darts containing 1 cc of ketamine hydrochloride. Only one coyote was captured because deep ravines and trees gave coyotes easily accessible cover. Steel traps were set by Jerry Lewis, local Animal Damage Control Agent, U.S. Fish and Wildlife Service, who was familiar with the ranch from earlier predator control work. He used either food scent or coyote urine as bait and fitted a tab (Balser 1965) on one jaw of each trap to tranquilize trapped coyotes. Traps were checked daily, usually in the morning, and any traps sprung were reset by Lewis. Two coyotes were trapped, one of them twice. Their weights and sexes were recorded, and the animals were collared with radios encased in plastic, designed and constructed by the Denver Wildlife Research Center. Each collar fitted around three-quarters of a coyote's neck and the final one-quarter consisted of a 1.5 in. (3.8 cm) nylon strap secured by four pop rivets, allowing each coyote to be fitted individually.

Coyotes were radiotracked at night for 2 weeks and in the early mornings for 4 additional weeks. An AVM receiver operating in the 164 frequency range and a three-element Yagi antenna were used to take readings at high points on the ranch. Initially, a 360 degree sweep was made with the elements held vertically to pick up a signal; when a signal was received, the elements were turned to the horizontal to pinpoint the direction of the signal. The signal was recorded and then, at another high point as near to a right angle to the first as possible, another bearing on the signal was recorded. Readings were then transcribed to U.S. Geological Survey maps or aerial photographs.

Predation Controls

Three conventional predator control methods (M-44s, shooting from a helicopter, and snares), and two experimental techniques of predation control (the toxic collar and spraying with ARS-CR2, a coyote repellent) were monitored during Segment B. The seven lambs killed during the toxic collar test were not included in tables dealing with documentation of sheep mortality.

M-44s, set within a metal cylinder driven into the ground, consisted of a spring-loaded rod beneath a capsule of powdered NaCN. The capsule holder, covered with beeswax-soaked cheesecloth, was screwed on top of the

ejector mechanism and baited with food scent. When a coyote tugged on the cheesecloth, the spring was tripped, releasing the rod which forced the NaCN into the predator's mouth. M-44s were set along fences where coyotes were known to travel and by sheep carcasses. Devices were checked in the morning and reset if fired. Predators were disposed of at the ranch dump after they were weighed and necropsied. One canine tooth was extracted from each coyote. Teeth were sectioned and aged by Gary Matson, an independent researcher.

Shooting from a helicopter involved the same method used for tranquilizing coyotes, except a shotgun was used in place of a tranquilizing rifle, and coyotes killed were recovered for examination. Flights were made for approximately 2 hours just after sunrise and 2 hours before dusk. Jerry Lewis was the gunner on 11 November and 16 and 30 December 1975, and Rick Severson was the gunner on 28 and 29 January 1976. Lewis could devote only limited time to shooting on the ranch, but Severson was assigned to the ranch for 10 days. He tracked coyotes on the ground for 1 week before using the helicopter.

Snares were made of 1/16 in. (0.16 cm) diameter steel cable and placed in paths coyotes were traveling regularly, usually under fences. Snares were looped around the bottom of fences so that the noose hung directly in line with travel routes.

The toxic collar, covering the ventral surface of the head and throat of a lamb, consisted of 10 plastic packets each containing liquid sodium cyanide. From three to six collars were used each day during the 30-day test period. Collared lambs were tethered by a back foot with a 12 in. (30.5 cm) rope, tied to a metal rod driven into the ground, and positioned in or near sheep herds. Tethered lambs were watered, fed, and examined for wounds every morning. Broken or leaking packets were replaced and buried in the field.

The coyote repellent, ARS-CR2, was sprayed on the neck and throat region of one herd of sheep, while the other herd was left unsprayed as a control.

CHAPTER III

RESULTS AND DISCUSSION

Documentation of Sheep Mortality

Total and Field Mortality. Total mortality, during both Segments A and B, included deaths that occurred from the beginning of lambing season until 14 March of the succeeding year. Field mortalities included only deaths recorded after sheep had been moved out of the lambing sheds. Total and field mortalities during both Segments are recorded in Table 1. Field mortalities for the entire herd were 19.8 and 21.7 percent of 2,664 and 3,712 sheep exposed to predation during Segments A and B, respectively. These percentages are lower than the 30.4 percent figure compiled by the State of Montana Department of Livestock (1974) from 1967 to 1969 for field mortalities throughout Montana. These figures are higher than the 9.5, 11.5, and 11.1 percent field mortality figures reported by Nass (1976) during 1973, 1974, and 1975, respectively, in Idaho, or the 14.5 and 11.7 percent field mortalities recorded by DeLorenzo and Howard (1976) during 1974 and 1975 in New Mexico.

The percentage of predator kills, 16.3 during Segment B, compared to 16.9 for Segment A, was again lower than the 18.3 percent predator losses reported by the State of Montana Department of Livestock (1974) for all of Montana from 1967 to 1969. Total mortality for lambs alone amounted to 30.9 percent of the 1,995 lambs born during 1975. This figure is lower than the 32.8 percent lamb mortality reported by Henne (1975), but is higher than the 8.4 percent lamb mortality reported by Nesse et al. (1976) on seven ranches in California during 1973. However, it is nearly the same as the 32.4 percent lamb mortalities observed by DeLorenzo and Howard (1976) during 1974 in New Mexico, but higher than the 18.1 percent recorded at the same location in 1975.

During Segments A and B, respectively, 355 of 397 (89.4%) and 486 of 617 (78.8%) lamb mortalities were attributed to predation. These percentages are higher than the 2.9 percent mean minimum lamb predation reported by Nass (1976) in Idaho, but are lower than the 40 to 74 percent lamb predation losses reported by Beasom (1976) on various ranches in West Texas. During 1974 and 1975, respectively, DeLorenzo and Howard (1976) attributed 53 of 116 (46) and 52 of 78 (67%) lamb mortalities to predation, lower than those recorded on the Cook Ranch.

More adult ewes and lambs were killed during Segment B than A, and the lower percentage of kills reflected an increase in flock size of 1,048 sheep from Segment A to B. During December 1975, 285 Columbia ewes were added to the original herd and are treated separately in Table 1 since they were exposed to predation for only 3 months.

Natural field deaths. Natural field deaths were those attributed to causes other than predation. Pneumonia, bacterial infections, and weak-calf syndrome were leading causes of natural field deaths among lambs (Table 2) during Segment B, just as in Segment A. Lamb deaths prior to exposure to predation occurred in the lambing sheds and corrals (Table 3), mostly within 1 week of birth. As indicated in Table 3, specific causes of death were often difficult to determine in young lambs. Natural field deaths of adult ewes (Table 4) were primarily due to old-age complications and pneumonia. The increased natural mortality in adult ewes, from 36 during Segment A to 67 during Segment B, reflected the increased average age of the herd from Segment A to B. Ewes bought to replace sheep lost to predation from the original herd were generally older, and therefore more disease prone, than the sheep they replaced.

Table 1. Field mortalities during Segments A and B, percentages of sheep in each category.

	Original						Entire inventory	
	Lambs		Ewes		New Ewes			
	A	B	A	B	A	B	A	B
No. of animals	1,210	1,995	831	1,432	623	285	2,664	3,712
Natural deaths	2.5	5.2	3.2	4.5	1.4	0.7	2.5	4.6
Predator kills	29.3	24.4	8.4	8.1	3.9	1.4	16.9	16.3
undetermined	1.0	1.4	0	0.2	0	0	0.5	0.8
Total field mortality	32.8	30.9	11.7	12.8	5.3	2.1	19.8	21.7

Table 2. Causes of natural field deaths by sex of lambs during Segments A and B, percentages of sheep in each category.

	Ewes		Wethers	
	A	B	A	B
Number examined	9	49	20	54
Accident	0	4.1	0	1.9
Accident and pneumonia	0	0	5.0	0
Bacterial infection	0	16.3	0	18.5
Bloat	0	2.0	0	1.9
Enterotoxemia	0	6.1	20.0	1.9
Founder	0	4.1	0	0
Intestinal blockage	0	2.0	5.0	0
Mother neglect and starvation	0	20.4	0	5.6
Paralysis	0	2.0	0	0
Pneumonia	55.6	16.3	25.0	27.8
Pneumonia and liver infection	11.1	0	10.0	0
Unspecified	22.2	6.1	20.0	13.0
Urinary calculi	0	0	5.0	0
Weak-calf syndrome	11.1	20.4	10.0	29.6

Table 3. Causes of lamb deaths prior to exposure to predation during Segments A and B, percentages of lambs in each category.

	A	B
Number examined	117	49
Abortions	19.7	59.2
Accident	0	2.0
Bacterial infection	0	2.0
Born dead	12.0	0
Exposure	0	20.4
Miscellaneous	45.3	0
Weak-calf syndrome	23.1	12.2
Unspecified	0	4.1

Undetermined deaths. During Segment B, causes of death were undetermined for 31 sheep. Twenty-two lambs were unaccounted for and nine carcasses were too decomposed for necropsy (Table 1). Henne reported 12 sheep deaths from undetermined causes, seven lambs unaccounted for and five carcasses too decomposed. These undetermined deaths comprised 0.8 and 0.5 percent of the herds during Segments B and A, respectively. Missing lambs may have been: overlooked carcasses, especially during summer months when vegetation was thickest and scavenging birds left the ranch area; small lambs removed from pastures by predators;

Table 4. Causes of natural field deaths for adult ewes during Segments A and B, percentages of ewes in each category.

	A	B
Number examined	36	67
Accident	5.6	1.5
Bacterial infection	0	13.4
Bladder infection	2.8	0
Blindness	2.8	0
Bloat	11.1	0
Enterotoxemia	5.6	3.0
Intestinal blockage	2.8	1.5
Lambing complications	0	4.5
Mastitis	2.8	9.0
Old age complications	8.3	13.4
Old age and intestinal blockage	5.6	0
Old age and pneumonia	13.9	16.4
On back, suffocated	2.8	1.5
Operational difficulties	2.8	0
Paralysis	2.8	0
Pneumonia	22.2	25.4
Pneumonia and liver infection	2.8	0
Severe maggot infestation	0	4.5
Unspecified	5.6	6.0

or lambs which crawled under fences into pastures beyond the range of searches.

Health of sheep killed by coyotes. Of the 602 sheep killed by coyotes during Segment B, health could be determined for 345 (Table 5). Since viscera were usually eaten before flesh, health could not be determined for many sheep fed upon by predators and/or scavengers. The total percentage of healthy lambs killed was slightly less, whereas the percentage of lambs with abnormalities or severe disorders was slightly higher in Segment B than in A. Animals were classified as healthy if the viscera were intact and the investigators could not discern abnormalities when examining carcasses in the field. Sheep were classified as having abnormalities if disease symptoms had not progressed to the point where movements and feeding were impaired. Sheep with severe disorders were those whose movements and feeding were impaired by disease. Figures for both Segments do not indicate a selection by coyotes for either healthy or unhealthy sheep ($X^2 = 3.24$, $p>0.05$, d.f. = 3). Killing patterns in Segments A and B indicated that coyotes were generally able to kill healthy sheep as easily as sick sheep.

Table 5. Health at time of death by sex and age class during Segments A and B, percentages of sheep in each category.

	Segment	Male lambs	Female lambs	Adult ewes	Totals
Number examined	A	101	94	76	271
	B	124	144	77	345
Healthy	A	73.3	77.7	75.0	75.3
	B	66.1	75.7	59.7	68.7
Abnormalities present	A	19.8	18.1	18.4	18.8
	B	23.4	16.0	28.6	21.4
Severe disorders evident	A	6.9	4.2	6.6	5.9
	B	10.5	8.3	11.7	9.9

Handicapped and wounded sheep. As in Segment A, numbers of wounded limping, or sick sheep were recorded to determine whether or not they were later selected by coyotes. Results (Table 6) showed no significant selection ($X^2 = 6.45$, $p>0.05$, d.f. = 3) for disabled sheep during either A or B.

Table 6. Percentages of handicapped sheep killed by coyotes during Segments A and B.

	Number observed		Number killed	
	A	B	A	B
Number examined	21	124	7	16
Handicapped (sick or crippled)	42.9	54.8	14.3	68.8
Wounded	57.1	45.2	85.7	31.3

Secondary Losses. Although secondary losses are hard to measure, they are reflected in lambing success, excitability of herds, growth and fattening of lambs, and loss of unborn lambs.

Ewe lambs retained from the 1975 lamb crop for breeding were kept in a separate pasture from 6 September to 29 December 1975. During that period, 43 of the 210 ewe lambs were killed. The lambing percentage for the surviving ewe lamb herd was 65 in 1976, down from 110 percent in 1975. Harassment by coyotes was probably one of the variables that caused the reduction of breeding efficiency.

Mr. Cook and his ranch hands reported that the sheep became harder to work with each year as predation increased. I noted that entire herds were excitable after

nights when multiple kills occurred. The sheep would "bunch-up" at my approach and run for a short distance.

The 1975 lamb crop, the last of which was shipped on 1 November 1975, was the latest to be shipped since Mr. Cook began raising sheep on this ranch. Above average precipitation fell during the summer of 1975 and the pastures were in excellent condition. At normal weaning and shipping time (1 September), less than half of the lambs were ready for market. The rest were held on pastures and stubble fields where they gleaned waste grain until 19 October. At that time, approximately 13 percent of the original lamb herd was still undersize and was not shipped with the rest. The possibility exists that many of the "runt" lambs were orphaned or otherwise influenced by coyote harassment. These small lambs did not fatten well even when placed in corrals and fed grain.

Adult ewes killed during the gestation period (December through March on the Cook Ranch) represented not only the loss of that ewe but also the lambs she would have produced. An accurate count of lambs lost to prenatal predation was impossible because coyotes typically fed upon the uteri of pregnant ewes. Despite intensive predator control during autumn 1975 and winter 1975-76 and moving the ewes to pastures near ranch headquarters on 23 January 1976, 49 ewes were killed during the gestation

period. When the herds went to pastures in the springs of 1974 and 1975, the ratio of ewes to lambs was approximately 1:1.4. Multiplying 1.4 times the 49 ewes killed during gestation in 1975 indicates that 68 unborn lambs, that might have gone to pastures in the spring of 1976, were killed by coyotes.

Types of predator kills. Coyotes were responsible for 99.3 percent of predator kills found during Segment B, and 97.1 percent in Segment A (Table 7). Coyotes were responsible for 77.4 percent of all predator kills on the McKnight Ranch in New Mexico (DeLorenzo and Howard 1976), 82 percent of predator losses on seven ranches in California (Nesse et al. 1976), and 73 percent of all predator losses on selected ranches in Idaho (Nesse et al. 1976). During Segment B, one fox kill was recorded and three deaths were attributed to ravens, the latter involved young lambs weakened by disease. Dogs were never seen in or near either sheep herd nor were dog kills verified during Segment B. Golden eagles, often seen scavenging on sheep killed by coyotes, were not known to kill sheep during Segment B.

Location of wounds. Significantly greater numbers of sheep were killed by neck and throat attacks during Segment B than in A ($X^2 = 9.83$, $p<0.25$, d.f. = 3). Neck and throat attacks were the method of killing in 80.4

percent of the sheep killed by coyotes during Segment B, compared to 71.8 percent in Segment A (Table 8). Although more instances of bites on the tops of heads were recorded in Segment B than in Segment A, one or two bites were typically made around the head, throat, and neck regions during both Segments. Possibly the significantly higher percentage of neck and throat wounds during my study reflected a trend toward older and smarter coyotes resulting from minimal predator control. DeLorenzo and Howard (1976) also found that neck and head areas were the primary locations for coyote attacks.

Table 7. Percentages of sheep killed by five species of predators during Segments A and B.

	Lambs killed		Ewes killed		Total No. Killed		% All Predation	
	A	B	A	B	A	B	A	B
Coyotes	80.0	80.1	20.0	19.9	436	602	97.1	99.3
Dogs	0	0	100.0	0	6	0	1.3	0.0
Foxes	100.0	100.0	0	0	3	1	0.7	0.2
Eagles	100.0	0	0	0	2	0	0.4	0.0
Ravens	50.0	100.0	50.0	0	2	3	0.4	0.5
Total					449	606	100.0[a]	100.0[a]

[a]After correcting rounding error.

Table 8. Location of wounds inflicted by coyotes during Segments A and B, percentages of sheep in each category.

	Segment	Neck-Throat	Neck-Face	Neck-Throat Other	Decapitated	Head-Throat Other	Total Examined
Total number	A	313	30	33	20	40	436
By category	B	438	2	27	10	68	545
Adult ewes	A	24.0	26.7	12.1	0	0	
	B	18.3	100.0	18.5	0	2.9	
Ewe lambs	A	43.4	36.7	48.5	45.0	30.0	
	B	46.3	0	51.9	80.0	48.5	
Wether lambs	A	31.3	36.7	39.4	50.0	67.5	
	B	35.4	0	29.6	20.0	48.5	
Unknown sex	A	1.3	0	0	5.0	2.5	
	B	0	0	0	0	0	
% of total selected	A	71.8	6.9	7.6	4.6	9.2	
	B	80.4	0.4	5.0	1.8	12.5	

Kill sites. Bottoms of draws, ravines, and washes were classified as low areas; all other sites were classified as high. Percentages of lambs and ewes killed in low areas of the ranch were significantly lower during Segment B than in A, ($X^2 = 15.5$, $p<0.01$, d.f. = 3) although the numbers of ewes killed in low areas during Segment B increased after lambs were sold (Table 9). From 15 November 1975 to 15 January 1976, 52.5 percent of the ewes killed by coyotes were found in draws or ravines. During winter months, tracks of sheep chased by coyotes often led from bedding grounds on high sites down to bottoms of draws where carcasses were found. When catching sheep for predator control studies, workers found that sheep slowed down when they approached bottoms of draws, especially if chased in herds, a factor coyotes probably used to their advantage.

Table 9. Kill sites in pastures with low areas during segments A and B, percentages of sheep in each category.

	Killed in low area		Killed on open ground	
	A	B	A	B
Number examined	102	149	150	417
Ewe lambs	41.9	21.0	58.1	79.0
Wether lambs	39.3	21.3	60.7	78.7
Adult ewes	39.7	48.6	60.3	51.4

Predator sightings and times of kills. From 15 March 1975 to 14 March 1976, coyotes were sighted on the ranch 61 times, dogs three times, and foxes twice. Twice, coyotes were observed chasing sheep but were never seen in the act of killing. During summer months of both Segments, kills typically occurred during early morning hours before searching of pastures began. During autumn and winter of Segment B, coyotes killed sheep later in the morning and were observed leaving fresh sheep kills on nine occasions. One coyote was observed feeding on a ewe at 1000 on 23 September 1975, and closer inspection, after the coyote left, revealed that the ewe was still alive, had a neck wound, and her abdomen was torn open.

Feeding on kills. Coyote feeding patterns were classified as follows:

1) extensive feeding--all organs and most muscles removed;

2) moderate feeding--some organs and muscles remaining;

3) light feeding--a portion of either the sternum, front or hind legs, or the entrails removed;

4) very light feeding--small areas of feeding noticeable; and

5) no consumption--carcasses left intact (found most frequently on days with multiple kills).

Feeding habits of coyotes were significantly different during Segments A and B (Table 10, $X^2 = 71.5$, $p<0.01$, d.f. = 9). More sheep were not fed upon and less were fed upon extensively in Segment B than in A. During Segments A and B, 9.1 and 15.5 percent of the carcasses examined for feeding patterns were left intact. DeLorenzo and Howard (1976) reported that 47.6 and 37.5 percent of the carcasses were not fed upon during 1974 and 1975 in New Mexico. This behavior is not completely understood, but Fox (1971) reported that "the prey killing response of a canid has a very high satiation level", a possible explanation for the phenomena of leaving carcasses intact and killing up to 12 sheep during a single night. Availability of prey is also important when considering feeding and killing patterns. The large number of lambs suddenly available when lambs and ewes were released in relatively isolated pastures during April and May might have triggered the killing response described by Fox (1971). Nass (1976) observed that most of the lambs killed by coyotes during his study in Idaho were found during the first 6 weeks after the sheep were released on the range. The amount of natural prey available to coyotes may influence the killing of livestock. Klebenow (1976), after evaluating alternate prey sources in Nevada, concluded that a relationship exists between natural prey and coyote predation on domestic sheep. He did not find a

direct relationship between increases in predator kills of domestic sheep and sharp declines in major natural prey species; however, coyotes inhabiting areas with low natural food bases had a greater tendency to kill sheep and fed more extensively on them than coyotes did in areas with abundant prey.

There are strong indications that individual coyotes that develop the habit of killing domestic livestock are the source of most predator kills. Henne (1975) reported that characteristic killing patterns could be recognized on several occasions during Segment A. Reichel (1976) concluded that with small, enclosed pronghorn (Antilocapra americana) herds individual coyotes that had developed a proficiency for killing fawns might be more of a detriment to antelope productivity than large numbers of coyotes. The localized nature of predation on domestic livestock also supports the idea that certain coyotes are the source of most problems. DeLorenzo and Howard (1976) observed that the level of predation was not consistent on ranches in New Mexico. Reichel (1976) found that only four of 593 scats collected during 1974-75 on the National Bison Range, approximately 60 miles north of the Cook Ranch, contained the remains of sheep. In DeLorenzo and Howard's (1976) words, "Perhaps the best approach for either federal or state agencies is to concentrate on key problem areas

at specific times during the year and whenever possible on problem individuals within the predator population."

Table 10. Percentages of carcasses fed upon by predators during Segments A and B.

	Segment	Ewe lambs	Wether lambs	Adult ewes	Total
Examined	A	172	144	79	395
	B	240	185	98	523
No consumption	A	11.6	8.3	5.1	9.1
	B	17.1	20.5	2.0	15.5
Very light	A	12.2	11.1	8.9	11.1
	B	25.4	30.3	45.9	31.0
Light	A	25.0	25.7	36.7	27.6
	B	22.5	22.2	31.6	24.1
Moderate	A	33.7	40.3	43.0	38.0
	B	27.9	17.3	18.4	22.4
Extensive	A	17.5	14.6	6.3	14.2
	B	7.1	9.7	2.0	7.1

Lambs selected by predators. The ratio of singles to twin lambs on the ranch during Segment B was 1:3.5, and since both herds were mixtures of twins and singles, the frequency of coyote attacks on twins and singles was compared (Table 11). Twins were not attacked significantly more often than singles during Segment B; (X^2 = 1.15, $p>0.05$, d.f. = 3) whereas, during Segment A twins were attacked significantly more often than singles (Henne, 1975). Since twins and singles were kept in separate herds

during Segment A, only an indirect comparison of twins versus singles attacked could be made.

Table 11. Sex of lambs and a comparison between numbers of twins and single lambs killed by coyotes during Segments A and B.

	Sample size		Total killed		% killed	
	A	B	A	B	A	B
Ewes		960	162	267	13.6	27.8
Wethers		896	140	199	11.9	22.2
Unknown		16		14		
Twins	844	1,523	247	291	29.3	18.2
Singles	344	461	61	99	17.7	21.1
Unknown		92		92		

Another comparison made during both Segments was between the numbers of ewe lambs and wether lambs attacked by coyotes (Table 11). Henne found significantly more ewe lambs were attacked than wethers during Segment A and proposed that there may be subtle, behavioral differences between ewes and wethers which make ewes more subject to attack. During Segment B, ewe lambs were not attacked significantly more often than wethers ($X^2 = 7.60$, $p>0.05$, d.f.= 3).

No black lambs were born on the ranch during Segment B; therefore, no comparison could be made with findings from Segment A that all four black lambs born on the ranch were killed by predators.

Average number of kills per day. The average number of kills per day, a figure computed on a monthly basis, reached a high of 3.57 in June 1975 when lambs were 2 to 3 months old and were relatively far from the ranch headquarters. A low of 0.03 kills per day occurred during February 1976 when lambs had been sold, testing of predator controls had been completed, and ewes were within 0.25 miles (0.40 km) of the ranch headquarters. Henne reported similar trends during Segment A (Fig. 2).

Leaving carcasses as carrion. From 2 August to 8 September 1975, 63 sheep carcasses were left in the field to determine the frequency of refeeding by predators. Carcasses were left undisturbed except for verification of causes of deaths. Evidence of refeeding was found on only two of the carcasses left in the field. The presence of these carcasses did not affect the average daily kills (Fig. 3). A similar test during Segment A also resulted in two instances of refeeding. Scavenging birds rapidly cleaned up meat exposed by predators and the remaining portions of carcasses decomposed rapidly since they were infested with fly larvae (Diptera) within 1 day.

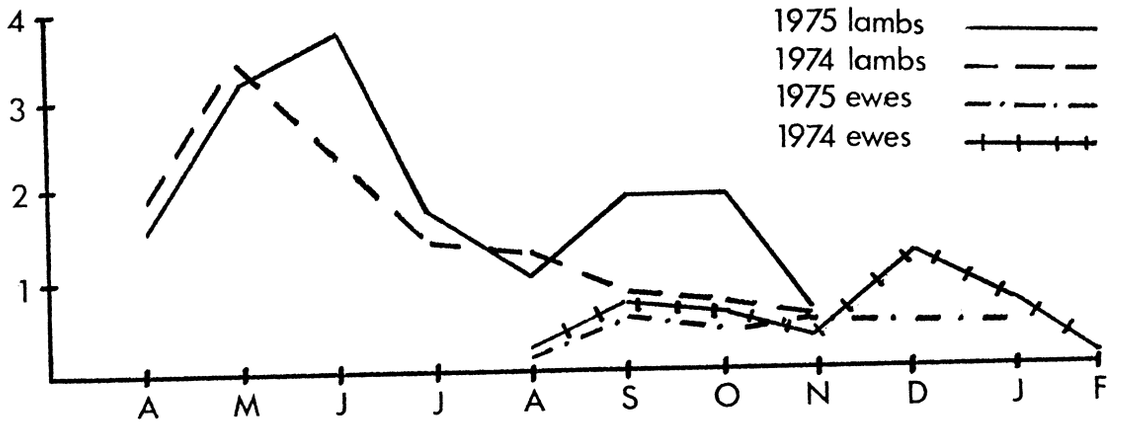

Fig. 2. Average Daily Kills by Month.

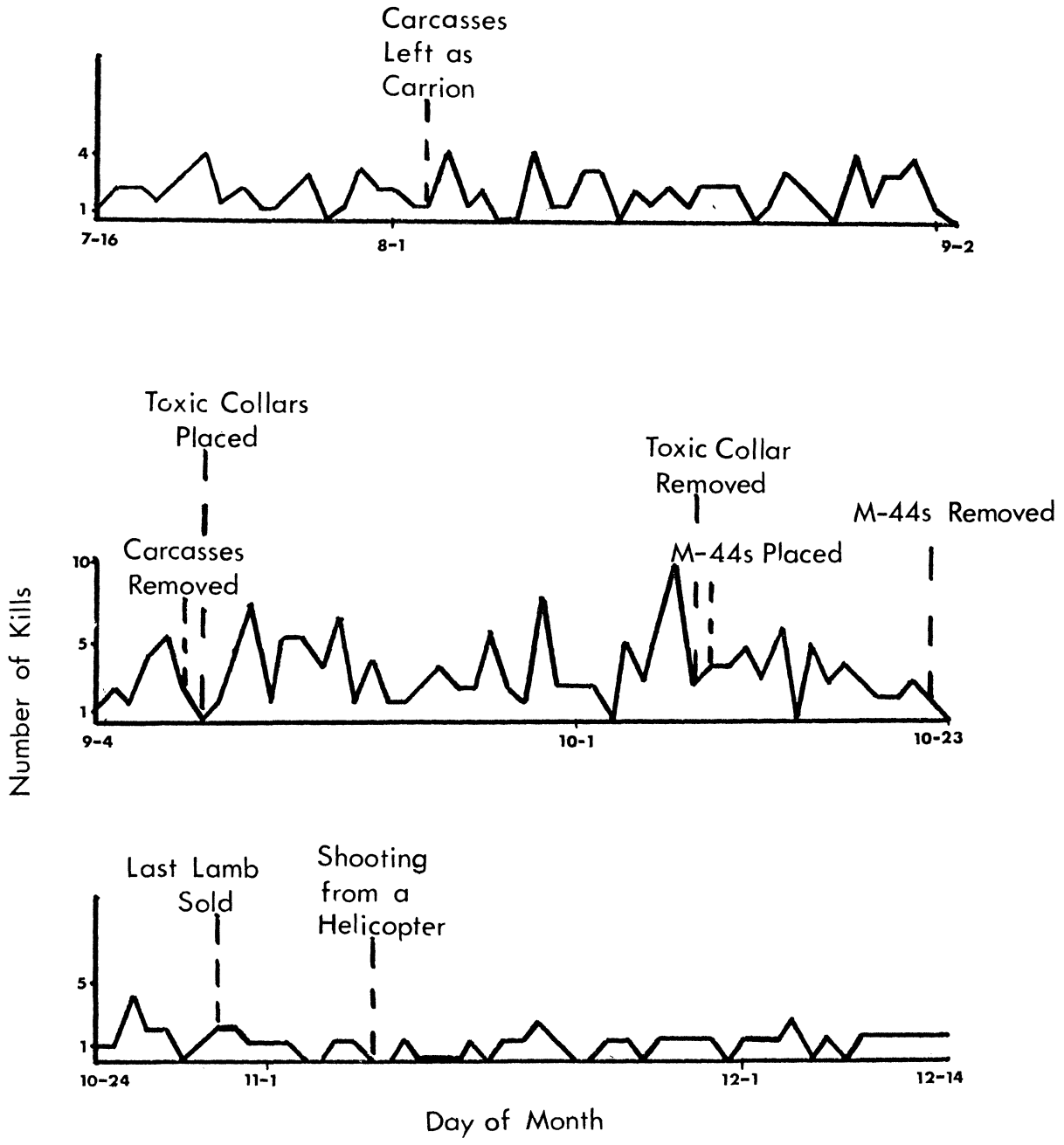

Fig. 3. Daily Predator Kills from 15 June 1975 to 14 March 1976.

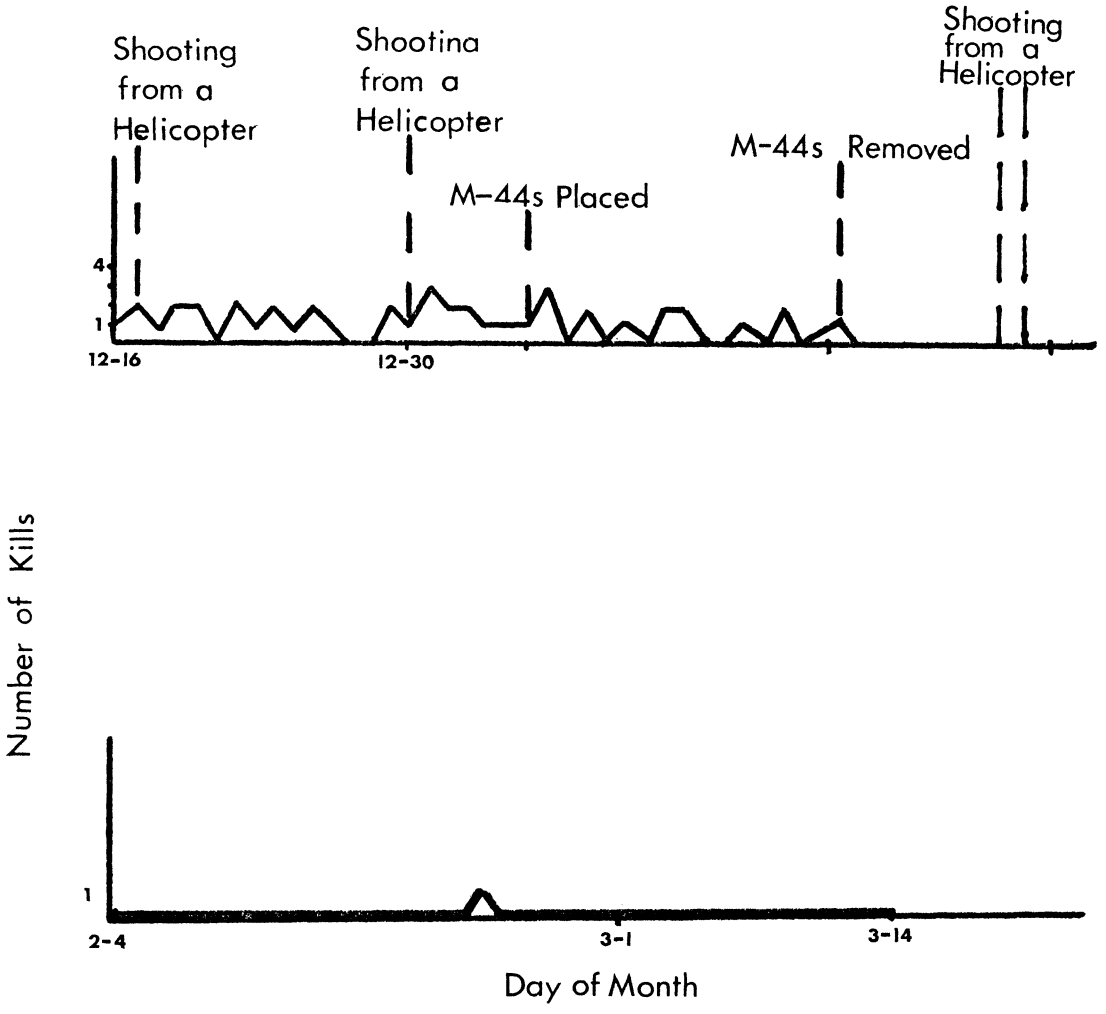

Fig. 3 Continued.

Radiotracking Coyotes

Fig. 4 indicates locations of three coyotes radiocollared during Segment B. Coyotes A and B were taken in steel traps baited with coyote urine and neither animal was injured severely. One, Coyote A, was trapped twice at different sites. Neither animal was consistently found in or around the sheep herds, and they generally remained 0.5 miles (0.80 km) SE of the ranch on the Three Mile Game Range. Coyote A was found seven times on the ranch and coyote B twice. Sheep were in the pasture immediately south of A's recorded position on one occasion, but B was never recorded near either sheep herd. B was last located 3 miles (4.8 km) north of the ranch in October 1975. Coyote C was tranquilized from a helicopter and radiocollared on May 1975. Generally, C remained on the west end of the ranch within 1 mile (1.6 km) of ranch headquarters and may have been responsible for two kills found in areas where C had been located the night before. Prior to being killed on 16 November 1975 by an M-44, C was recorded 21 times at positions within and 10 times outside ranch boundaries. The radiocollar was still in good working order with no outward sign of wear, and when necropsied, C showed no apparent injuries from the collaring.

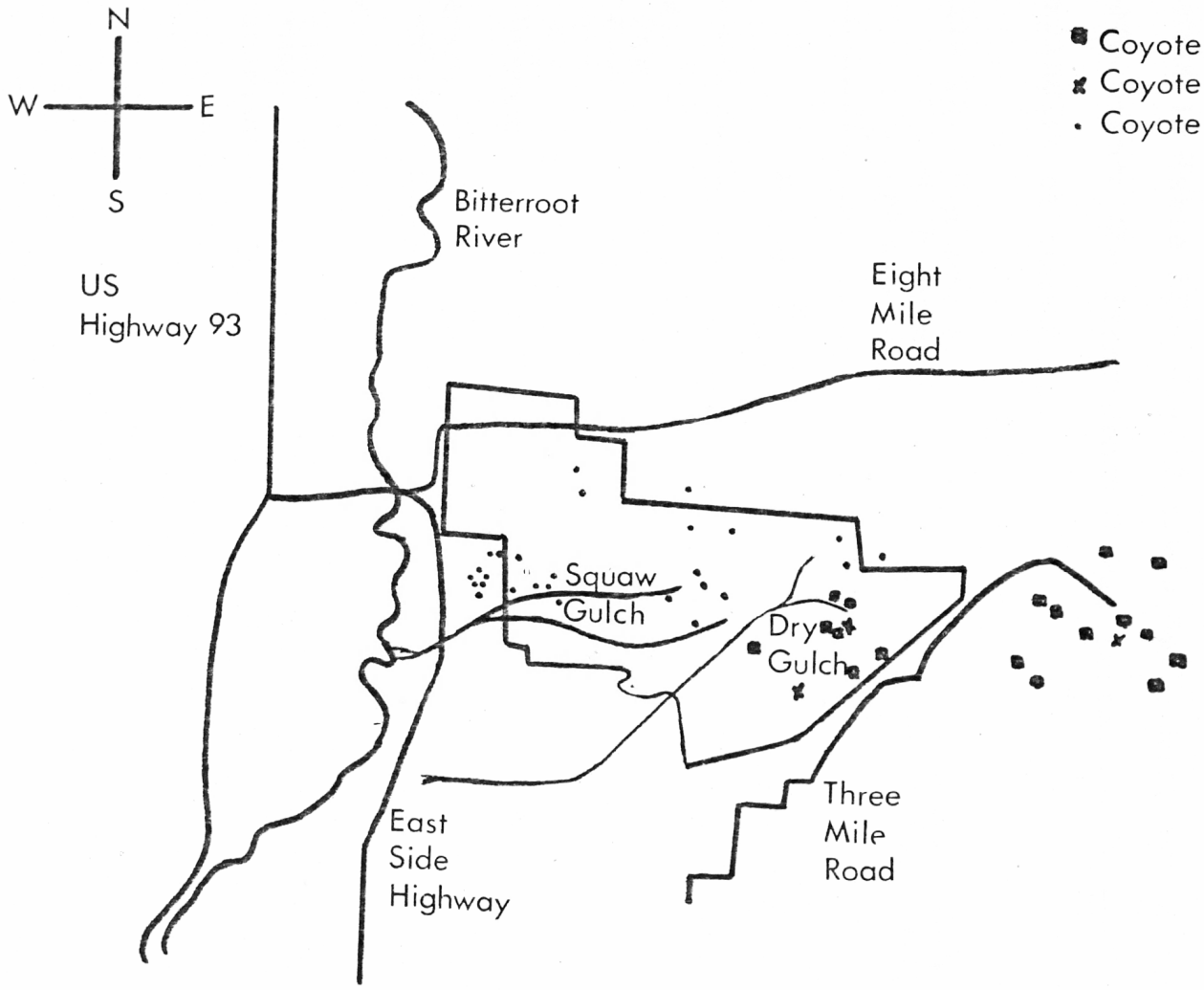

Fig. 4. Locations of Coyotes A, B, and C (2.4 in.=1 mi. or 6.1 cm.=1.6 km.).

Predation Controls

During Segment B, 44 coyotes were taken by three predator control methods (M-44s, shooting from a helicopter and snares) plus two coyotes were shot from the ground. Sexes, ages, and average weights of these 46 coyotes are listed in Table 12. Fig. 2 gives daily kill rates for a month before the first control was tested until the conclusion of Segment B.

Table 12. Numbers of coyotes killed during Segment B, with ages in years, sexes, and average weights (pounds/kilograms).

	M-44s	Helicopter shooting	Shot from ground	Snares	Total
Age:					
Pup	11	4	0	1	16
0.5	1	10	1	2	14
1.5	0	5	0	0	5
2.5	3	3	0	0	6
Unknown	3	1	1	0	5
Average weight	22.7/10.2	24.5/11.0	24/10.8	19/8.6	
Sex:					
Male	7	11	1	0	19
Female	9	12	1	3	25
Unknown	2	0	0	0	2

M-44s. The first conventional predator control device used, after the unsuccessful toxic collar test, was the M-44. M-44s were used during two, 2-week periods at different seasons (Table 13). Test I, from 10 to 22 October 1975, resulted in 16 coyotes killed by 20 M-44s found pulled. No coyotes had been killed during Segment B prior to Test I and weather conditions were mild and relatively dry. During Test II, from 5 to 21 January 1976, two coyotes were killed by six M-44s found pulled. Prior to Test II, 29 coyotes had been killed during other control tests and cold, wet weather was prevalent. The number of M-44 nights per coyote taken was 13.5 and 104 during Test I and II, respectively. This compares to 229 M-44 nights per coyote taken reported by Beasom (1974) in south Texas. The Beasom study utilized several other predator control devices during the same time M-44s were used. His primary objective was not to monitor the results of M-44s, but, rather, to clear a study area as completely as possible of predators.

Coyote tracks were found near, and teeth marks were evident on the shell holders of M-44s pulled during Test II when no coyotes were killed. Causes of M-44 failures may have been either cyanide capsules which were faulty and the powdered NaCN became solidified or firing mechanisms which malfunctioned, especially during below freezing temperatures during Test II. If cyanide solidified, coyotes were

probably able to spit out the poison before receiving a lethal dose.

Table 13. Comparison of two M-44 test periods during Segment B.

	Test I 10-22 Oct. 1975	Test II 5-21 Jan. 1976
Males	7	1
Females	9	1
Number pulled	20	6
% success	80[a]	33.3
Number set	18	13
M-44 nights per coyote taken	13.5	104

[a]Includes one fox killed by M-44.

Advantages of M-44s included: the devices were easy to set and check; they were relatively effective in dry weather; and they killed coyotes quickly. Dead coyotes were generally found within 30 yds. (27.4 m) of pulled M-44s. Disadvantages of M-44s were that these devices frequently failed during cold, wet weather, and they appeared to be selective for young coyotes. Of the 15 coyotes killed by M-44s, 12 were 0.5 year old or younger. M-44s seemed effective for population controls of coyotes, but for older, sheep-killing coyotes that must

be killed on short notice, other methods would probably be more effective.

Shooting from helicopter. Lewis killed 13 coyotes during flights on 7 November and 16 and 30 December 1975. Severson shot 10 coyotes on 28 and 29 January 1976 (Table 14). When Lewis gunned, 18 coyotes had been killed by predator controls and sheep were being killed regularly by predators. When Severson gunned, 31 coyotes had been killed by predator controls; sheep predation was at a low and the sheep were close to ranch headquarters. On the average, three coyotes were taken per helicopter hour. Shooting from a helicopter did not stop predation the first time used and after the second hunt in January, the sheep were located near ranch headquarters where effect on predation could not be adequately assessed (Fig. 2). Shooting from a helicopter was most efficient in open areas with fresh snow. Its disadvantages were the high cost of operation ($125.00 per hour) and the necessity of having experienced gunners. The major advantages were that more older coyotes were killed by shooting from a helicopter than by any other means tested during Segment B, and predation could be dealt with rapidly. Of 23 coyotes killed by shooting from a helicopter, eight were older than 0.5 years.

Table 14. Coyotes shot from a helicopter during Segment B.

	7 Nov. 1975	30 Nov. 1975	16 Dec. 1975	28. Jan. 1976	29 Jan. 1976
Killed	0	2	11	5	5
Ave. weights			22.5	26.8	24.2
Age:					
Unknown		0	1	0	0
0.5 or less		1	7	3	3
1.5		1	2	1	1
2.5		0	1	1	1
Weather	mild no snow	cold trace of snow	cold fresh snow	mild trace of snow	mild no snow

Snares. Three coyotes, two foxes, and one domestic dog were caught in snares placed by Severson from 20 January to 13 March 1976. Prior to tests using snares, 21 coyotes had been killed by other means and the ranch foreman had caught a coyote in one of several snares he set.

Because the ARS-CR2 test was only a preliminary trial, results were insufficient for statistical evaluation. Therefore, no results or conclusions were published by Gates following the ARS-CR2 test. Further tests are currently underway by Gates and results will be analyzed after these tests are completed.

Toxic collars. From 9 September to 8 October 1975, I participated in a test of the toxic collar under the direction of Guy Connolly, Denver Wildlife Research Center. Seven tethered lambs outfitted with sodium cyanide collars were attacked by coyotes. Four of these seven lambs were bitten on the neck, resulting in one punctured packet in each case, but no dead coyotes were found. On three lambs attacked from the rear, the collars were not broken. Two of the collared lambs which were attacked were not killed. Of the five lambs killed, coyotes fed extensively on three and heavily on two. As tested, the sodium cyanide collars were ineffective. They were conspicuous and the toxicant had a strong odor and probably an adverse taste. Attacking coyotes apparently detected the poison and broke off the attack before receiving a lethal dose. Work is currently underway in the Denver Research Center to improve the toxic collar and select more effective toxicants.

Location of coyotes killed by control devices during Segment B. Of the 23 coyotes shot from a helicopter, 14 were killed on the ranch and nine were killed outside, but within 1 mile (1.6 km), of ranch boundaries (Fig.5). The 21 coyotes killed by other predator controls were taken within ranch boundaries. The total number of coyotes killed on or near the ranch amounted to 1.3 per mi^2 (0.5 per km^2) in a 35 mi^2 (90.6 km^2) area.

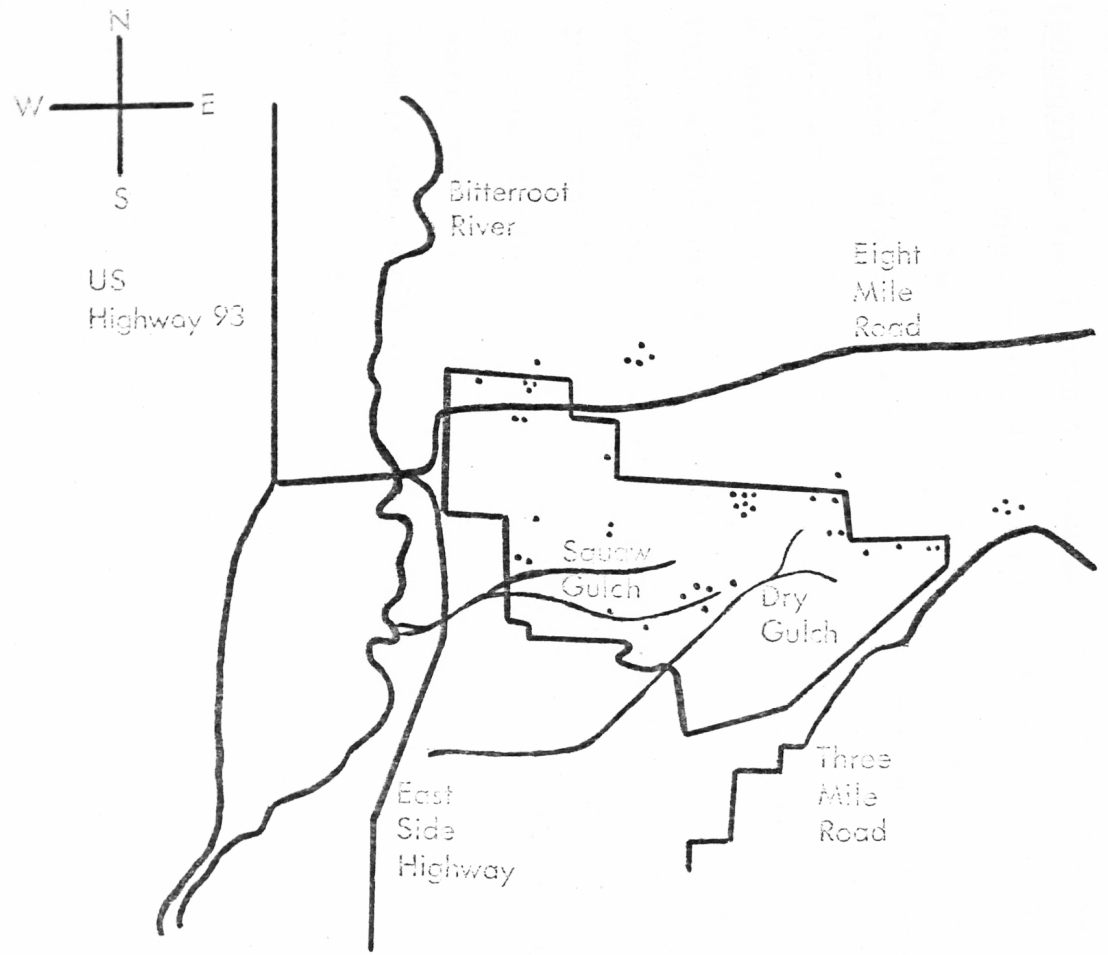

Fig. 5. Locations of 44 coyotes killed by predator controls during Segment B (2.4 in. = 1 mi. or 6.1 cm. = 1.6 km.).

Stomach contents of coyotes killed. Stomach contents of 34 coyotes were examined and often more than one food item was found in an individual coyote's stomach. Of 29 coyotes that had food present in their stomachs, 12 had fed upon mice (Microtus spp.), 11 upon sheep (Ovis aries), 8 upon cattle (Bos taurus), 4 upon red osier dogwood (Cornus stolonifera), and 1 each upon deer (Odocoileus spp.), rabbit (Lepus spp.), and insects (Fig. 6). One coyote, killed by an M-44 50 yds (45.7m) from a fresh lamb kill, had 6.3 lbs (2.9 kg) in its stomach. Average stomach content weight was 1.8 ozs (56.0 gr) for 34 coyotes. Four coyotes had no measurable stomach contents. Reichel (1976) reported that Microtus, with a 69.8 percent frequency of occurrence, was the most important prey item found in coyote scats during 1974 and 1975 on the National Bison Range. Other important food sources included native ungulates during late spring and early summer; insects, seeds, and berries during late summer and early fall; and cattle during winter.

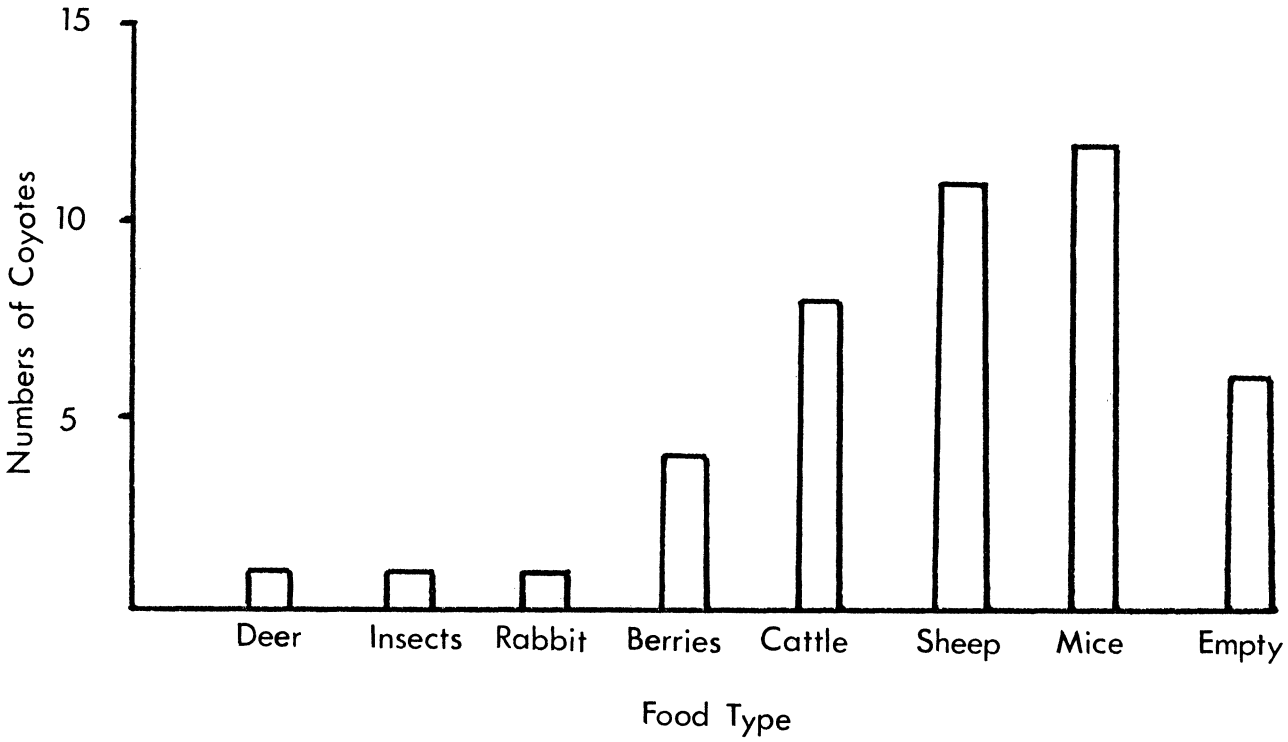

Fig. 6. Frequency of occurence of various food items in stomachs of 34 coyotes collected during Segment B.

CHAPTER IV

SUMMARY

Causes of domestic sheep mortality on a western Montana ranch were documented from 15 March 1975 to 14 March 1976. Henne (1975) had collected similar mortality data for the production year 15 March 1974 to 14 March 1975. During both studies, predators were not controlled from the beginning of lambing (March) until marketing (September). Predators were controlled on a limited basis after marketing of lambs in 1974-75 and on a more extensive basis during 1975-76.

Occupied sheep pastures were searched daily from horseback or truck, depending on the terrain, vegetation, and time of year. Sheep carcasses were necropsied in the field with special emphasis placed on determining locations of wounds, if any, and health of the sheep at the time of death.

During the first year, 449 (16.9%) of the total flock (2,664 sheep), including 355 (29.3%) of 1,210 lambs born in 1974, were killed by coyotes. During the second year, 606 (16.3%) of the total flock (3,712 sheep), including 486 (24.4%) of 1,995 lambs born in 1975, were

killed by coyotes. Twelve (0.5%) sheep were not accounted for during 1974-75 and 31 (0.8%) during 1975-76.

Sheep killed by coyotes were generally healthy and no selection for sick sheep was noted. Of the sheep killed by coyotes during the first and second years, 71.8 percent and 80.7 percent, respectively, were bitten on the neck and throat.

Coyotes were sighted on the ranch 61 times, dogs 3 times, and foxes twice during 1975-76. On several occasions, coyotes were sighted feeding on or in the vicinity of recently killed sheep, and twice coyotes were observed chasing sheep. Feeding on kills was most often light to moderate, and return feeding was not common during the summer months of either year.

Sheep lost to natural causes accounted for 2.5 percent of the total losses during the first year and 4.6 percent during the second year. Wet, cold weather during spring 1975 and older age of ewes probably accounted for the differences in natural mortality. Pneumonia, weak-calf syndrome, and old age complications were the primary causes of death during both years.

Secondary losses, resulting from harassment by coyotes, included reduced lambing success, increased excitability of flocks, reduced growth rates and difficulty in fattening lambs, and loss of unborn lambs.

Success of three conventional predator controls and two experimental predation controls was monitored from 10 September 1975 to 13 March 1976. Conventional controls included shooting from a helicopter, M-44s, and snares. From 12 October 1975 to 13 March 1976, 44 coyotes were killed, 23 by shooting from a helicopter, 18 by M-44s, and 3 by snares. Stomach contents from 34 coyotes were examined, and, of 29 coyotes that had food in their stomachs, 11 contained wool. The two experimental predation controls were the sodium cyanide collar and a spray-on adversive agent, ARS-CR2. As used, neither method reduced predation.

Three radiocollared coyotes, tracked from 15 July to 30 August 1975, were found most of the time away from sheep flocks; while radioed, one of these coyotes could have been involved in killing two sheep.

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