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RELATIONSHIPS BETWEEN SHEEP MANAGEMENT AND COYOTE PREDATION

by

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INTRODUCTION

Predation by coyotes (Canis latrans) on sheep (Ovis aries) flocks has been considered to be a major problem among stockmen in the western half of the United States since the mid-1800's. Through the 1960's, control of coyote numbers by trapping, poisoning, shooting, and den hunting was the principal goal of government programs and bounty systems in an effort to resolve the conflict (Wagner 1972). The attitudes of the public concerning predator control changed during the 1960's (Leopold et al. 1964), and climaxed in 1972 with the banning of the use of all toxicants for predator control on public land (Nixon 1972).

Emphasis in coyote damage control has been directed toward non-lethal methods following the ban on toxicants. Research in this area has increased tremendously since 1972, with studies conducted in relation to causes and magnitude of sheep losses (Bowns et al. 1973; Davenport et al. 1973; Henne 1975), behavior (Jansen 1974, Lehner 1976), taste-aversion conditioning (Gustavson 1974), olfactory repellents (Lehner et al. 1976), and toxic collars (Willson 1975). However, few, if any, recent studies have given results that have been of direct benefit to the livestock producer (Linhart 1975).

Factors related to the management of sheep have been suggested as being important in reducing or preventing losses to coyotes. Fencing (Jardine 1908, 1909, and 1911; Shelton 1973a; Thompson 1976), lights (Gier 1968), bells (Hawbecker 1939), dogs (Howard 1974b), confinement at night (Gier 1968) and during lambing

(Early et al. 1974a and 1974b), and method of disposal of sheep carcasses (Boggess 1975) have all been suggested as possible factors in relation to predation by coyotes; however, an intensive study of these factors has never been conducted.

Statements by two authors best summarize the need for a study of the relationships between sheep management and coyote predation. Gilbert (1973:45) states that "steps taken to prevent the initial attack may be much more practical than attempts to break the killing habit." Balser (1974b:173) reported: "Ultimately, we should be able to characterize losses to predators so a more refined management program can be designed to alleviate damage." Lack of knowledge in the area of coyote damage prevention through management was ample justification for this study.

LITERATURE REVIEW

Conflicts between livestock and predators have occurred in the United States since domestic animals were first introduced (Presnall 1949). Losses of cattle (*Bos taurus*), sheep, swine (*Sus scrufa*), goats (*Capra hircus*), and poultry have occurred most often (Balser 1974b), with wolves (*Canis lupus* and *C. niger*), coyotes, mountain lions (*Felis concolor*), bobcats (*Lynx rufus*), and dogs (*Canis domesticus*) being the principal predators (Wentworth 1948). Today, the conflict centers on predation by coyotes on sheep and lambs (Cain et al. 1972; McCabe and Kozicky 1972; Balser 1974a and 1974b).

Most of the sheep-coyote problem occurs in the 17 western states. About 80 percent of the sheep in the United States are in the states west of and including North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas (Gee and Magleby 1976). Historically and presently, the highest densities of coyotes occur in this same area (Young and Jackson 1951), although the coyote has expanded its range to the north (Dobie 1961) and the east (Richens and Hugie 1974).

Several methods have been used in attempts to resolve the livestock-predator problems. The payment of bounties was initiated in the late sixteenth century by the Jesuit Fathers in Lower California (Presnall 1949) and by the Massachusetts Bay Colony in 1630 (Wentworth 1948). This practice was continued and expanded through the 1800's and early 1900's following the assumptions that the bounty system reduced predator numbers and, in turn, predator losses of livestock. In Kansas, bounties were first paid on coyotes in 1877, and the system was in effect through the 1960's (Gier 1968).

The bounty on coyotes came under question as early as 1905 (Lantz 1905a and 1905b). Up to $20,000 per year was being paid in Kansas without materially affecting coyote numbers. The damage attributed to coyotes was likewise not being reduced (Bennitt 1948). Nielsen (1973) reported that bounty hunters would typically hunt where they had the best success (not necessarily where livestock losses were occurring) and would move on after taking the coyotes in an area that were the easiest to trap or shoot. Many bounties were paid to opportunists who, after killing a coyote, decided to collect the bounty. The bounty itself did not create the incentive to hunt. Most bountied animals were taken during the fall and winter months when hunting is easiest. This is, in effect, a harvest of the annual surplus and not a method of population reduction. Fraud was also common in many bounty programs and was a reason (along with the ineffectiveness of the system) for repealing many bounty laws (Young 1932, Gerstell 1941). The bounty on coyotes was removed in Kansas in 1970 (Henderson 1972).

The Federal Government became involved with the issue of predator control on 1 July 1915, when $125,000 was appropriated to the Biological Survey in the Department of Agriculture for organizing a program to reduce losses of livestock to predatory mammals. Annual livestock losses to predators in the West ranged from $20-$30 million at that time (Bell 1921, Henderson 1930). Shooting, trapping, and poisoning accounted for 424 wolves, 9 mountain lions, 11,890 coyotes, and 1,564 bobcats the first year. An outbreak of rabies in 1916 led to an emergency appropriation of $75,000 for rabies control (Bell 1921). By 1926, losses to predators had been reduced substantially, as had the number of gray wolves, primarily through the use of poison baits (Bell 1926). The rabies outbreak had also been controlled. Goldman (1925) advocated extermination of mountain lions and wolves and effective control of coyotes "as their extermination is apparently a practical impossibility" (Goldman 1925:33). He stated that large predatory mammals no longer had a place in the advancing civilization because of their destruction of livestock and game (Goldman 1925 and 1930).

Objections to the policy of extermination of the larger predators were voiced as early as 1925. Howell (1930) and Hall (1930) suggested that the cost of control by the Biological Survey was greater than the loss inflicted by predators. Adams (1930) and Howell (1930) felt that drastic reduction or elimination of coyotes would be followed by excessive increases in rabbits and rodents which would necessitate control of the new pests. Dixon (1930) and Hall (1930) objected to the wastage of fur of animals caught during the summer months when fur was not prime and to the destruction of non-target furbearers that often were not skinned. Dice (1925) stated that the predatory mammals are of great value in scientific study and should not be exterminated. Anthony (1931) called for research on the poisoning program of the Biological Survey and reduction of the use of poisons.

In 1931, Congress supported the existing program by authorizing the Biological Survey to conduct control of predatory mammals and injurious rodents for an additional 10 years (Young 1932). The program was transferred to the Department of the Interior's Fish and Wildlife Service in 1939 and became known as the Division of Predator and Rodent Control. General population reduction of the coyote was the main goal of the Division, but taking of individual, offending animals also became a useful strategy during this period. The control tools most widely used prior to 1940 included trapping, shooting, denning, and poison (usually strychnine) drop baits. In the early 1940's, the cyanide gun or "coyote getter" came into wide use along with thallium later in the decade (Wagner 1972). Sodium monofluoracetate, commonly called 1080, was developed during World War II and was used extensively in predator control beginning about 1948 (Atzert 1971). The program continued along these lines through the 1950's and early 1960's, except that the use of thallium was discontinued because of its high toxicity and nonselectivity (Wagner 1972).

The Leopold Report (Leopold et al. 1964) recommended that the Division of Predator and Rodent Control reassess its goals and that more research be conducted in the area of animal damage control. This report led to the formation of the Division of Wildlife Services (Berryman 1966) with a philosophy based on minimum effective control (Cain et al. 1972). To apply this philosophy, 1080 use was reduced and control was aimed more specifically at troublesome individuals rather than general population reduction. M-44's (spring-loaded cyanide guns) extensively replaced the "coyote getters" during this period, also (Wagner 1972).

To further examine the subject, an intensive study and evaluation of the entire predator control situation was conducted in 1971 by the Advisory Committee on Predator Control (Cain et al. 1972). Fifteen recommendations were suggested, the most important of which was Number 2:

> "We recommend that immediate Congressional action be sought to remove all existing toxic chemicals from registration and use for operational predator control. We further recommend that these restrictions extend to those toxicants used in field rodent control whose action is characterized by the secondary poisoning of scavengers. Pending, and in addition to, such Congressional action, we recommend that the Secretary of the Interior disallow use of the aforementioned chemicals in the federal operational program of predator and rodent control, and that this ruling be made a standard in cooperative agreements with the states. Moreover, we recommend that the individual states pass legislation to ban the use of toxicants in predator control" (Cain et al. 1972:5-6).

This recommendation triggered Executive Order 11643 (Nixon 1972) in February of 1972, restricting the use of chemical toxicants on Federal lands for the purpose of killing predatory mammals or birds. An order issued in March of 1972 by the Environmental Protection Agency (Ruckelshaus 1972) halted interstate shipment of all pesticides registered for use in controlling predatory animals. Sodium cyanide, strychnine, and 1080 were banned because of their highly toxic effect on non-target species and because of the secondary poisoning hazard of 1080.

Experimental use permits for M-44's were granted to several states from February 1974 through February 1975. It was concluded from the experimental period that M-44's are safe and reasonably selective when used by trained applicators under supervision (Matheny 1976). Following President Ford's modification of Executive Order 11643 (Ford 1975), several state Departments of Agriculture and the Department of the Interior obtained registrations approving M-44's for use in predator control (Matheny 1976).

Predator control has also been conducted under private and state sponsorship, but aside from a few bounty records such as Gier (1968), documentation has been poor. During the last 3 decades of the nineteenth century, many ranches employed full-time wolf and coyote hunters (Presnall 1949) and some ranchers today employ trappers to conduct control on their lands (Wagner 1972). Sport hunting and fur trapping also contribute to the harvest by the private sector. In California in 1967-68, sportsmen took about 8 times (84,900) as many coyotes as federal trappers (10,316) according to Howard (1974a). In most cases, tools used by the Federal Government in predator control have also been available to private individuals, and have been used in a similar manner but to an unknown extent.

In Kansas, the bounty system was in effect from 1877 to 1970. The Division of Predator and Rodent Control program was used for a short time during the 1940's and in a few western counties from 1953 to 1967 without state assistance. Cyanide guns, drop baits, and 1080 were used in this program. In 1953, the extension trapper system similar to that used in Missouri (Sampson and Brohn 1955) was begun. Extension specialists teach producers how to stop their losses themselves by using control techniques or changing management practices. The program is a predator damage control program, not predator control as such (Henderson 1972). Although the M-44's were used in Kansas during the experimental use period, they are not presently registered for use in predator control in the state (Matheny 1976).

Prior to 1960, most of the research on coyotes dealt with the search for effective control methods and the determination of the coyotes' relationships with livestock and game animals (primarily through studies of food habits). Food habits have been studied by analyzing stomach contents (Dixon 1925) and scats (Murie 1946). The first complete analysis was done by Sperry (1933, 1934, 1939, and 1941) followed by Bond (1939), Grater (1943), Murie (1945), Fitch (1948), Murie (1951), Fichter et al. (1955), Fitch and Packard (1955), Tiemeier (1955), and Korschgen (1957). From these studies, it was determined that rabbits made up a large portion of the coyote's diet, followed in importance by rodents and livestock (much of which was carrion). Of lesser importance were poultry, game birds and mammals, fruits, and insects. Coyotes seem to be opportunists and take whatever is available. Additional studies of food habits by Ozoga and Harger (1966), Gier (1968), Hawthorne (1972), Chesness (1973), Korschgen (1973), Mathwig (1973), Gipson (1974 and 1975), Meinzer et al. (1975), Boggess (1975), Gipson and Sealander (1976), and Nellis and Keith (1976), have confirmed the results of the earlier studies.

It was recognized early that coyotes in their relations with livestock had the greatest impact on sheep (Presnall 1948). A rule of thumb among sheepmen was that coyotes destroyed about $1.00 worth of lamb and mutton per ewe per year. Coyotes have generally not caused severe problems with cattle operations. Fitch (1948) stated that the coyotes' relations with range cattle are generally harmonious, but occassionally individual coyotes may cause serious damage by learning to kill small calves. Coyotes may also worry heifers in the act of calving which may result in a dead calf (Boles 1949). Severe predation on goats occassionally occurs in areas where these animals are raised in large numbers (Hawbecker 1939). Poultry are quite vulnerable to coyotes when running loose and confinement is necessary to prevent extensive losses (Gier 1968). The first study done to obtain an accurate estimate of predator losses over a state was done by Boles (1949). He estimated the predator losses and costs of control at over $350,000 for 1948 in Kansas.

Sportsmen have often backed predator control programs in the belief that more game can be raised if the predator population is reduced. Several authors in the early 1940's recommended predator control for the enhancement of game populations (Horn 1941; Kartchner 1941; Pauley 1941; Riter 1941). The food habits studies showed that, in general, game animals make up only a small part of the coyote's diet. However, Arrington and Edwards (1951) reported that, through intensive coyote control, an antelope (Antilocapra americana) population was able to increase dramatically. Although in most cases, coyotes are not able to control deer populations through predation (Randle 1943), in certain instances they may account for a large proportion of the fawn mortality (Cook et al. 1971). Removal of coyotes and other predators led to better reproduction and survival in white-tailed deer (Odocoileus virginianus), turkeys (Meleagris gallopavo), and bobwhite quail (Colinus virginianus) in Texas (Beasom 1974a). Other studies of coyotes and game animals have concerned waterfowl nest depredations (Sooter 1946) and predation on elk (Cervus canadensis) (Robinson 1952).

Most of the research on steel traps, coyote getters, poisons, and other control methods was conducted by Robinson (1943, 1948, 1953a, and 1962). Finding the cheapest and most effective means of predator control was the goal of his work. Castro and Presnall (1944) compared the efficiency and humaneness of chain-noose and steel-jaw traps. Ward and Spencer (1947) determined lethal dose levels of 1080 for several predators and scavengers. Balser (1965) described the use of tranquilizer tabs to be used in conjunction with steel traps to make trapping more humane and to allow release of pets unharmed. Little research into non-lethal methods of control was conducted until the 1960's. Balser (1964) and Linhart et al. (1968) used antifertility agents in attempts to suppress reproduction in coyotes with varied success.

Early work on population trends of coyotes was conducted by Robinson (1953b) who determined trends on selected areas in Wyoming, Colorado, and New Mexico. This work was extended (Robinson 1961a, Linhart and Robinson 1972) and served as a basis for modern censusing methods (Linhart and Knowlton 1975). Bennitt (1948) and Gier (1968) attempted to convert numbers of coyotes bountied to actual population sizes. Population dynamics and coyote-prey interactions have been studied intensively by Knowlton (1972), Clark (1972), and Wagner and Stoddart (1972).

Other early research was concerned with diseases and parasites (Day and Shillinger 1935; Eads 1948; Gier 1948 and 1968), aging by tooth cementum layers (Linhart and Knowlton 1967) and tooth wear (Gier 1968), movements (Robinson and Grand 1958, Hawthorne 1971), and hybrids with dogs (Bee and Hall 1951, Kennelly and Roberts 1969) and wolves (Kolenosky 1971).

During the 1960's, the attitudes of the public concerning predator control in general and coyotes in particular were changing (Leopold et al. 1964). Coyotes had historically been thought of as vermin by most people while the methods and magnitude of control by stockmen and government trappers had been questioned by only a few. But public sentiment turned from control of predators more toward aesthetic values as people became aware of and concerned with the coyote-livestock problem. This sentiment reached a peak in the early 1970's—the same time the ban on toxicants was issued (Nixon 1972)—and was stated well by Reed (1972:403): "We feel that it is no longer in the national interest for the Federal Government to be conducting an operational program which largely focuses on the killing of resident animals for the benefit of private and commercial interests."

Many recommendations dealing with the conflict over predator control were offered during this period; a few of the most significant ones follow. Reduction in use or complete banning of toxicants for use in predator control was suggested by Cain et al. (1972) and Hornocker (1972) and was carried out by President Nixon (1972) as stated above. The same authors recommended that the Division of Wildlife Services be professionalized with emphasis placed on qualified wildlife biologists as field agents. McCabe and Kozicky (1972) and Leopold (1972) stated that predator control should not be handled by the Bureau of Sport Fisheries and Wildlife; Cummings (1972) and Howard (1974a) believed that this responsibility belonged to the U. S. Department of Agriculture or the state Departments of Agriculture because a conservation agency (U. S. Department of Interior) cannot do a good job of animal control. Cain et al. (1972), McCabe and Kozicky (1972), and Berryman (1972) suggested that an insurance system to cover livestock losses be examined. With this method, the livestock industry as a whole would pay for the losses of a few of its members. Hall (1966) recommended that sheep be excluded from public land and stated that this exclusion would remove the principal excuse for federal predatory mammal control. McCabe and Kozicky (1972) stated that proper domestic animal husbandry may lessen or abolish the need for predator removal. Several authors (Berryman 1966; Cain et al. 1972; Cummings 1972; Hornocker 1972; Howard 1972; Reed 1972) agreed that more research was needed in the areas of predator management and control.

Following the change in public attitude toward predator control and the ban on toxicants came a redirection of research efforts in depredations control through non-lethal methods (Linhart 1975). Determination of causes and magnitude of losses is the first step in analysis of the predator-livestock problem (Balser 1974a). Several authors including Bowns et al. (1973), Davenport et al. (1973), Henne (1975), Bowns (1976), and Connolly et al. (1976) have described the carcasses of sheep and lambs killed by coyotes and other predators. Few estimates of the magnitude of sheep losses to predators had been made prior to 1973 (Boles 1949; Nielsen and Curle 1970; Reynolds and Gustad 1971; Cain et al. 1972; Wagner 1972). Several recent studies have recorded predator losses under varying degrees of predator control in various areas of the western United States (Bowns et al. 1973; Davenport et al. 1973; Wagner and Pattison 1973; Early et al. 1974a and 1974b; Boggess 1975; Henne 1975; Magleby 1975; DeLorenzo and Howard 1976; Dorrance and Roy 1976; Klebenow and McAdoo 1976). Predator losses ranged from less than 1 percent of the total sheep flock to over 8 percent of the ewes and nearly 30 percent of the lambs. Losses ranging from 2 to 4 percent were most commonly reported.

Several studies dealing with the life history and ecology of the coyote have been conducted to gather information that can possibly be applied in livestock loss reduction. Investigations into home-range sizes (Gipson and Sealander 1972, Chesness 1972 and 1973), population dynamics (Mathwig 1973; Boggess 1975; Connolly and Longhurst 1975; Nellis and Keith 1976), reproductive biology (Gipson et al. 1975; Bekoff and Diamond 1976; Kennelly and Johns 1976), physical development (Bekoff and Jamieson 1975), behavior (Jansen 1974, Lehner 1976), communications (McCarley 1975), elicited howling (Wenger 1975), taxonomy (Gipson et al. 1974, Richens and Hugie 1974), and habits of suspected damaging coyotes (Andelt 1976) have been reported. An extensive annual survey to determine population trends in coyotes was implemented in 1972 using scent-station lines (Linhart and Knowlton 1975).

Specific research on methods of livestock loss reduction has dealt primarily with non-lethal methods,,but several projects have analyzed the effectiveness and selectivity of lethal control methods (Beasom 1974b; Beasom and Gober 1975; Gipson 1975; Matheny 1976). Non-lethal techniques studied include taste-aversion conditioning (Gustavson 1974; Gustavson et al. 1974; Bekoff 1975; and Gustavson et al. 1975), use of olfactory repellents (Lehner et al. 1976), and the use of toxic collars on sheep (Willson 1975). Few, if any, of the above studies have given results that have been of direct benefit to the livestock producer.

Several authors have suggested that techniques of sheep management may affect losses to predators (Young and Jackson 1951, Balser 1974a and 1974b). Fencing was used as early as the 1890's to deter coyotes (Thompson 1976). Early experiments with coyote-proof pastures were reported by Jardine (1908, 1909, and 1911). Relationships between fencing and predators have been discussed by Lantz (1905b), Coll (1922), McAtee (1939), Kalmbach (1948), Fitzwater (1972), Shelton (1973a), Henderson (1974), and Thompson (1976). The use of barrier fencing in Australia to reduce sheep losses to dingoes was discussed by Bauer (1964) and McKnight (1969). Other factors of sheep management that may be related to predator losses include the use of herders (Kalmbach 1948, McCabe and Kozicky 1972), lights (Gier 1968), bells (Hawbecker 1939), and dogs (Howard 1974b); confinement at night (Gier 1968, Wade 1973a) and during lambing (McCabe and Kozicky 1972; Huston and Shelton 1973; Wade 1973a; Early et al. 1974a and 1974b); and proper disposal of sheep carcasses (Tiemeier 1955; Boggess 1975; Lehner 1976; Todd and Keith 1976). Although the above factors have all been suggested as possible deterrents to predation (especially by coyotes), an intensive study of these methods has never been conducted. Since little research has been conducted in this area, this study was initiated in an effort to determine the importance of these and other factors in reducing losses to predators.

STUDY AREA

A 9-county study area was selected in south-central Kansas; more specifically the counties of Dickinson, Marion, McPherson, Rice, Reno, Kingman, Sedgwick, Harvey, and Butler (Figure 1). A total confinement operation in Cowley County was also examined because of its uniqueness. This area was chosen because nearly 40 percent of the state's sheep industry is in these nine counties. All nine counties are in the top 17 of the state's sheep-producing counties, with Reno, Sedgwick, Harvey, and McPherson counties ranked first, second, third, and fourth, respectively (Kansas State Board of Agriculture 1975).

Most of the area lies in the Great Bend Prairie geographical region, with the Flint Hills bordering on the east, the Smoky Hills Upland on the north, and the Red Hills on the southwest. The Arkansas River bisects the area from northwest to southeast (Socolofsky and Self 1972). Topography ranges from nearly level to strongly sloping or hilly, with most of the area falling into the category of gently rolling. The soils on the area were formed primarily from loess and alluvial materials under tall and mid-grass prairies; however, limestone and shale were the parent materials in the Flint Hills (United States Department of Agriculture 1966, 1974a, 1974b, and 1975).

The area has a continental climate that is characterized by large seasonal changes of temperature, warm to hot summers, moderate humidity, light precipitation in winter, considerable sunshine, moderate winds, and a pronounced rainfall maximum in

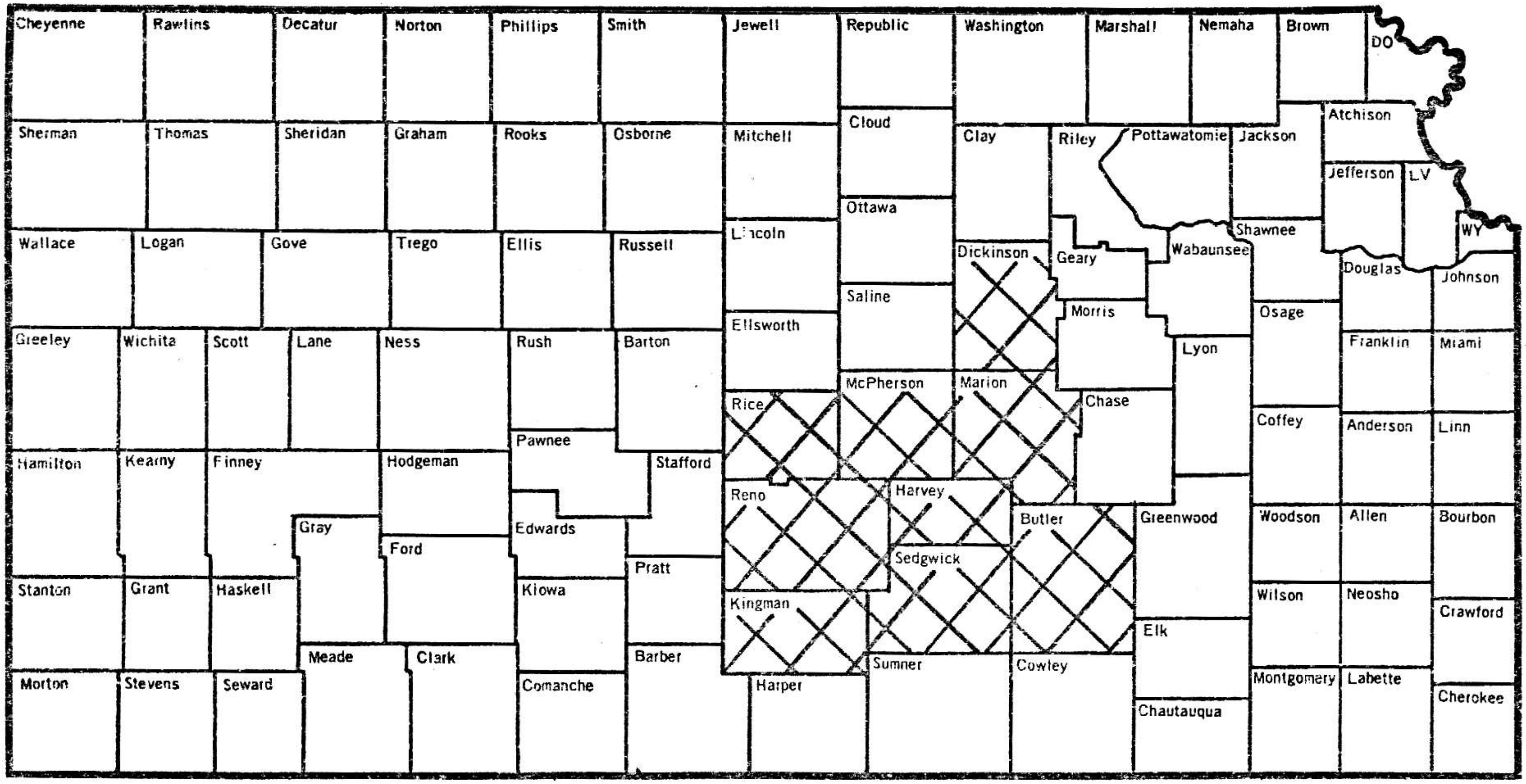

Fig. 1. Cross-hatching denotes study area in Kansas.

late spring and early summer. Average annual precipitation ranges from 66.5 cm in the northwest to 81.5 cm in the southeast (United States Department of Agriculture 1966, 1974a, 1974b, and 1975).

Grain and livestock production are the major forms of land use in the area. Fifty-two and a half percent of the 22,132 square km in the study area are under cultivation, with wheat (68.4 percent of cultivated land) and grain sorghum (23.8 percent of cultivated land) being the principal crops, with corn, soybeans, forage and silage sorghums, oats, barley, and rye also being grown in smaller amounts. Hay and pasture lands make up 38.1 percent of the study area, with cattle and hogs being the main livestock produced (Kansas State Board of Agriculture 1975).

Sheep production in the area is characterized by small to medium sized farm flocks (50 to 300 stock sheep) raised as a sidelight to grain production. However, a few large farm flocks (more than 300 stock sheep) occur in the area that provide most of the income for those particular operations. The sheep flocks often utilize crop residues and small pastures unfit for cultivation or large-scale cattle production. Lamb production is the primary goal of the industry with production of wool being of secondary importance. Income from lamb and wool marketing in the study area amounts to about $2 million annually, about 40 percent of the state's total (Clifford Spaeth, personal communication).

METHODS

All sheep producers in the study area were contacted by mail and asked to participate in the study. Names and addresses were obtained from a list of Kansas Sheep Association members. One hundred ten sheep producers agreed to cooperate in the study.

Sheep Numbers and Losses

Cooperating sheep producers were mailed a supply of "Sheep Loss Report Cards" at the beginning of the study. Losses were recorded on these cards and mailed to the investigator each month from June 1975 through August 1976. Number of sheep and lambs on hand each month, number lost each month, and cause of loss were reported. The sheep producers used their personal judgment to determine cause of loss. "Reminders" were mailed to the cooperators shortly after the first of each month to encourage them to send their card reporting losses for the previous month. When cards were not received from sheep producers, personal interviews were conducted with them and missing data collected in this manner. Excellent cooperation was received from sheep producers in the study. Correspondence with sheep producers is presented in the Appendix.

Necropsies were performed by the investigator on sheep carcasses whenever possible during the study period to determine actual cause of death. To facilitate necropsy examination, participating sheepmen used the inward KSU Extension WATS telephone system to report losses for part of the study period. Necropsy methods followed those outlined by Rowley (1970). Criteria for determining cause of death were adopted from Marsh (1958), Cole (1966), Gier (1968), Rowley (1970), Scott (1971), Bowns et al. (1973), Davenport et al. (1973), and Jensen (1974).

Management Practices

Each sheep operation was personally visited and husbandry methods were examined and recorded. By personal interview, each cooperator explained his management practices in response to a number of questions. Method of disposal of sheep carcasses, season and location of lambing, number of dogs, method and success of predator control, season of shearing, breed of sheep, poultry management practices, types of pastures used, use of bells, time of day sheep turned out to pastures and shut in corrals, and confinement practices were reported to the investigator during these interviews.

The distance from each sheep operation to the nearest town or settled area was determined from respective county maps obtained from the State Highway Commission of Kansas.

Several factors that may influence losses to predators in pastures were examined through personal observation. Height and type of pasture cover, pasture topography, drainage characteristics, height and type of fences, crops and woody cover on adjacent land, presence of roads bordering pasture, and number and species of other livestock in pasture were personally observed and recorded. Heights of pasture cover and fences were measured to the nearest 5 cm. Topography was rated on a subjective scale from 1 to 6 with category 1 being flat and category 6 being rough.

Aerial photographs were obtained from the respective county Agricultural Stabilization and Conservation Service offices and used in determining size and shape of pasture, percent of fenceline in woody cover, percent of pasture in woody cover, and distances from pasture to farm buildings and residence. Size of pasture was calculated to the nearest tenth of a hectare, percent of fenceline in woody cover to the nearest percent, and percent of pasture in woody cover to the nearest 5 percent. Distances from farm buildings and residence to the nearest point, center, and farthest point of the sheep pastures were calculated to the nearest 5 meters. Sheep density was calculated by dividing number of sheep on a pasture by the size of the pasture.

Factors examined by personal observation that may contribute to predator losses in corrals include the use of lights, size and shape of corral, distance to residence, height and type of fence, and number and species of other livestock in same and adjacent corrals. Light intensity was measured at night to the nearest tenth of a foot-candle with a Gossen-TRI-LUX, Model C Footcandle Meter (Kling Photo Corporation, New York) at the corners and center of the corral. Size of corral was determined by pacing length of corral fences, multiplying by average pace length to convert to meters, and calculating area by use of geometric formulas. Distance to residence was determined by the pacing method when convenient, and by measuring on aerial photographs when pacing was not convenient.

Chi-square tests (Snedecor and Cochran 1973) were used to determine significance of the management factors examined.

Predator Abundance

During late August and early September of 1975 and early September of 1976, surveys were conducted to obtain indices to the predator population on the study area. The standard Bureau of Sport Fisheries and Wildlife predator survey method (Linhart and Knowlton 1975) was modified for use in this study following advice from Robert Roughton, BSF&W, Logan, Utah (personal communication). Each index line was made up of five scent stations placed at 0.5 km intervals; each station consisted of a 3-foot circle of sifted earth with a perforated plastic capsule (Tissue-Tek Plastic Capsules, Lab-Tek Products, Naperville, Illinois) containing coyote urine (Robbins Scent Company, 1206 Rockridge Road, Connellsville, Pennsylvania) in the center. Scent stations were placed alternately on the left and right sides of the road and scent lines were alternated from north-south to east-west roads to reduce the influence of changing winds. Three scent lines were run within 5 miles of each sheep producer in the study, each line being placed on a county road in typical coyote habitat. Predator density indices were determined by using data from 120 scent lines run for three consecutive days each year. Coyote and dog visits (determined by tracks) were recorded at scent stations and indices were calculated for each line as follows:

$$\text{Index} = \frac{\text{Total visits}}{\text{Total operative station nights}} \times 1000$$

Presently, no method is available to convert indices to estimates of actual coyote numbers.

Paired comparisons using T-tests (Snedecor and Cochran 1973) were used to compare 1975 and 1976 indices in each county and the study area as a whole.

Going-Out-of-Business Survey

A mail survey was conducted to determine the causes of Kansas sheepmen going out of business. Questionnaires were mailed to sheepmen living in the study area that had gone out of business between March 1973 and April 1975 (as indicated during our initial contact at the beginning of the study).

Former sheepmen were given a list of causes of quitting the sheep business and asked to rank them in order of importance in relation to their own operations. Causes listed were related to profitability of the industry, labor and marketing problems, switching to other types of agricultural production, age and health problems, and predator problems. Two hundred twenty-five former producers were surveyed.

RESULTS

Sheep Numbers

Numbers of stock sheep and lambs on hand and the number of cooperators in the study each month are given in Table 1. The number of stock sheep stayed relatively constant during the study period, ranging from a high of 17,023 in August 1975 to a low of 14,578 in August 1976. Lamb numbers varied considerably during the study reaching a low of 4,113 in September 1975, increasing (due to lambing) during the fall and winter to a peak of 19,905 in March 1976, and decreasing (due to marketing) during the spring and summer to 4,509 in August 1976. Seasonal trends of numbers of stock sheep in the study are shown in Figure 2 and of lambs are shown in Figure 3.

Average size of the breeding flocks (ewes and rams) in the study was 154 sheep and ranged from 4 to 913. Using the categories of Gee and Magleby (1976), 33 (30 percent) of the 109 sheep operations in the study were non-commercial operations (less than 50 head), 24 (22 percent) were small farm flocks (50-99 head), 38 (35 percent) were medium farm flocks (100-299 head), and 14 (13 percent) were large farm flocks (300-999 head). No large-scale commercial operations (more than 1,000 head) were included in the study.

Sheep Mortalities

Losses amounting to 1,362 stock sheep and 2,230 lambs were reported by cooperators from 1 June 1975 through 31 August 1976.

Table 1. Numbers of sheepmen, stock sheep, and lambs in study and losses to coyotes, dogs, and non-predatory causes by month.

Month	Number of Sheepmen	Stock Sheep				Lambs			
		Number	Loss			Number	Loss		
		On Hand	Coyote	Dog	Non-predator	On Hand	Coyote	Dog	Non-predator
June 75	108	16811	23	4	66	6718	24	6	77
July 75	108	16896	32	5	82	5846	21	5	75
August 75	109	17023	32	3	101	5079	19	3	80
September 75	109	17021	21	4	144	4113	18	4	44
October 75	106	16590	4	1	82	8094	29	6	104
November 75	106	16565	4	2	74	11229	19	8	234
December 75	105	16012	1	2	67	12966	18	17	290
January 76	104	15853	0	1	85	15057	19	1	329
February 76	103	15339	0	0	71	18009	9	0	280
March 76	102	15315	2	1	68	19905	0	0	191
April 76	102	15506	11	2	67	14828	12	2	61
May 76	99	15176	7	9	59	11016	6	2	56
June 76	99	14724	6	3	60	7361	1	0	54
July 76	99	14709	4	19	45	5818	7	0	29
August 76	96	14578	25	1	62	4509	22	0	48

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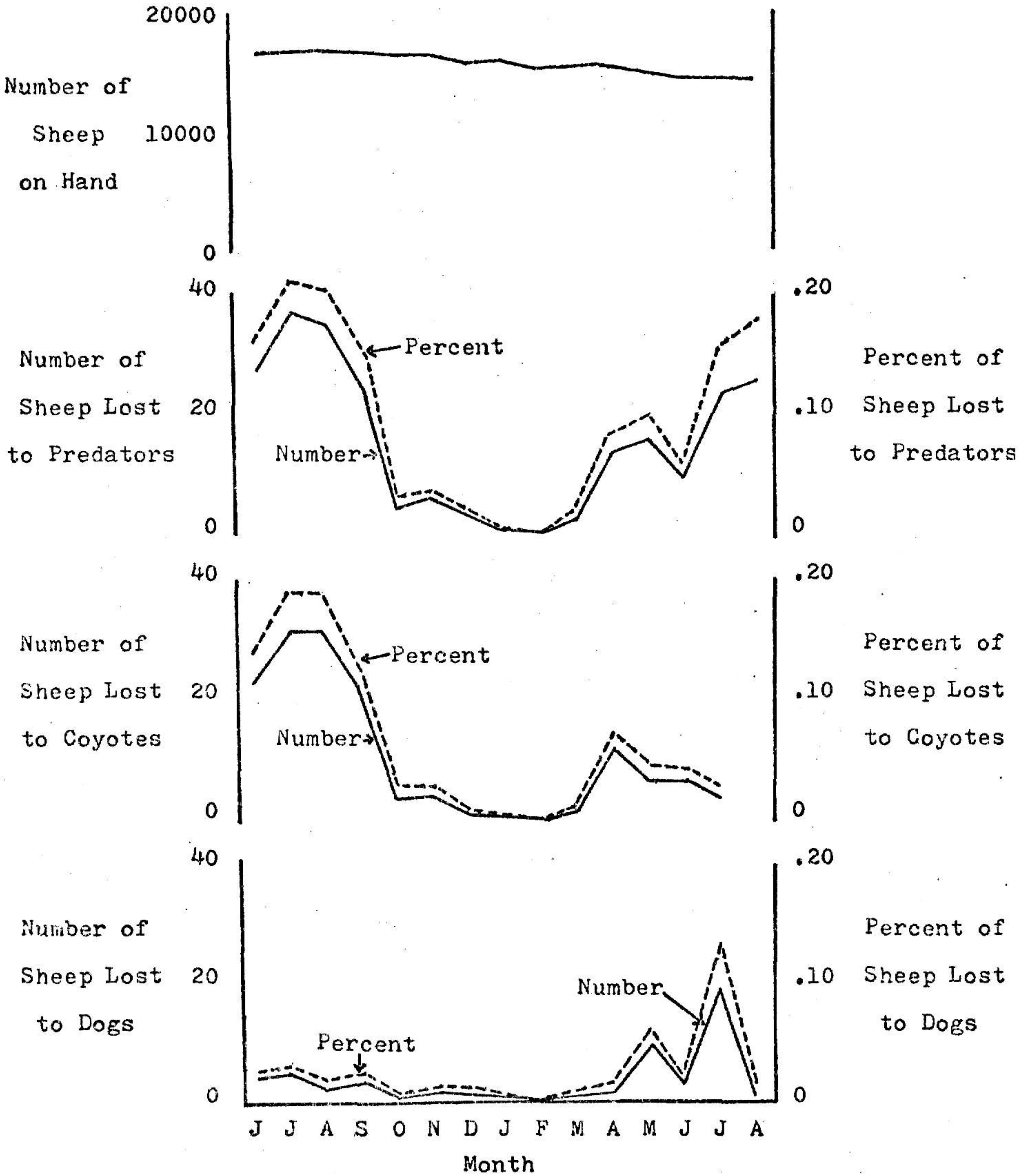

Fig. 2. Number of stock sheep in study, and numbers and percentages of stock sheep lost to predators, coyotes alone, and dogs alone, by month.

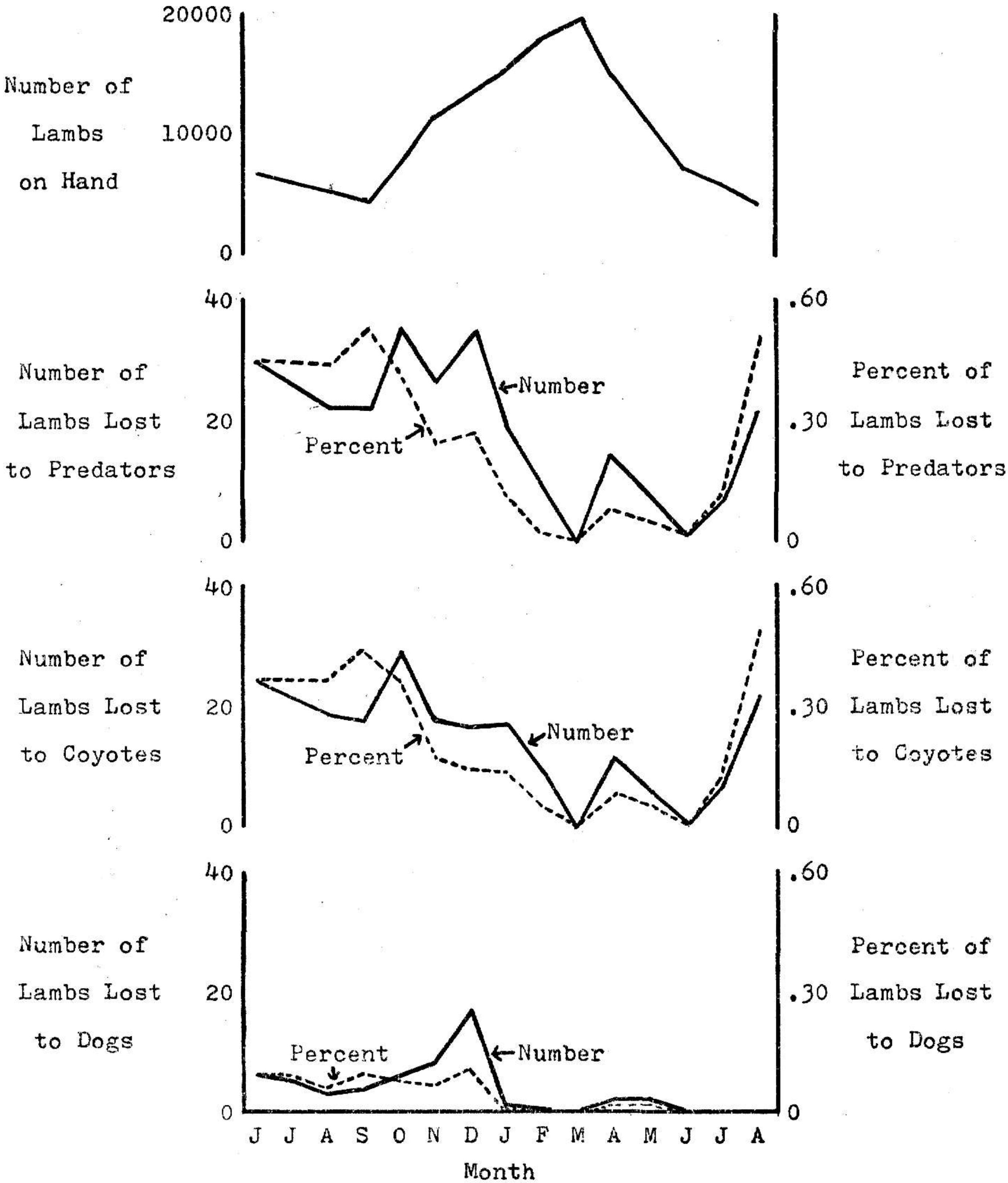

Fig. 3. Number of lambs in study, and numbers and percentages of lambs lost to predators, coyotes alone, and dogs alone, by month.

Predators (coyotes and dogs) accounted for 229 stock sheep and 278 lambs, with coyotes being responsible for about 78 percent of the loss to predators (Table 2). Monthly distributions of losses to coyotes, dogs, and non-predatory causes are given in Table 1.

Loss rates of stock sheep and lambs were calculated on an annual basis. Since data for two summers were used, the averages of the losses reported in each summer month (June, July, and August) were used with the losses reported in each of the remaining nine months in order to represent each month equally.

Loss to predators was calculated to be 0.9 percent of the stock sheep inventory (on an annual basis) and non-predator loss amounted to 5.8 percent giving a total loss of 6.8 percent. Predator loss of lambs also amounted to 0.9 percent, non-predator loss was calculated to be 7.0 percent, and total lamb loss was 7.9 percent.

Old age was the major cause of death among stock sheep (Figure 4), accounting for over 30 percent of the mortality on an annual basis. Predators accounted for 14.0 percent of the losses, lambing complications for 9.3 percent, pneumonia for nearly 4 percent, and poison plants for nearly 2 percent. Unknown and other causes represented large portions of the mortality, each over 20 percent. Some of the causes cited under "Other" include weather conditions, parasites, other diseases, and accidents.

Lambing complications (Figure 5) were by far the most important causes of death in undocked lambs (docking is usually done

Table 2. Numbers and percentages of stock sheep and lambs killed by coyotes and dogs.

Predator	Number of Stock Sheep and Lambs Killed	Percent of Total	Number of Lambs Killed	Percent of Total	Number of Stock Sheep Killed	Percent of Total
Coyote	396	78.1	224	80.6	172	75.1
Dog	111	21.9	54	19.4	57	24.9
Total	507		278		229	

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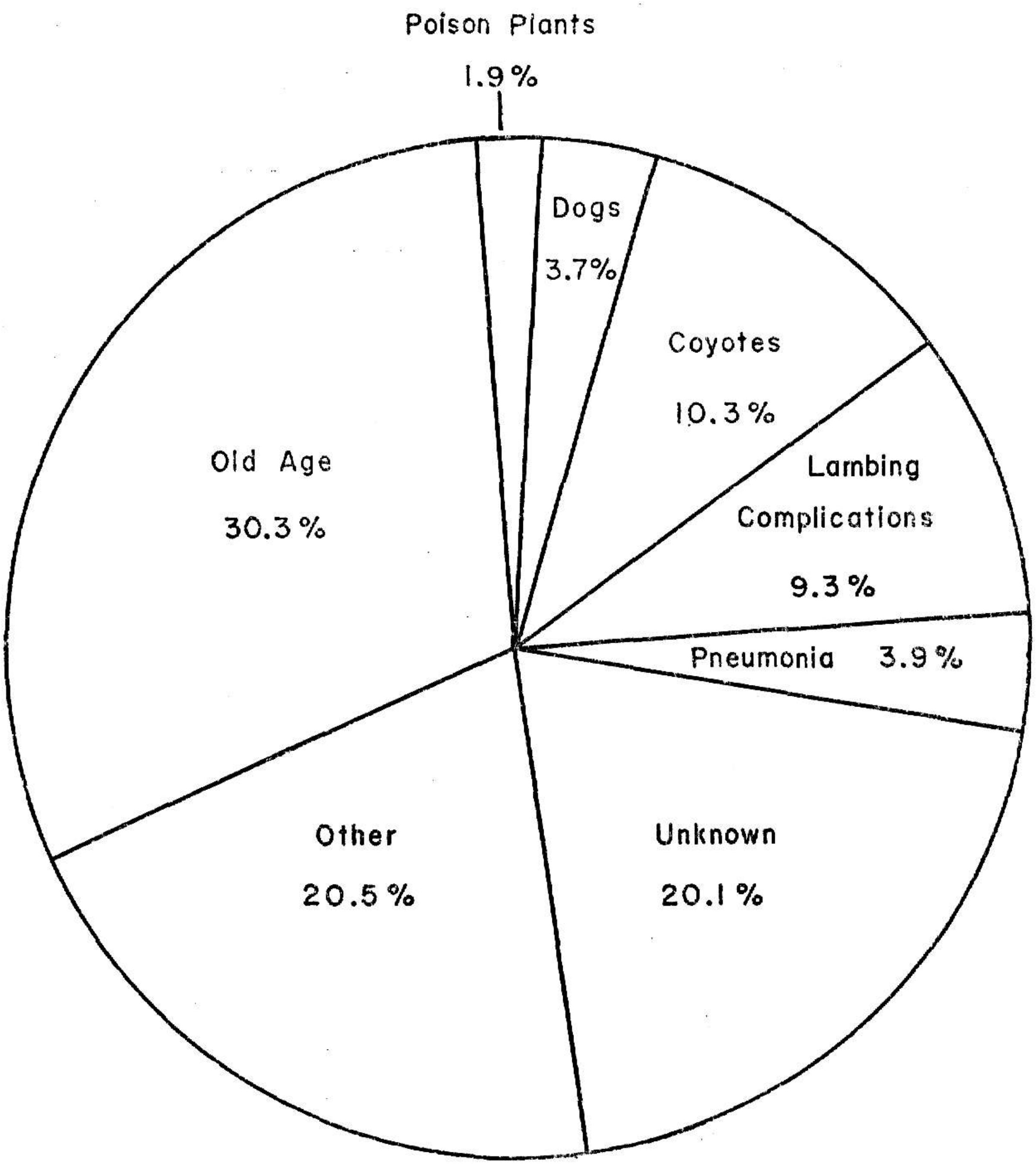

Fig. 4. Percentages of stock sheep losses due to various causes.

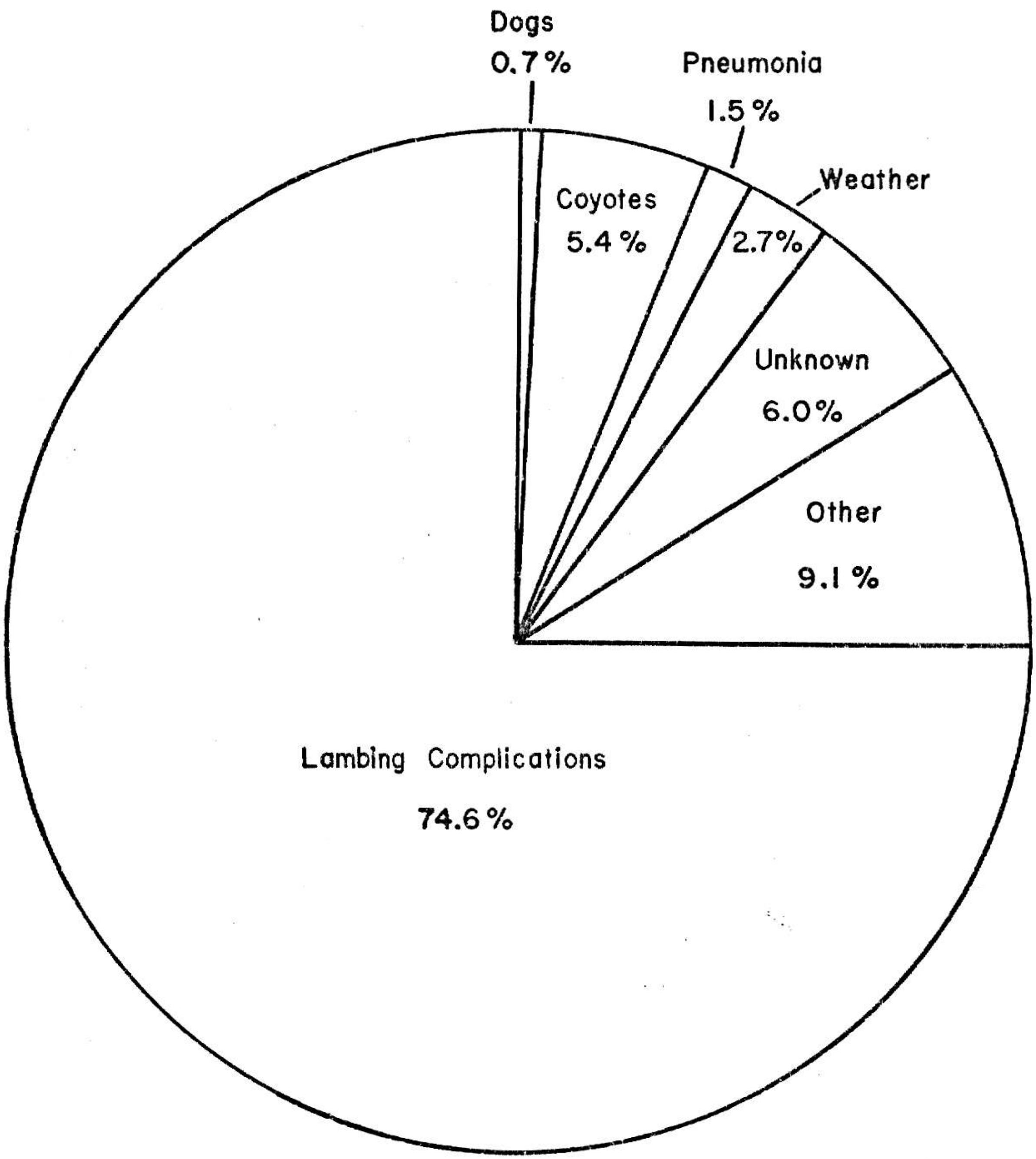

Fig. 5. Percentages of losses of undocked lambs due to various causes.

at 2 to 4 weeks of age). Stillbirths, deaths due to abnormal fetus presentations, and starvation of lambs due to mismothering or lack of milk were placed in this category and represented 74.6 percent of the mortality of small lambs. Predators accounted for 6.1 percent, weather for 2.7 percent, and pneumonia for 1.5 percent of the losses. Six percent of the mortality was due to unknown causes and 9.1 percent was attributed to other causes including other diseases, accidents, and poisoning.

Enterotoxemia was the major cause of death in docked lambs (Figure 6) followed closely by predators (20.8 percent and 20.1 percent, respectively). Pneumonia (9.2 percent), urinary calculi (5.8 percent), and weather conditions (2.1 percent) were other important mortality factors. Unknown and other causes were also important mortality factors in docked lambs (18.7 and 23.3 percent, respectively). "Other" reasons include screw worms, rectal prolapse, docking and castration complications, other diseases, internal parasites, and accidents.

Seasonal trends in numbers and percentages of losses to predators are shown for stock sheep in Figure 2 and lambs in Figure 3. Predator losses of stock sheep were highest from June through September, quite low from October through March, and fairly high again in April through August. Lamb losses followed a similar trend; however, high numbers of summer and fall losses continued through January. Percentage loss to predators was decreasing during this period as lamb numbers increased due to lambing from October through March. Predator losses of lambs were much lower during June and July of 1976 than the same period in 1975. Coyote losses tended to be more seasonal in extent than dog losses.

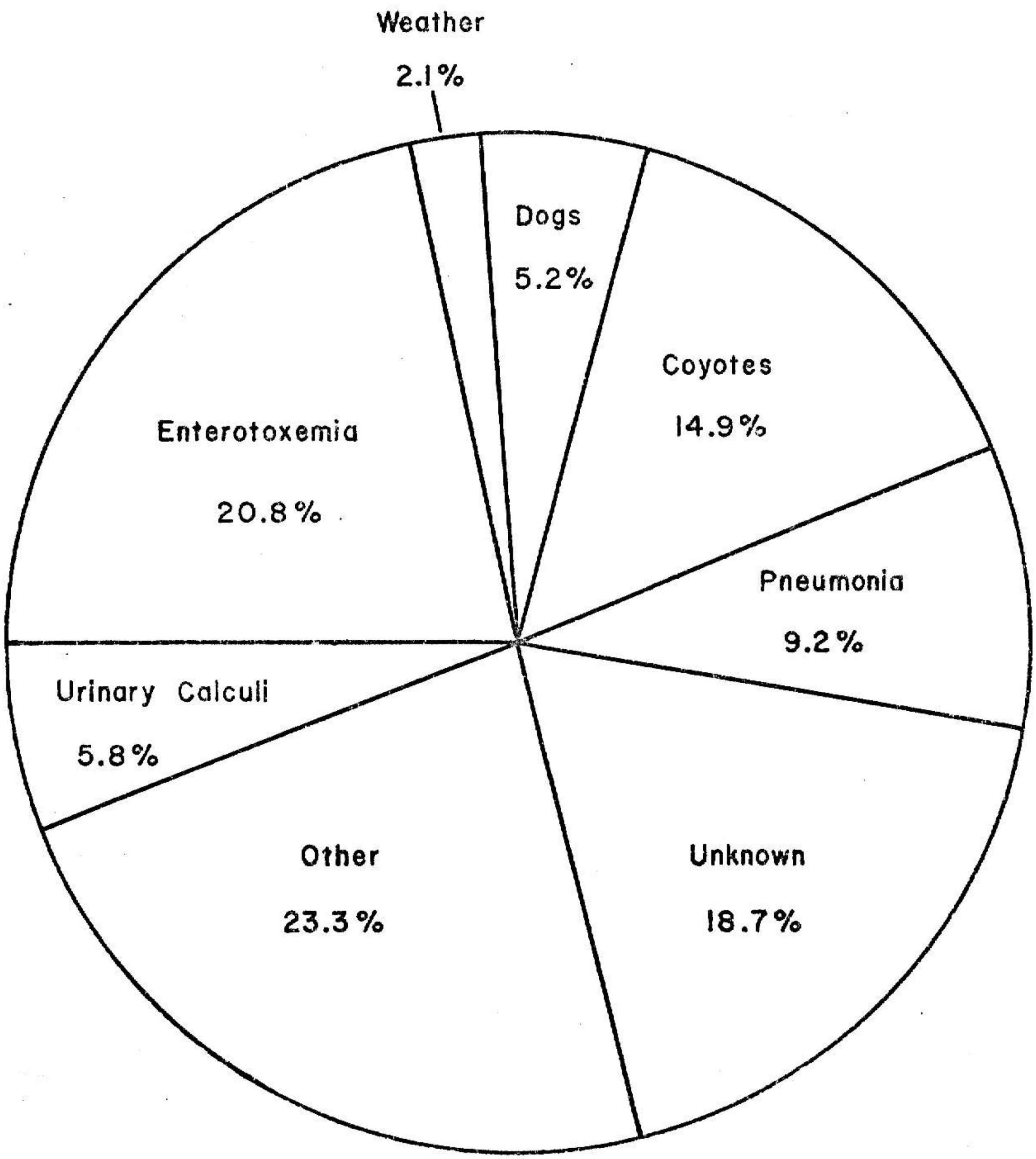

Fig. 6. Percentages of losses of docked lambs due to various causes.

A comparison of predator and non-predator losses on a monthly basis is shown for stock sheep in Figure 7. Non-predator losses stayed relatively constant throughout the study period and losses to predators varied seasonally as stated above. Figure 8 presents similar data for lambs. However, non-predator losses (primarily associated with lambing) were quite high during the fall and winter months, with lower losses reported during spring and summer.

The distribution of extent of predator losses among the sheep producers during the study is presented in Figure 9. Fifty (46 percent) of the sheepmen in the study suffered no predator losses and 29 sheepmen (27 percent) lost from one to four sheep and lambs during the 15-month study period. Sixteen sheep producers (15 percent) suffered predator losses in excess of 10 animals with four of these losing more than 20 sheep and lambs (25, 29, 45, and 67). Eighty percent of the losses were absorbed by only 22 percent of the sheepmen in the study.

A limited number of sheep and lamb carcasses were examined during the study by the investigator and cause of death determined when possible. Necropsies were performed on 23 fresh carcasses (9 lambs and 14 adult sheep) with cause of death being identified on 18 carcasses. Many more carcasses were very decomposed and it was not possible to accurately determine cause of death. A major portion of the field work was conducted during the summer months when heat caused rapid deterioration of carcasses.

Two of the nine lambs examined were determined to have been killed by coyotes, two died of pneumonia, and one each died of overeating disease, heat exhaustion, infection, drowning,

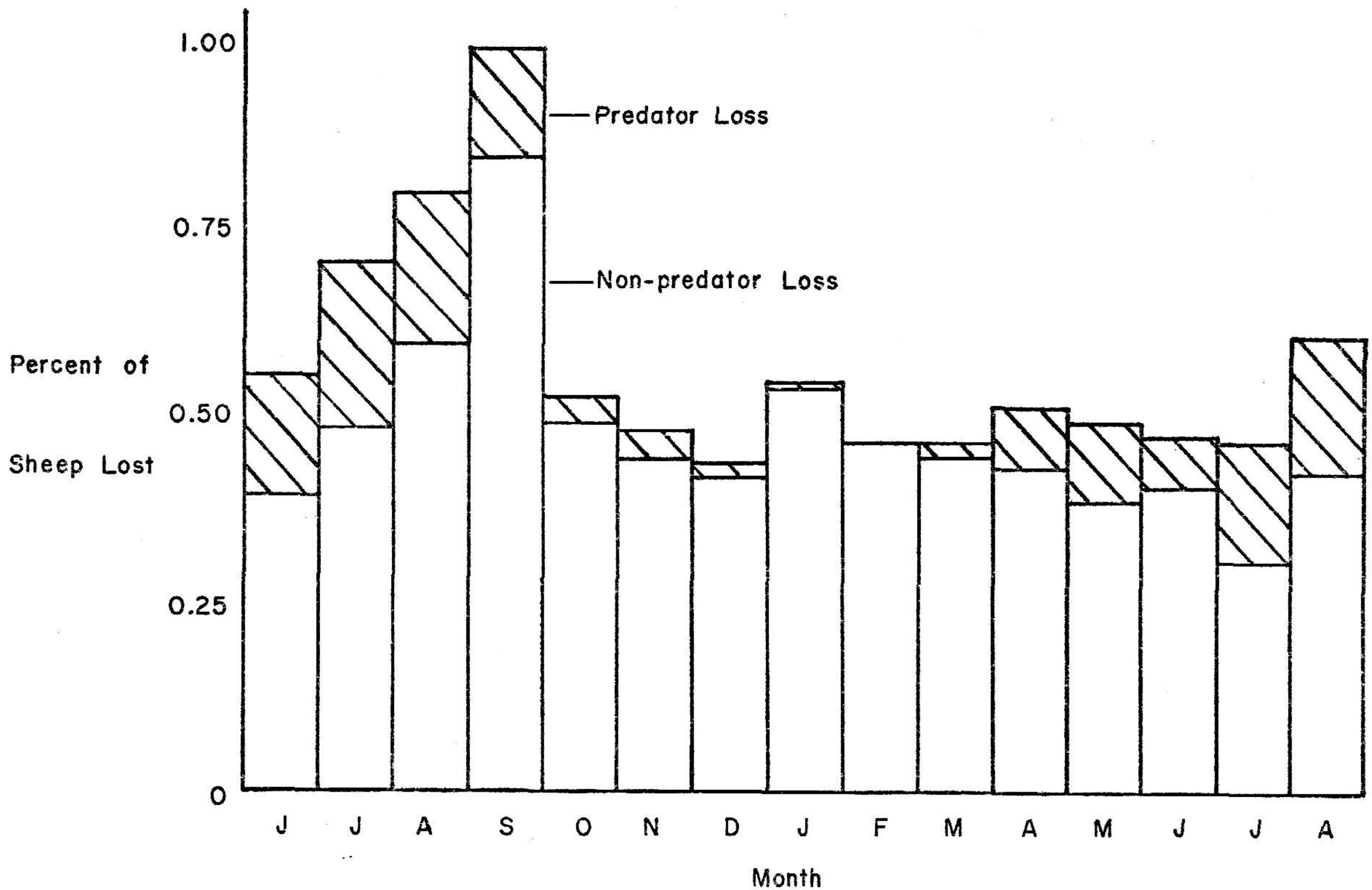

Fig. 7. Rate of loss of stock sheep to predators and non-predatory causes by month.

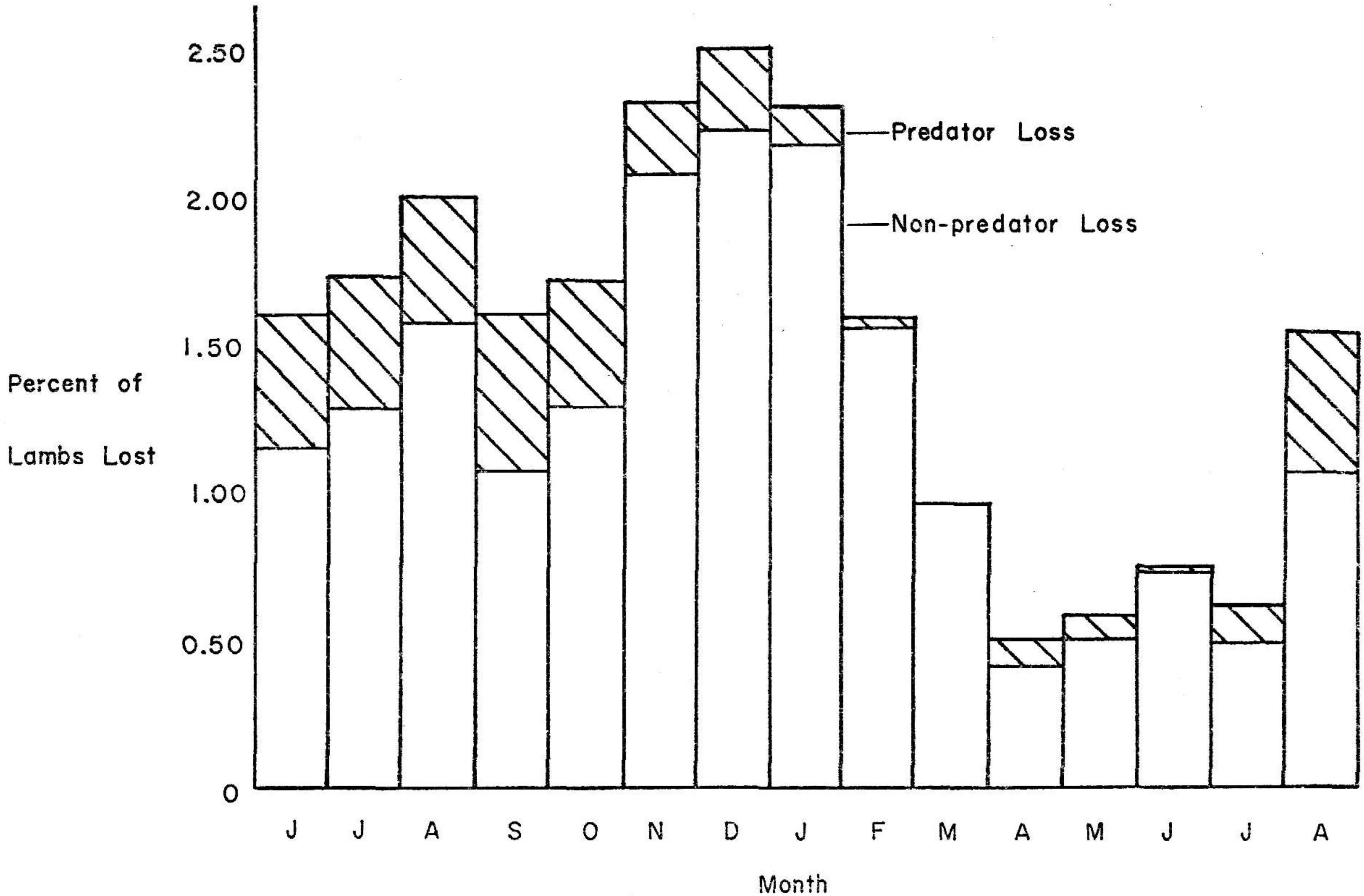

Fig. 8. Rate of loss of lambs to predators and non-predatory causes by month.

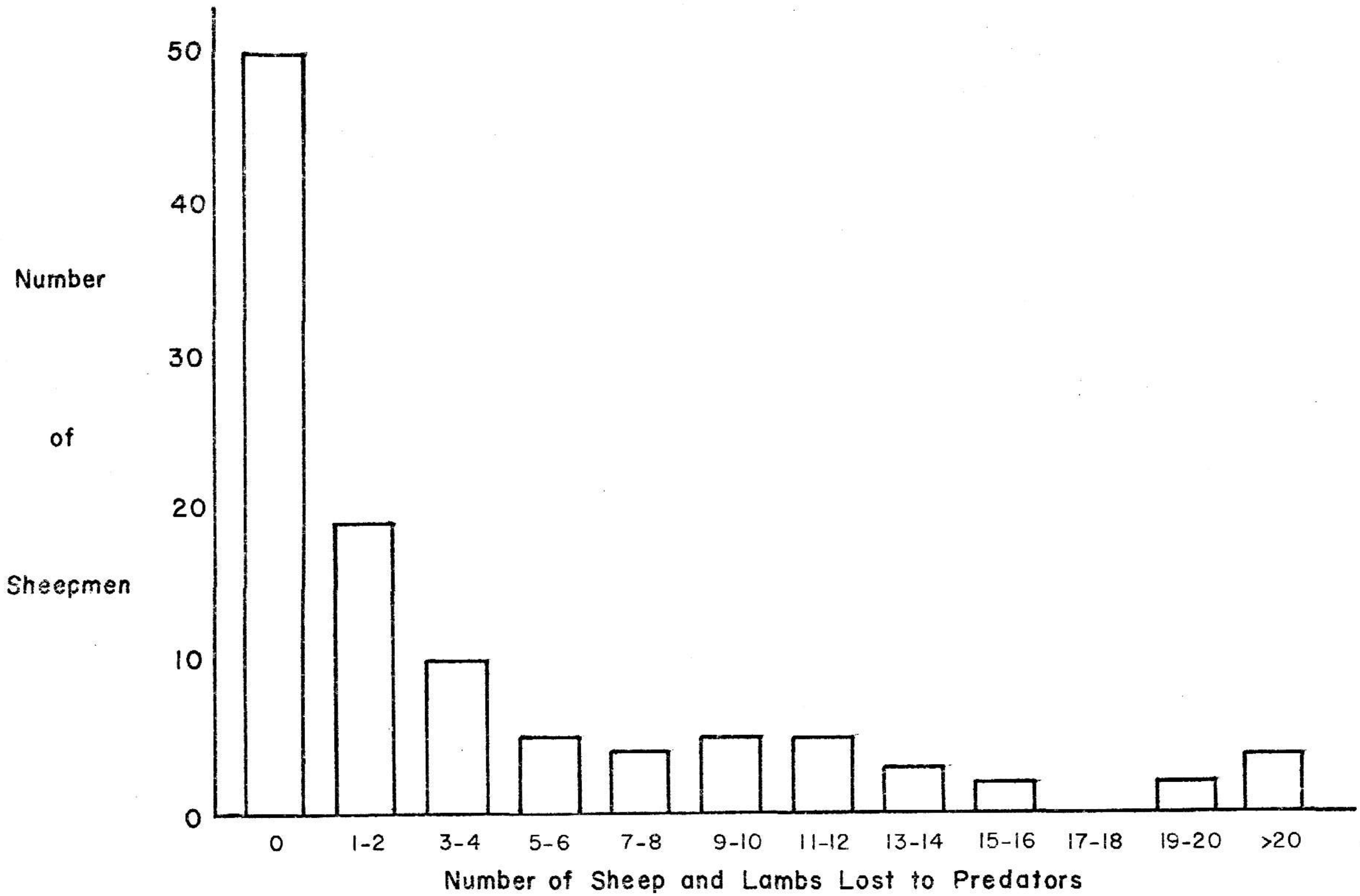

Fig. 9. Distribution of losses to predators among sheep producers in the study.

and starvation. Five of the adult sheep died of unknown causes (no identifiable lesions), three were killed by coyotes, three were killed by dogs, and one each died of pneumonia, rectal prolapse, and bloat. All 14 of the adult sheep examined were ewes.

Due to the small sample size of necropsied animals, a statistical comparison with losses reported by sheep producers was not conducted. However, causes of loss of necropsied animals appeared similar to those reported by sheepmen in the study.

Value of Sheep Lost to Predators

The value of sheep lost to predators in this study was calculated by multiplying the number of stock sheep and lambs lost by the respective value of each. Clifford Spaeth, Kansas State University Extension Sheep Specialist, reported (personal communication) that the average value of a breeding ewe during the study period was approximately $35.00. The average market value of a 70-pound lamb (Reynolds and Gustad 1971) during the study was calculated to be $31.70 from data supplied by the Kansas Crop and Livestock Reporting Service.

The value of the 229 stock sheep lost to predators was calculated to be $8,015, and the value of the 278 lambs was calculated to be $8,813 giving a total value of sheep lost of $16,828. Multiplying this value by 80 percent converts it to an annual loss value, since losses were recorded in the study over a 15-month period. This results in an annual loss of $13,462. Since this value represents predator losses suffered by 19.0 percent of the sheep in Kansas (see DISCUSSION: Sheep Numbers),

the value of losses statewide can be calculated ($70,855) if the rate of loss in the rest of Kansas is similar to that observed in the study area. This value represents an estimated 964 stock sheep and 1171 lambs lost to predators annually in Kansas. F. R. Henderson (personal communication) reported losses to predators in the study area to be comparable to those observed statewide.

Management Practices

The husbandry practices examined in relation to predator losses were placed into three categories: (1) General management factors, (2) Pasture factors, and (3) Corral factors. The first category includes factors that stayed constant for given sheep producers during the course of the study and also an overall examination of general management (pasturing and confinement) by month. The second and third categories include factors examined specifically in pastures and corrals, respectively. These factors often varied from month to month and analysis by examination of sheep-months of exposure under various conditions was necessary. A fourth category was included in this section, a description of the total confinement operation examined in this study.

Losses to coyotes and losses to dogs were examined separately since field experience suggested that losses often occurred to the respective predators under different circumstances.

General Management Factors

Several factors in this category were determined to be important in contributing to losses to predators——flock size, method of disposal of sheep carcasses, season of lambing, possession of dogs, distance of sheep operation from town or settled areas, and predator control. Factors also examined but not considered significant in affecting predator losses include location of lambing, season of shearing, breed of sheep, and production and management of poultry.

Flock Size

Larger flocks appeared more susceptible to predation than smaller flocks, although there were no differences statistically (χ^2=1.55, P=0.671). Predator losses were suffered by 42 percent of the non-commercial operations, 50 percent of the small farm flocks, 63 percent of the medium farm flocks, and 57 percent of the large farm flocks. Total predator losses per flock were greater in larger flocks—non-commercial operations and small farm flocks each lost an average of 2.1 sheep and lambs to predators, medium farm flocks lost 7.0, and large farm flocks lost 10.1. However, percent loss tended to decline as flock size increased. Rate of loss to predators expressed as percent loss per month is given in Table 3.

Table 3. Percent of total sheep lost to predators per month by flock size.

	Flock size			
	<50	50-99	100-299	≥ 300
Rate of loss to predators	0.313	0.177	0.132	0.093

A breakdown of predator losses to coyotes and dogs follows the trend reported above for total predator losses. Table 4 presents losses to coyotes within each of the four flock-size categories. The first row (percent of total sheep-months followed by the number of sheep-months in parentheses) represents the amount of exposure of sheep to predators in each category. The second row gives the percent of total coyote losses suffered in each category followed by the number of coyote losses represented in parentheses. The percent of total sheep-months in each category also represents the expected percent of total coyote loss in each category if no differences exist between categories due to treatment effects. The third row gives the rate of loss to coyotes in each category expressed as percent loss per month. Chi-square value, degrees of freedom, and probability of a greater chi-square value occurring if no differences exist between treatments (flock sizes) are given at the bottom of the table. This reporting procedure will be followed for other management practices below.

Table 4. Percentages of total sheep-months and losses to coyotes by flock size. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Flock size			
	<50	50-99	100-299	>300
Sheep-months	4.9 (19,181)	10.6 (41,293)	45.5 (176,978)	38.9 (151,479)
Losses to coyotes	11.9 (47)	11.4 (45)	49.0 (194)	27.8 (110)
Rate of loss to coyotes	0.245	0.109	0.110	0.073

χ^2=52.72 3 df P=0.000

Loss rate was greater in non-commercial flocks (<50 head) than in commercial flocks (χ^2=40.79, P=0.000). Rate of loss to coyotes was lower in flocks of greater than 300 breeding sheep than in flocks of less than 300 (χ^2=20.75, P=0.000). Rate of loss to coyotes tended to decrease as flock size increased, despite greater absolute losses in larger flocks.

The relationship between flock size and losses to dogs was similar to that reported above for coyotes (Table 5). Rate of loss to dogs decreased as flock size increased. Differences in loss rates was greatest between flocks of less than 100 breeding sheep and flocks of 100 or greater (χ^2=38.46, P=0.000).

Table 5. Percentages of total sheep-months and losses to dogs by flock size. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Flock size			
	<50	50-99	100-299	>300
Sheep-months	4.9 (19,181)	10.6 (41,293)	45.5 (176,978)	38.9 (151,479)
Losses to dogs	11.7 (13)	25.2 (28)	35.1 (39)	27.9 (31)
Rate of loss to dogs	0.068	0.068	0.022	0.020
χ^2=38.54	3 df	P=0.000		

Disposal of Carcasses

One of four procedures was generally followed in disposing of sheep dying from disease, predation, old age, or other causes: (1) Hauled carcasses to pasture or dump site if animals died in corral, or left carcasses where animals died, (2) Buried carcasses, (3) Burned carcasses, and (4) Made carcasses unavailable to scavengers (includes disposal to rendering plants and dumping in inaccessible pits; i.e., old wells, ets.). Table 6 presents degrees of exposure of sheep and losses to coyotes under the four methods of disposal.

Table 6. Percentages of total sheep-months and losses to coyotes under four methods of sheep carcass disposal. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Method of Disposal			
	Pasture	Buried	Burned	Rendering Plant
Sheep-months	42.6 (165,678)	20.1 (77,995)	2.0 (7,647)	35.4 (137,611)
Losses to coyotes	59.3 (235)	10.4 (41)	3.3 (13)	27.0 (107)
Rate of loss to coyotes	0.142	0.053	0.170	0.078
χ^2=55.92	3 df	P=0.000		

Sheep producers that disposed of carcasses in pastures or let them lie where the animals died suffered higher losses to coyotes (χ^2=45.40, P=0.000) than producers that disposed of carcasses by other methods. Producers that buried carcasses or made carcasses unavailable to scavengers by use of rendering plants or deep pits suffered lower losses (χ^2=23.23, P=0.000 and χ^2=12.10, P=0.001, respectively) than producers using other methods of disposal. Burning of carcasses was done by a few producers but no conclusions as to the effectiveness of the method could be drawn due to the small sample size.

No trends were evident in the relationships between dog losses and methods of carcass disposal.

Season of Lambing

Lambing usually occurs under one of three programs in Kansas: (1) Fall lambing—October, November, and December, (2) Winter lambing—January, February, and March, and (3) Year-around lambing—any month of the year. The third category includes both accelerated programs (lambing every 8 months) and programs that leave the rams with the ewes continuously. Table 7 presents the degrees of exposure of sheep and the losses to coyotes under the three season-of-lambing categories.

Table 7. Percentages of total sheep-months and losses to coyotes by season of lambing. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Season of lambing		
	Fall	Winter	Year-around
Sheep-months	57.0 (221,719)	30.7 (119,550)	12.3 (47,662)
Losses to coyotes	50.5 (200)	40.4 (160)	9.1 (36)
Rate of loss to coyotes	0.090	0.134	0.076
χ^2=18.22	2 df	P=0.000	

Rate of loss to coyotes was greater (χ^2=17.40, P=0.000) in flocks that lamb during the winter months than in the other categories. Loss rates were lower under fall lambing (χ^2=6.86, P=0.009) and year-around lambing (χ^2=3.67, P=0.056) when tested against the other categories.

Losses to dogs were similar to those described above for coyotes (Table 8). Losses were highest (χ^2=16.76, P=0.000) in

Table 8. Percentages of total sheep-months and losses to dogs by season of lambing. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Season of lambing		
	Fall	Winter	Year-around
Sheep-months	57.0 (221,719)	30.7 (119,550)	12.3 (47,662)
Losses to dogs	45.0 (50)	48.6 (54)	6.3 (7)
Rate of loss to dogs	0.023	0.045	0.015
χ^2=17.60	2 df	P=0.000	

winter-lambing flocks and lower in flocks that lambed in the fall (χ^2=6.50, P=0.011) and year-around (χ^2=3.65, P=0.056).

Possession of Dogs

Predator losses suffered by sheep producers that owned dogs were compared with losses suffered by producers that did not own dogs to determine the influence, if any, that dogs near the sheep or around the producers' farmsteads may have on predator losses. Only dogs that were outside all the time were considered in this comparison. Several breeds were represented, but Border Collies and Australian Shepherds were the most common. Eighty-eight (81 percent) of the producers in the study owned dogs that were considered to possibly influence predator losses. Twenty-one (19 percent) producers did not own dogs that fit the above description.

Table 9 gives comparisons of exposure and losses to coyotes suffered by producers that owned dogs and those that did not.

Table 9. Percentages of total sheep-months and losses to coyotes under the presence and absence of dogs on farmsteads. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Dogs present	Dogs absent
Sheep-months	83.8 (326,078)	16.2 (62,853)
Losses to coyotes	74.0 (293)	26.0 (103)
Rate of loss to coyotes	0.090	0.164
^{2}=28.35	1 df	P=0.000

Lower losses to coyotes were suffered by sheepmen that owned dogs than by sheepmen that did not (^{2}=28.35, P=0.000) suggesting a possible repelling effect of dogs toward coyotes.

Higher losses of sheep and lambs to dogs were suffered by sheepmen that owned dogs than by those that did not (^{2}=14.78, P=0.000) as shown in Table 10. Very few losses to dogs occurred when the sheepmen themselves did not own dogs. Three cooperators reported losses to their own dogs during the study while six reported catching neighbors' dogs in the act of sheep-killing.

Table 10. Percentages of total sheep-months and losses to dogs under the presence and absence of dogs on farmsteads. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Dogs present	Dogs absent
Sheep-months	83.8 (326,078)	16.2 (62,853)
Losses to dogs	97.3 (108)	2.7 (3)
Rate of loss to dogs	0.033	0.005
^{2}=14.78	1 df	P=0.000

Distance to Towns or Settled Areas

Two important trends were observed in the relationship between losses to predators and distances from sheep operations to towns or settled areas. In general, losses to coyotes tended to increase as distance to towns increased. Conversely, losses to dogs decreased as this distance increased.

Table 11 presents exposure in sheep-months and losses to coyotes by distance to town. Rate of loss tended to increase with distance; however, this increase was erratic. A comparison of losses suffered by sheep operations 4.8 km or less from towns with those greater than 4.8 km indicated significantly greater losses to coyotes (χ^2=5.91, P=0.015) at the greater distances.

Losses to dogs were greater near towns than several km away (Table 12). Rate of loss to dogs decreased markedly as distance from town increased. The most marked difference was observed when a comparison was made between sheep operations 3.2 km or less from town with those greater than 3.2 km. Losses to dogs were significantly lower (χ^2=59.36, P=0.000) at the distances. Nearly 68 percent of the exposure in sheep-months occurred in operations over 3.2 km from towns but only 32 percent of the losses occurred under these conditions.

Predator Control

Twenty-four of the 95 sheep producers that remained in the study for the full 15 months practiced some form of predator control (hunting or trapping) during the study. No poisons of any type, including the M-44 mechanism, were legal in Kansas for use in predator control during the study period (Matheny 1976). Predator control was generally not practiced until losses

Table 11. Percentages of total sheep-months and losses to coyotes by distance to town or settled area. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Distance (in km)					
	<1.6	1.7-3.2	3.3-4.8	4.9-6.4	6.5-8.0	>8.0
Sheep-months	11.6 (45,163)	20.8 (80,886)	17.1 (66,610)	18.6 (72,212)	19.9 (77,372)	12.0 (46,688)
Losses to coyotes	6.6 (26)	26.0 (103)	10.9 (43)	16.9 (67)	16.2 (64)	23.5 (93)
Rate of loss to coyotes	0.057	0.127	0.065	0.093	0.083	0.199
	χ^2=71.56		5 df		P=0.000	

Table 12. Percentages of total sheep-months and losses to dogs by distance to town or settled area. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Distance (in km)					
	1.6	1.7-3.2	3.3-4.8	4.9-6.4	6.5-8.0	8.0
Sheep-months	11.6 (45,163)	20.8 (80,886)	17.1 (66,610)	18.6 (72,212)	19.9 (77,372)	12.0 (46,688)
Losses to dogs	36.9 (41)	29.7 (33)	10.8 (12)	16.2 (18)	3.6 (4)	2.7 (3)
Rate of loss to dogs	0.091	0.041	0.018	0.025	0.005	0.006
	χ^2=91.16		5 df		P=0.000	

to predators occurred; control was often conducted then in an effort to curtail these losses. Twenty-two (40.7 percent) of the 54 sheepmen suffering losses to predators conducted predator control; only two (4.9 percent) of 41 sheepmen that did not suffer losses to predators conducted any type of predator control. The 24 sheepmen conducting predator control took an average of 5.4 coyotes and 0.4 dogs each during the study. Ten of these 24 sheepmen (41.7 percent) reported stopping their losses to predators completely by removing from one to three "offending" animals; several others reported decreased losses following trapping or hunting. High coyote pelt prices during the study was an additional incentive to capture coyotes.

Location of Lambing

One hundred one (94.4 percent) of the 107 sheepmen having ewes on hand during lambing lambed their ewes in enclosed buildings, corrals, or a combination of buildings and corrals. Only six (5.6 percent) of the sheepmen in the study did not lamb their ewes under confinement conditions. These six flocks tended to be small——four averaged less than 25 ewes, one averaged 66 ewes and one flock averaged 130 ewes. No statistical tests were conducted since nearly all lambing was done under confinement conditions.

Season of Shearing

One hundred five (98.1 percent) of the 107 sheepmen that had sheep on hand to be sheared did so in March, April, or May. Only two sheepmen (1.9 percent) did their shearing during the remaining nine months of the year. Most of the shearing was done in April——65 producers (60.7 percent) reported shearing during this month. Sixteen sheepmen (15.0 percent) sheared during March and 24 (22.4 percent) sheared during May. Two sheepmen that sheared their ewes during the spring had feeder lambs that were sheared in January. Again, no statistical tests could be conducted since nearly all shearing was done during a brief period in the spring.

Breed of Sheep

Breeds of ewes, rams, and lambs had little effect in losses to predators during this study. Commercial ewes (Columbia-Rambouillet cross) were by far the most widely used breeding ewes in the study, making up 79.1 percent of the total ewe-months. Mixed ewes (multiple-crosses and unknown breeds) made up 8.5 percent of the total ewe-months followed by Suffolk ewes with 6.2 percent. Other breeds represented include Hampshire, Dorset, Corriedale, Rambouillet, Southdown, Shropshire, and crosses of two or more of the above breeds. No significant differences were observed between breeds of ewes in losses to coyotes (χ^2=3.51, P=0.320) or dogs (χ^2=5.66, P=0.129).

Suffolks made up the majority of the breeding rams (77.8 percent) followed by Hampshires (13.0 percent) and other breeds (9.2 percent). Other breeds represented include Columbia, Dorset, Finn, Corriedale, Southdown, and Shropshire. A comparison of losses of ewes and lambs to predators in flocks with rams present was made between ram breeds. This comparison revealed no significant differences between breeds of rams in losses to coyotes (χ^2=1.13, P=0.568) or dogs (χ^2=4.51, P=0.105).

As expected, most lambs were the result of crossing commercial ewes with Suffolk rams. This cross made up 58.5 percent of the total lamb-months in the study. Feeder lambs of unknown heritage made up 20.0 percent of the total lamb-months followed by purebred Suffolks (6.6 percent) and commercial-Hampshire crosses (4.7 percent). Several other breeds were represented, mostly as crosses of the ewe and ram breeds described above. Again, no significant differences between breeds were observed in losses of lambs to coyotes (χ^2=1.46, P=0.834) or dogs (χ^2=3.10, P=0.541).

Poultry Management

Losses of poultry to predators were not recorded in this study; however, poultry management schemes and possible relationships with predator losses of sheep and lambs were examined. Four general categories of poultry management were observed: (1) No poultry produced, (2) Poultry allowed to run unconfined at all times, (3) Poultry not confined during daylight but confined at night, and (4) Poultry confined at all times. Most sheep production in the study (72.1 percent of total sheep-months) had no poultry production associated with it; but 5.9 percent of the sheep production was associated with the poultry production of category 2 above, 10.9 percent with category 3, and 11.1 percent with category 4. No signigicant differences in losses of sheep and lambs to coyotes (χ^2=4.62, P=0.202) or dogs (χ^2=1.26, P=0.739) were observed between categories of poultry management.

Pasturing and Confinement Management Schemes

Four main categories of sheep management in relation to confinement were followed during the study: (1) Sheep were on pasture during the day and confined in a corral at night, (2) Sheep were pastured during the day with access to a corral but were not confined at night, (3) Sheep remained in pasture day and night with no access to a corral, and (4) Sheep were confined in a corral day and night.

The highest rate of loss to coyotes occurred in flocks that remained in pastures day and night and did not have access to a corral (Table 13). The rate of loss was nearly as high in flocks that had access to a corral but were not confined in it at night. Flocks that were pastured during the day but confined at night had a significantly lower loss rate than flocks that were not confined at night (^{2}=14.49, P=0.000). The lowest rate of loss by far occurred in flocks that were confined in corrals both day and night.

The pattern for losses to dogs was identical to that described above for coyotes with only the magnitude of losses differing (Table 14). The highest rate of loss occurred in flocks that remained on pasture both day and night and had no access to corrals. Lower losses were observed in flocks that had access to a corral but were not confined at night and in flocks that were confined at night. Very low losses to dogs were reported in flocks that were confined in corrals both day and night.

The seasonality of pasturing and confinement is important in understanding the distribution of predator losses through the year. In general, about 80 percent of the sheep were pastured from June 1975 through September, with total confinement increasing in the fall and reaching a peak of nearly 70 percent in February. By May, over 60 percent of the sheep were again on pasture with

Table 13. Percentages of total sheep-months and losses to coyotes under the four principal management schemes. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Pastured day, confined night	Pastured day, corral available, not confined night	Pastured day and night	Confined day and night	Other
Sheep-months	39.4 (151,707)	8.8 (33,655)	10.8 (41,673)	40.3 (154,947)	0.7 (2,645)
Losses to coyotes	51.8 (205)	16.7 (66)	21.7 (86)	7.3 (29)	2.5 (10)
Rate of loss to coyotes	0.135	0.196	0.206	0.019	0.378
	χ^2=217.09	4 df	P=0.000		

Table 14. Percentages of total sheep-months and losses to dogs under the four principal management schemes. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Pastured day, confined night	Pastured day, corral available, not confined night	Pastured day and night	Confined day and night	Other
Sheep-months	39.4 (151,707)	8.8 (33,655)	10.8 (41,673)	40.3 (154,947)	0.7 (2,645)
Losses to dogs	27.9 (31)	9.9 (11)	52.3 (58)	9.0 (10)	0.9 (1)
Rate of loss to dogs	0.020	0.033	0.139	0.006	0.038
	χ^2=192.56	4 df	P=0.000		

this figure rising to nearly 80 percent in July and August 1976. These trends are presented graphically in Figure 10.

Pasture Factors

The majority of losses to predators in this study occurred while sheep were on pastures with only a small portion occurring in corrals. A total of 80.3 percent of the losses to coyotes and 78.6 percent of the losses to dogs occurred in pastures.

Several factors associated with the grazing of sheep on pastures were found to be important in relation to predator losses. Size of sheep flock pastured, size of pasture, distance from pasture to residence, type of pasture, height of pasture cover, and topography were all determined to be important in affecting losses to predators. Fencing practices, use of bells on sheep, and time of day that sheep were turned out to pasture and shut in corrals did not appear to affect losses of sheep and lambs to predators in pastures following testing with the chi-square procedure. Several variables were eliminated from further consideration following a subjective comparison of predator losses under various treatments. In general, a 10 percent or less difference in loss rates between treatments was basis for dropping the variable; however, this difference varied depending on magnitude of standard deviations. The variables dropped on this basis include analyses of woody cover in pastures and along fencelines, crops and woody cover on adjacent lands, other livestock in the same pastures, sheep density, pasture shape, and the presence of roads bordering pastures.

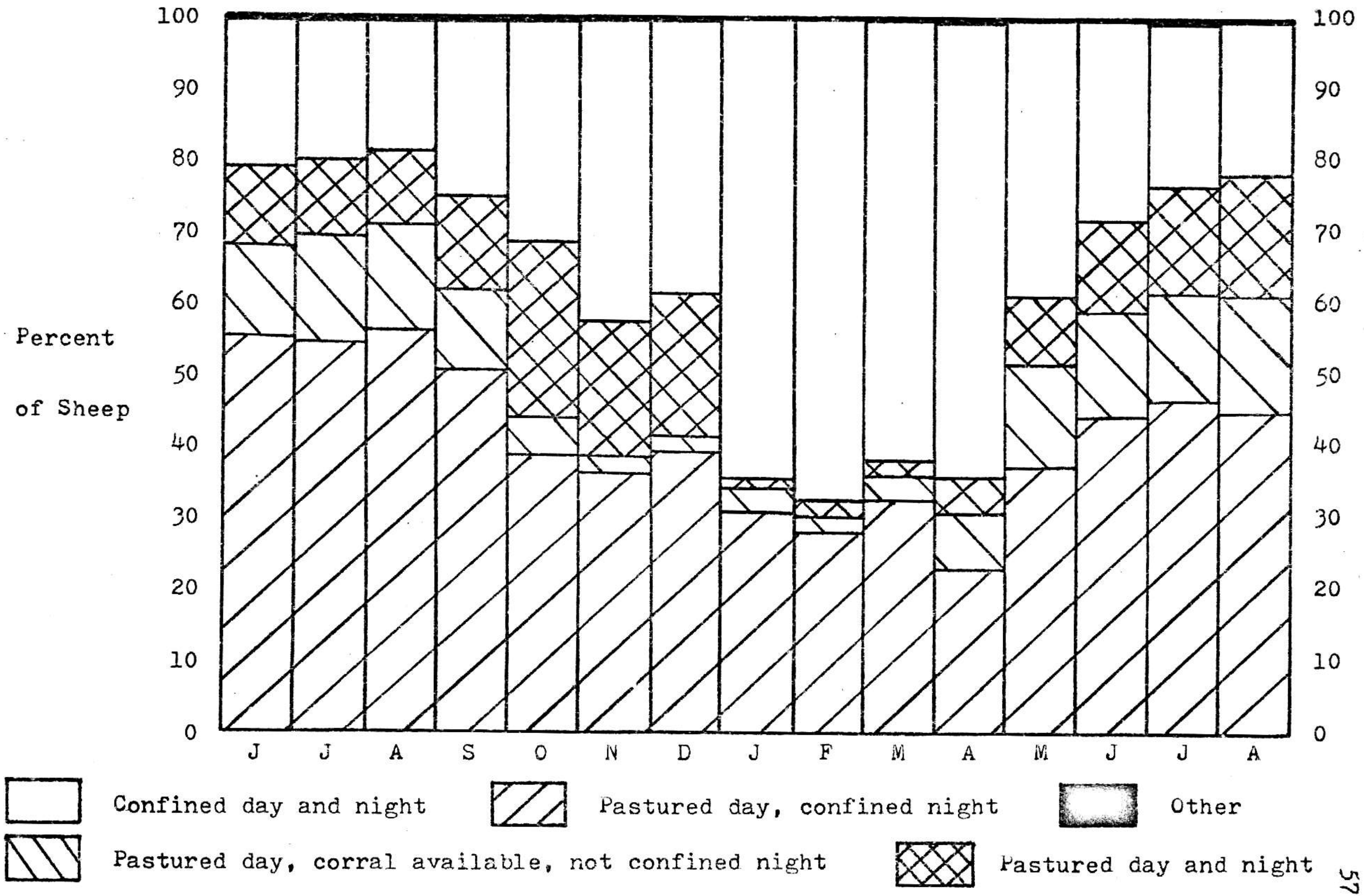

Fig. 10. Percent of sheep under each type of management by month.

Flock Size

Three factors that were closely related were determined to be important in affecting losses to predators. In general, losses tended to be greater in large flocks than in small flocks as stated above, large pastures had greater losses than small pastures, and losses were greater in pastures far from residences than in those close to residences. However, large flocks tended to be grazed in large pastures, and large pastures were typically far from residences. The relationships between these factors must be recognized before the results can be interpreted.

Although absolute numbers of losses to coyotes increased with flock size, rate of loss decreased. Table 15 presents a comparison of exposure in pastures and losses to coyotes by flock size. Differences in rates of loss to coyotes were greatest between flocks of less than 100 sheep and those of 100 or more (χ^2=18.67, P=0.000).

Table 15. Percentages of total sheep-months and losses to coyotes in pastures by flock size. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Flock size			
	<50	50-99	100-299	≥300
Sheep-months	4.1 (10,210)	9.1 (22,385)	41.9 (103,272)	44.9 (110,521)
Losses to coyotes	6.2 (20)	15.2 (49)	42.1 (136)	36.5 (118)
Rate of loss to coyotes	0.196	0.219	0.132	0.107

χ^2=21.49 3 df P=0.000

The above trend was not evident in losses to dogs. The rate of loss actually increased from 0.028 percent per month for flocks of less than 300 head to 0.039 percent per month in flocks of 300 or more. However, this increase was not significant (χ^2=2.24, P=0.134).

Pasture Size

Although rate of loss to coyotes was inversely related to flock size, a direct relationship was noted between rate of loss to coyotes and size of pasture (Table 16). As pasture size increased, rate of loss to coyotes also increased. Flocks grazed on pastures of less than 12.1 hectares in size had lower losses than expected (χ^2=21.98, P=0.000) while flocks grazed on pastures of 24.3 hectares or more had greater losses than expected (χ^2=19.09, P=0.000).

Table 16. Percentages of total sheep-months and losses to coyotes by pasture size. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Size of pasture (in hectares)			
	<4.0	4.0-12.0	12.1-24.2	≥24.3
Sheep-months	13.0 (32,013)	33.9 (83,606)	24.4 (60,187)	28.6 (70,582)
Losses to coyotes	8.4 (27)	27.6 (89)	24.5 (79)	39.6 (128)
Rate of loss to coyotes	0.084	0.106	0.131	0.181
χ^2=22.85	3 df	P=0.000		

A similar although not as dramatic trend was noted in losses to dogs (Table 17). Rate of loss to dogs tended to increase

Table 17. Percentages of total sheep-months and losses to dogs by pasture size. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Size of pasture (in hectares)			
	<4.0	4.0-12.0	12.1-24.2	≥24.3
Sheep-months	13.0 (32,013)	33.9 (83,606)	24.4 (60,187)	28.6 (70,582)
Losses to dogs	6.2 (5)	27.2 (22)	37.0 (30)	29.6 (24)
Rate of loss to dogs	0.016	0.026	0.050	0.034
χ^2=9.26	3 df	P=0.026		

with pasture size, with the exception of the last category. Flocks grazed on pastures of less than 12.1 hectares in size had lower losses to dogs than expected (χ^2=8.46, P=0.004) while flocks grazed on pastures of 12.1 to 24.2 hectares had greater losses than expected (χ^2=6.95, P=0.008).

Distance to Residence

The distance from the center of each pasture to the nearest residence was subjectively chosen from the six pasture-to-farmstead measurements as the variable to be analyzed. This measurement appeared the most logical as a true gauge of distance from human activity to sheep activity that may affect losses to predators.

Distance from residence to center of pasture appeared to affect losses to coyotes minimally. Rates of loss to coyotes were slightly higher at pasture distances of 200-399 meters (0.141 percent loss per month) and 400 meters or more (0.128 percent loss per month) from residences than at distances of less than 200 meters (0.120 percent loss per month). This difference was not significant (χ^2=1.50, P=0.472).

Losses to dogs did increase significantly as distance from residence to pasture increased (Table 18). Rate of loss to dogs was lowest at distances of less than 200 meters (χ^2=7.97, P=0.005) and greatest at 400 meters or more (χ^2=10.87, P=0.001).

Table 18. Percentages of total sheep-months and losses to dogs by distance from center of pasture to nearest residence. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Distance to pasture from residence (in meters)		
	<200	200-399	≥400
Sheep-months	30.5 (75,174)	43.6 (107,385)	25.9 (63,829)
Losses to dogs	16.0 (13)	42.0 (34)	42.0 (34)
Rate of loss to dogs	0.017	0.032	0.053
χ^2=13.64	2 df	P=0.001	

Type of Pasture

Sheep and lambs were grazed primarily on three types of pasture during the study with grass (48.7 percent of total sheep-months), sudan (19.8 percent), and wheat and rye (18.7 percent) accounting for nearly 90 percent of the total sheep-months on pasture. Both native and tame grasses were considered under the "grass" category. Other forages utilized include milo stubble, wheat stubble, alfalfa, and various combinations of the above six categories. Use of given pasture types was quite seasonal, with grass pastures being heavily used from May to September, sudan from July to September, wheat and rye from October to March, and milo stubble from October to December.

Losses of sheep and lambs to coyotes on the various types of pasture are presented in Table 19. Losses to coyotes were significantly higher than expected in milo stubble (χ^2=17.14, P=0.000). Chi-square values approached significance for higher losses in grass (χ^2=3.02, P=0.082) and combination grass-and-sudan pastures (χ^2=3.77, P=0.052). Lower losses were reported in sudan (χ^2=10.31, P=0.001) and wheat and rye pastures (χ^2=30.03, P=0.000).

Losses to dogs (Table 20) were distributed somewhat differently than losses to coyotes. Higher-than-expected losses were reported in sudan pastures (χ^2=6.92, P=0.008) while lower losses than expected were reported in grass (χ^2=9.00, P=0.003) and wheat and rye (χ^2=3.15, P=0.076).

Height of Pasture Cover

Losses to predators were examined in grass and sudan pastures in relation to height of cover. Nearly 70 percent of the total sheep-months on pasture occurred on these two pasture types. Although extensive grazing occurred on wheat and rye pastures, most took place during the fall and winter months when the cover was generally less than 10 cm tall. Losses in milo stubble were also not examined in relation to height of cover because little variation in height occurred between pastures. Harvest of the grain by combine usually left 50 to 70 cm of stubble standing.

Losses to coyotes in grass pastures are presented in Table 21. Losses tended to increase with height of grass in the pastures. The lowest rate of loss to coyotes (χ^2=10.41, P=0.001) was observed

Table 19. Percentages of total sheep-months and losses to coyotes by type of pasture. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Type of pasture					
	Grass	Sudan	Wheat and rye	Milo Stubble	Grass and sudan	Other
Sheep-months	48.7 (120,065)	19.8 (48,800)	18.7 (46,086)	4.9 (12,129)	2.8 (7,010)	5.0 (12,298)
Losses to coyotes	53.6 (173)	12.7 (41)	6.8 (22)	9.9 (32)	4.6 (15)	12.4 (40)
Rate of loss to coyotes	0.144	0.084	0.048	0.264	0.214	0.325
	$\chi^2=89.67$		5 df	P=0.000		

Table 20. Percentages of total sheep-months and losses to dogs by type of pasture. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Type of pasture				
	Grass	Sudan	Wheat and rye	Milo stubble	Other
Sheep-months	48.7 (120,065)	19.8 (48,800)	18.7 (46,086)	4.9 (12,129)	7.8 (19,308)
Losses to dogs	32.1 (26)	33.3 (27)	11.1 (9)	8.6 (7)	14.8 (12)
Rate of loss to dogs	0.022	0.055	0.020	0.058	0.062
	χ^2=19.65	4 df		P=0.001	

Table 21. Percentages of total sheep-months and losses to coyotes in grass pastures by height of cover. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Height of cover (in cm)		
	<15	15-30	≥30
Sheep-months	25.1 (30,096)	41.8 (50,140)	33.2 (39,829)
Losses to coyotes	14.4 (25)	32.4 (56)	53.2 (92)
Rate of loss to coyotes	0.083	0.112	0.231
χ^2=32.29	2 df	P=0.000	

in pastures with grass cover less than 15 cm tall. The highest rate of loss was observed in pastures with grass cover 30 cm tall or taller (χ^2=31.22, P=0.000).

Losses to dogs showed a similar tendency for highest losses to occur in the tallest cover (Table 22). Rate of loss to dogs was highest in pastures with grass cover that was 30 cm tall or taller (χ^2=7.11, P=0.008). The lowest losses occurred in pastures with grass cover ranging from 15 to 30 cm in height (χ^2=9.86, P=0.007).

Losses to coyotes in sudan pastures showed no relationship with height of cover. Losses were distributed as expected based on sheep-months of exposure (χ^2=0.27, P=0.874).

Height of sudan did appear to have an effect on losses to dogs, however (Table 23). Losses were highest (χ^2=27.13, P=0.000) in sudan pastures with the tallest cover (75 cm or greater), with nearly all losses to dogs occurring in this category.

Table 22. Percentages of total sheep-months and losses to dogs in grass pastures by height of cover. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Height of cover (in cm)		
	<15	15-30	≥30
Sheep-months	25.1 (30,096)	41.8 (50,140)	33.2 (39,829)
Losses to dogs	30.8 (8)	11.5 (3)	57.7 (15)
Rate of loss to dogs	0.027	0.006	0.038
χ^2=10.83	2 df	P=0.004	

Table 23. Percentages of total sheep-months and losses to dogs in sudan pastures by height of cover. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Height of cover (in cm)		
	<25	25-75	≥75
Sheep-months	4.9 (2,372)	52.3 (25,512)	42.9 (20,916)
Losses to dogs	3.7 (1)	3.7 (1)	92.6 (25)
Rate of loss to dogs	0.042	0.004	0.120
χ^2=27.71	2 df	P=0.000	

Topography

Topography of pastures in the study ranged from flat through gently rolling and rolling to rough. Six topography categories were recognized during the field research; however, category 6 was represented by only 2,743 sheep-months of exposure. Categories 5 and 6 were combined in the analysis in order to give roughly equal representation to each category.

The highest rate of loss to coyotes (χ^2=8.51, P=0.004) was recorded in the flattest topography category (Table 24). Losses were somewhat lower in categories 2 (χ^2=2.67, P=0.102), 3 (χ^2=7.72, P=0.006), and 4 (χ^2=0.00, P=1.000). However, losses were slightly higher in the roughest topography category (5), but not significantly (χ^2=1.41, P=0.235).

Table 24. Percentages of total sheep-months and losses to coyotes by topography category. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Topography category				
	1 (Flat)	2	3	4	5 (Rough)
Sheep-months	24.0 (59,232)	21.7 (53,473)	15.1 (37,316)	21.2 (52,287)	17.9 (44,080)
Losses to coyotes	31.0 (100)	18.0 (58)	9.6 (31)	21.1 (68)	20.4 (66)
Rate of loss to coyotes	0.169	0.108	0.083	0.130	0.150
χ^2=16.27		4 df	P=0.003		

The highest rate of loss to dogs (χ^2=85.12, P=0.000) was also recorded in the flattest topography category (Table 25). Losses in the other four categories of increasing roughness were all lower than expected.

Streams

Comparisons of losses to predators were made between pastures with streams and pastures with no streams. Streams are defined in this study as any drainage system with a year-round flow of water. Streams were often associated with rough topography categories and heavy woody cover.

Table 25. Percentages of total sheep-months and losses to dogs by topography category. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Topography category				
	1 (Flat)	2	3	4	5 (Rough)
Sheep-months	24.0 (59,232)	21.7 (53,473)	15.1 (37,316)	21.2 (52,287)	17.9 (44,080)
Losses to dogs	67.9 (55)	17.3 (14)	2.5 (2)	4.9 (4)	7.4 (6)
Rate of loss to dogs	0.093	0.026	0.005	0.008	0.014
χ^2=89.10		4 df	P=0.000		

Losses to coyotes in this comparison are presented in Table 26. The rate of loss was higher in pastures with streams than in pastures without streams (χ^2=48.37, P=0.000).

Table 26. Percentages of total sheep-months and losses to coyotes in pastures with and without streams. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Streams	No streams
Sheep-months	11.9 (29,353)	88.1 (217,035)
Losses to coyotes	24.5 (79)	75.5 (244)
Rate of loss to coyotes	0.269	0.112
χ^2=48.37 1 df	P=0.000	

Losses to dogs were lower (χ^2=5.15, P=0.023) in pastures with streams than in pastures without streams. Table 27 presents these results.

Table 27. Percentages of total sheep-months and losses to dogs in pastures with and without streams. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Streams	No streams
Sheep-months	11.9 (29,353)	88.1 (217,035)
Losses to dogs	3.7 (3)	96.3 (78)
Rate of loss to dogs	0.010	0.036
χ^2=5.15 1 df P=0.023		

Fencing Practices

Several types of fencing materials were used to confine sheep in pastures. Woven wire was the most widely used material, and was often used in conjunction with barbed wire above the woven. Three mesh sizes of woven wire were used: (1) 15 x 15 cm, (2) 30 x 15 cm, and (3) 30 x 20 cm. Measurements were made of the largest mesh on each type of woven wire. Woven wire was the main fencing material associated with 87.4 percent of the sheep-months, while barbed wire only (7.3 percent), electric fence (4.5 percent), and no fence (0.8 percent) were used to confine sheep to a lesser extent. No differences were observed in losses to coyotes (χ^2=3.95, P=0.557) or dogs (χ^2=2.35, P=0.799) between the various fencing material categories.

Height of fence was also considered. Most fences ranged from 80 to 100 cm in height. The lowest point of each pasture fence was used to test the effects of fence height on predator losses——again, no differences were observed in losses to coyotes (χ^2=2.50, P=0.475) or dogs (χ^2=3.48, P=0.323) between categories of fence height. Access to pastures was quite easy for predators in most cases. Holes in woven wire, holes below woven wire, large mesh size, and low fences all contributed to easy access by predators. Coyote and dog tracks were seen in pastures on many occasions. The pasture fences in the study were built to contain sheep, not to exclude predators.

Bells

Several sheep producers used bells on some or all of their sheep in an effort to discourage predators. The use of bells was associated with 13.6 percent of the total sheep-months of exposure in pastures. No differences in losses to coyotes (χ^2=0.66, P=0.417) or dogs (χ^2=0.10, P=0.752) were observed between flocks in which some or all sheep wore bells and flocks in which no bells were worn. However, no instances of predator losses were observed or reported in which the given sheep or lamb attacked was wearing a bell.

Time Sheep Turned Out and Shut In

In flocks that were confined at night, the times of day that the sheep were turned out to pasture and confined at night varied from one sheep producer to the next. Tests were conducted to determine if losses to predators were affected by the time of day that the sheep were turned out and shut in. No differences in losses to coyotes (χ^2=2.27, P=0.321) or dogs (χ^2=2.56, P=0.278) were observed between flocks turned out earlier than an hour, from 1 to 2 hours, or later than 2 hours after sunrise. Similarly, no differences in losses to coyotes (χ^2=0.29, P=0.865) or dogs (χ^2=4.12, P=0.128) were observed between flocks shut in earlier than 2 hours, from 1 to 2 hours, or later than an hour before sunset.

Corral Factors

Only a small segment of the total predator loss in the study occurred in corrals—19.7 percent of the loss to coyotes and 21.4 percent of the loss to dogs. The 79 sheep and lambs lost to coyotes in corrals appeared adequate for statistical analysis; however, only 22 losses to dogs occurred in corrals making statistical analysis difficult and conclusions possibly invalid. Results of losses in corrals to dogs will not be reported for all factors considered.

Three factors related to the confinement of sheep in corrals were determined to affect losses to predators. The use of lights at night and the use of bells on sheep were important in deterring predator losses in corrals, as was total confinement as opposed to partial confinement (confined at night only). Flock size, corral size, distance from corral to residence, and fencing practices did not appear to affect losses to predators following testing with the chi-square procedure. In addition, number and species of other livestock in the sheep corrals and adjacent corrals, density of sheep in corrals, and shape of corral were eliminated from further consideration following the subjective analysis described above under "Pasture Factors".

Lights

The use of lights above corrals at night had perhaps the most obvious effect on losses to predators of any factor examined in the study. Forty-three (39.4 percent) of the 109 producers in the study used lights on all or part of their sheep at least part of the time during the study. Of those using lights, 34 producers (79.1 percent) used mercury vapor lights with electric-eye sensors that automatically turned the lights on at dusk and off at dawn. Nine producers (20.9 percent) used bulb-type lights with either timers or manual switches. Light intensities were measured with a meter; however, intensities were too low in most cases to register on the meter and an analysis of intensities was not conducted. The highest intensity recorded was 1.2 foot-candles directly below a mercury vapor light. Intensity decreased as distance from the light increased and could not be measured in any instance at distances greater than 25 meters.

Losses to coyotes were highest (χ^2=34.25, P=0.000) in corrals with no lights and greatly reduced in corrals with lights (Table 28). Only three of the 79 losses to coyotes in corrals occurred in corrals with lights although over 35 percent of the sheep-months of exposure was in corrals with lights.

Table 28. Percentages of total sheep-months and losses to coyotes in corrals with and without lights. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Lights	No lights
Sheep-months	35.3 (108,429)	64.7 (198,664)
Losses to coyotes	3.8 (3)	96.2 (76)
Rate of loss to coyotes	0.003	0.038

χ^2=34.25 1 df P=0.000

Losses to dogs did not follow the pattern represented by losses to coyotes. Losses to dogs were higher than expected in corrals with lights (χ^2=5.37, P=0.020) and lower than expected in unlit corrals (Table 29). The small sample of losses to dogs in corrals must be considered when drawing conclusions from these data.

Table 29. Percentages of total sheep-months and losses to dogs in corrals with and without lights. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Lights	No lights
Sheep-months	35.3 (108,429)	64.7 (198,664)
Losses to dogs	59.1 (13)	40.9 (9)
Rate of loss to dogs	0.012	0.005
χ^2=5.37	1 df	P=0.020

Bells

Contrary to the results reported above for pastures, the use of bells on sheep did appear to have some utility in preventing predation in corrals. Although only 8.7 percent of the sheep-months represented in the corral analysis were associated with the use of bells, no losses to either coyotes or dogs were reported in corrals when bells were worn on a portion of the flock. Tables 30 and 31 present these results. The small sample of dog losses precludes the attainment of significance; however, the results suggest some benefit with the use of bells.

Table 30. Percentages of total sheep-months and losses to coyotes in corrals with bells used and with bells not used. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Bells used	Bells not used
Sheep-months	8.7 (26,672)	91.3 (280,421)
Losses to coyotes	0.0 (0)	100.0 (79)
Rate of loss to coyotes	0.000	0.028
χ^2=7.56	1 df	P=0.006

Table 31. Percentages of total sheep-months and losses to dogs in corrals with bells used and with bells not used. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Bells used	Bells not used
Sheep-months	8.7 (26,672)	91.3 (280,421)
Losses to dogs	0.0 (0)	100.0 (22)
Rate of loss to dogs	0.000	0.008
χ^2=2.08	1 df	P=0.149

Confinement

Sheep confined in corrals were divided into two categories: (1) Those that were confined 24 hours a day, and (2) Those that were confined at night only and pastured during the day. The categories were nearly equal, with 50.9 percent of the sheep-months in corrals falling under the first category and 49.1 percent falling under the second.

Losses in corrals to coyotes were higher (χ^2=6.35, P=0.012) in flocks that were confined at night only than in flocks under total confinement (Table 32). Losses to dogs were also slightly higher in flocks confined at night only, but not significantly (χ^2=0.88, P=0.348).

Table 32. Percentages of total sheep-months and losses to coyotes in corrals in flocks under total and partial confinement. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Total confinement	Confined at night only
Sheep-months	50.9 (156,221)	49.1 (150,872)
Losses to coyotes	36.7 (29)	63.3 (50)
Rate of loss to coyotes	0.019	0.033
χ^2=6.35	1 df	P=0.012

Flock Size

The rates of loss in corrals to coyotes were nearly equal under the four categories of flock size described above for pastures. Flocks of less than 50 sheep had a loss rate of 0.018 percent per month; this rate was 0.037 percent per month in flocks of 50-99 animals, 0.020 percent in flocks of 100-299, and 0.029 in flocks of 300 or more. These values did not differ significantly (χ^2=4.21, P=0.240). Losses appeared proportional to the size of the flock as rates of loss were nearly equal under the four categories.

Corral Size

A direct relationship was noted between flock size and corral size; large flocks tended to be confined in large corrals. As above, no differences in losses to coyotes between four categories of corral size were found (χ^2=5.06, P=0.168). The four categories and their rates of loss to coyotes were: (1) Less than 1,000 square meters, 0.024 percent per month, (2) 1,000 to 3,999 square meters, 0.025 percent per month, (3) 4,000 to 6,499 square meters, 0.037 percent per month, and (4) 6,500 square meters or greater, 0.018 percent per month.

Distance to Residence

A factor related to flock size and corral size was the distance from the corral to the residence. The distance used in the analysis was from the residence to the farthest point in the corral. Larger corrals held larger flocks and as a rule, the larger corrals were farther from the residences than were smaller corrals.

Three categories of distance were used in the analysis: (1) Less than 100 meters, (2) 100-199 meters, and (3) 200 meters or greater. The rate of loss to coyotes was slightly higher in category 3 (0.040 percent per month) than in categories 1 (0.026 percent per month) and 2 (0.023 percent per month), but the difference was not significant (χ^2=3.54, P=0.170).

Fencing Practices

Materials used in construction of corrals were similar to those used for pasture fences. The three types of woven wire used for pasture fences were also used for corrals, as was a fourth mesh size (7 x 15 cm being the largest mesh with this type). Woven wire was the primary fencing material associated with 89.0 percent of the sheep-months in corrals, with barbed wire only (9.2 percent), wood slat with electric fence (1.3

percent), and woven wire with electric fence (0.5 percent) used as the main fencing material to a lesser extent. No differences were observed in losses to coyotes (χ^2=7.04, P=0.317) or dogs (χ^2=3.18, P=0.786) between the various categories of fencing materials.

Corral fences were generally higher and maintained better than pasture fences. Most corral fences ranged from 100 to 120 cm in height. However, holes were numerous enough, mesh was often large enough, and fences low enough to permit fairly easy access by predators in many instances. No differences were observed in losses to coyotes (χ^2=2.34, P=0.505) between four categories of fence height (less than 80 cm, 80-99 cm, 100-119 cm, and 120 cm or higher).

Total Confinement

To further study the effects of confinement on losses to predators, a total confinement sheep operation in Cowley County was examined. This operation is owned and operated by Richard Marrs of rural Arkansas City. From 650 to 1032 stock sheep were on hand during the study along with lambs numbering from 100 to 750. No losses to predators occurred during the course of the study. Losses to other causes totaled 101 stock sheep and 86 lambs.

All sheep were confined at all times except for grazing on winter wheat during November, December, and January. About 650 ewes and 100 to 200 lambs were grazed under supervision for about 2 hours a day during this time. Mercury vapor lights were used above the corral at night and carcasses of dead sheep were disposed of about 2 miles away. Lambing was done primarily in the fall and took place in the corral or in the attached shed. Four Border Collies were owned by Mr. Marrs, and were often within sight of the sheep flock.

Welded wire 95 cm in height and 15 x 15 cm mesh woven wire (90 cm high) with one strand of barbed wire above at 95-100 cm made up the corral fence. No predator control was conducted in association with the sheep flock during the study.

Predator Abundance

Use of the scent-station method to determine relative predator abundance yielded 1,561 usable station-nights of data in 1975 and 1,686 in 1976. Wet weather in 1975 obliterated many stations and reduced the number of usable station-nights. Results of the surveys by county are given in Figures 11 and 12 for coyotes and dogs, respectively. The 1975 index, 1976 index, percent change from 1975 to 1976, number of survey lines, and probability that the observed difference represents an actual change in the index are given for each county and the study are as a whole in each figure. The average coyote indices for the 120 scent lines were 175 in 1975 and 157 in 1976. The average dog indices were 84 and 57 for the same two years. The indices for coyotes were not significantly different between years; however, the dog index was significantly lower in 1976 than in 1975.

Coyote Indices

An attempt was made to examine the relationship between relative coyote abundance (as determined by the scent-station

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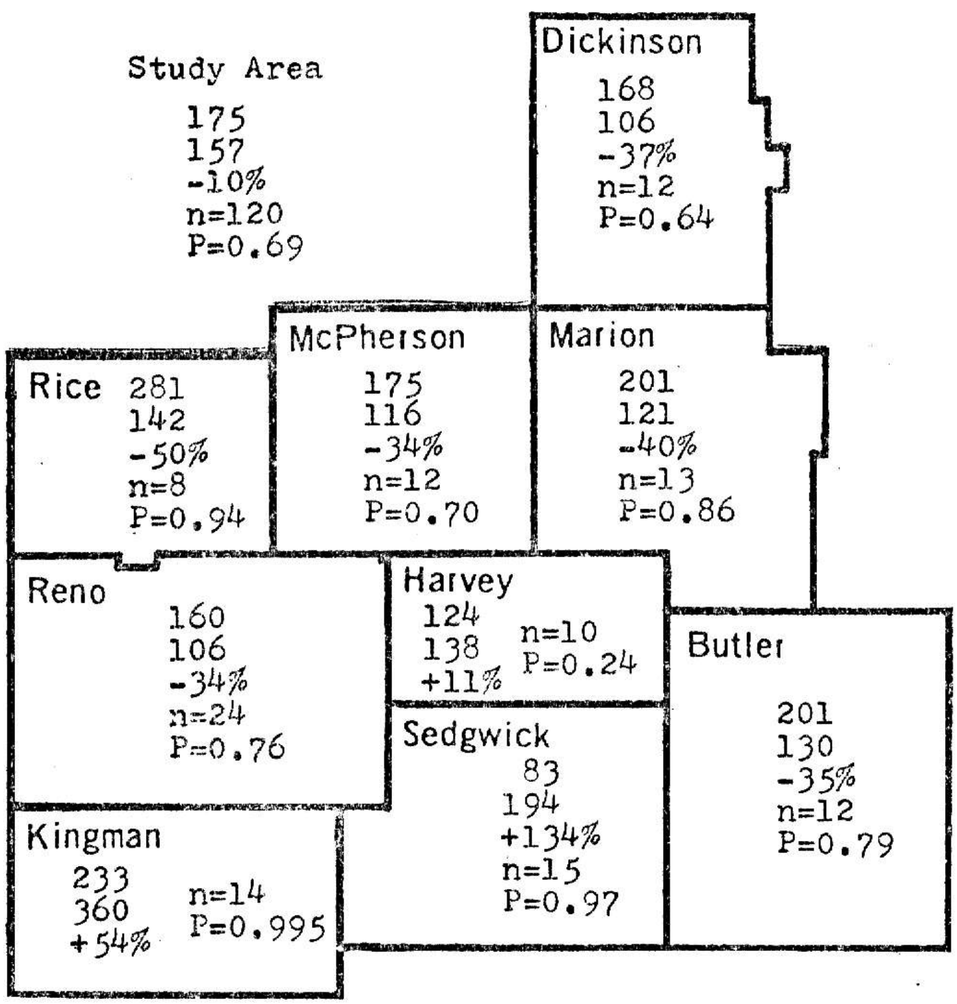
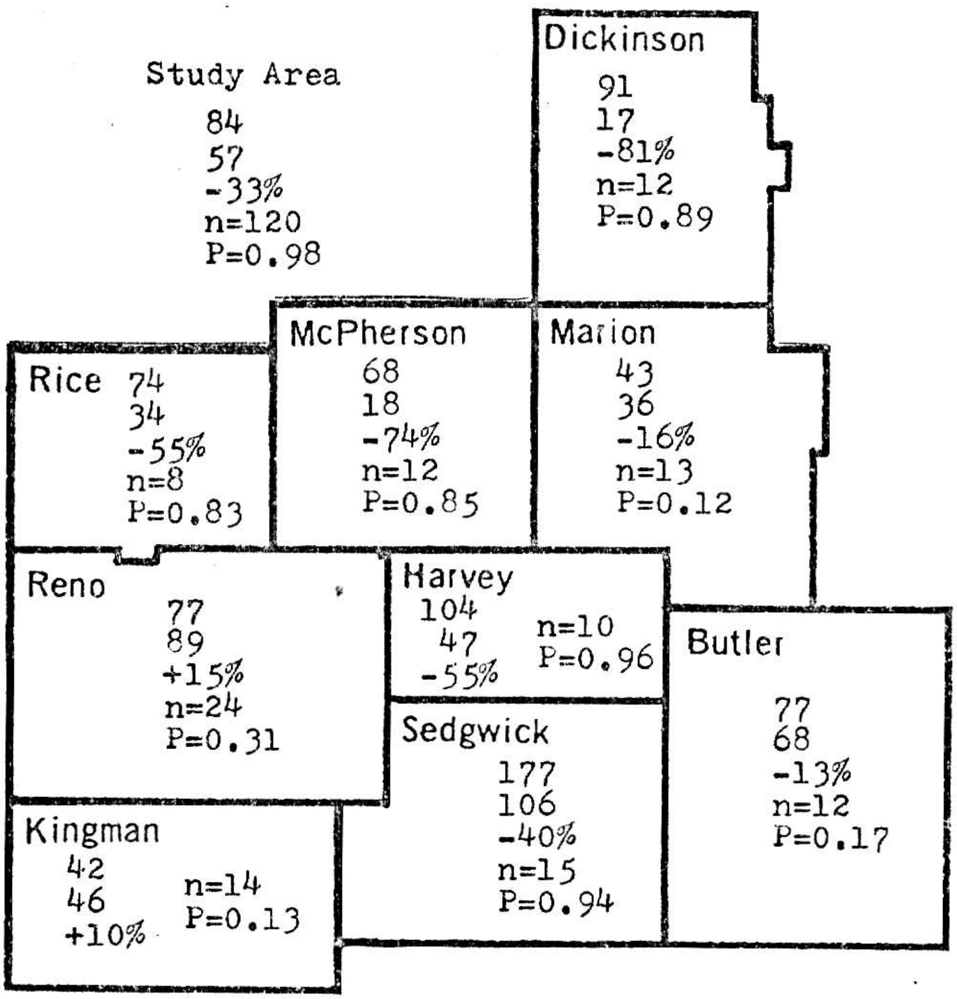


<u>Explanation of numerals within county outlines:</u>

233	=	1975 coyote index
360	=	1976 coyote index
+54%	=	Percent change from 1975 to 1976
n=14	=	Number of survey lines
P=0.995	=	Probability that the observed difference represents an actual change in the index

Fig. 11. Results of 1975 and 1976 survey of predator abundance (coyotes).



Explanation of numerals within county outlines:

42 = 1975 dog index
46 = 1976 dog index
+10% = Percent change from 1975 to 1976
n=14 = Number of survey lines
P=0.13 = Probability that the observed difference represents an actual change in the index

Fig. 12. Results of 1975 and 1976 survey of predator abundance (dogs).

method) and losses of sheep and lambs to coyotes. The six index values (three in each year of the study) obtained for each sheep preducer were averaged and each operation was subsequently placed in a category of coyote abundance (low if average index was less than 100, moderate if equal to or greater than 100 and less than 150, and high if equal to or greater than 150). Category boundaries were selected to place approximately equal numbers of sheep-months in each category for the sake of comparison.

Table 33 gives the percentages and numbers of sheep-months and losses to coyotes along with the rate of loss to coyotes in each category of coyote abundance. Losses to coyotes were highest in the category of highest coyote abundance (χ^2=6.36, P=0.042) and lowest under moderate abundance (χ^2=7.04, P=0.030). Losses under low abundance were as expected based on amount of exposure (χ^2=0.00, P=1.000).

Table 33. Percentages of total sheep-months and losses to coyotes under three categories of coyote abundance. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Coyote abundance		
	Low	Moderate	High
Sheep-months	32.3 (125,562)	30.9 (120,192)	36.8 (143,177)
Losses to coyotes	32.3 (128)	24.7 (98)	42.9 (170)
Rate of loss to coyotes	0.102	0.082	0.119
χ^2=8.88	2 df	P=0.012	

A comparison was made between average index values of sheep producers that suffered losses to coyotes during the study and index values of producers that did not suffer losses to coyotes. Only values for producers that stayed in the study for the full 15 months were used in this comparison. Producers that suffered losses to coyotes had an average coyote index of 163 and those that suffered no losses to coyotes had an average of 137. However, this difference was not significant ($t=0.374$, $P=0.709$).

Dog Indices

The relationship between relative dog abundance and losses of sheep and lambs to dogs was examined in the same manner as done for coyotes above. However, lower index values were used to place sheep operations in respective categories since dog indices averaged less than half the values obtained for coyote indices. Dog abundance was considered low if index values were less than 50, moderate if equal to or greater than 50 but less than 100, and high if equal to or greater than 100. Use of these values placed approximately one third of the total sheep-months in each category.

Rates of loss to dogs were higher in the moderate ($\chi^2=5.67$, $P=0.017$) and high ($\chi^2=3.25$, $P=0.071$) abundance categories as shown in Table 34. Losses were lowest under low dog abundance ($\chi^2=18.70$, $P=0.000$).

As done for coyotes above, a comparison of average index values was made between producers that suffered losses to dogs and those that suffered no losses to dogs. Producers that suffered losses to dogs had an average dog index of 87 while those that suffered no losses to dogs had an average of 79. This difference was not significant ($t=0.160$, $P=0.873$).

Table 34. Percentages of total sheep-months and losses to dogs under three categories of dog abundance. Numbers of sheep-months and losses are shown in parentheses. Rate of loss is expressed as percent of total sheep per month.

	Dog Abundance		
	Low	Moderate	High
Sheep-months	30.6 (119,071)	36.8 (143,259)	32.6 (126,601)
Losses to dogs	11.7 (13)	47.7 (53)	40.6 (45)
Rate of loss to dogs	0.011	0.037	0.036
$\chi^2=18.74$	2 df	P=0.000	

Going-Out-of-Business Survey

One hundred twenty-two of the 225 questionnaires (54.5 percent) mailed to former sheep producers were returned. The results are shown in Table 35. The first column gives the reason for quitting the sheep business. The second column gives the number of times that reason was given as the only cause for quitting, or if more than one cause was given, the main reason for quitting. The third column gives the number of times a reason was listed as a contributing cause, but not the main cause for quitting the sheep business.

Old age of the sheepmen and predator problems were the main reasons given for quitting the sheep business. Unfavorable prices, health problems, and switching from raising sheep to other livelihoods were also important in this respect.

Twelve of the 110 sheepmen in the management-predation study at the beginning sold out during the 15-month study period.

The reason for quitting the business given by six of these sheepmen was old age; two sheepmen quit because of labor problems; and only one said predator problems caused him to quit (at 72 years of age). Two others sold out because of economic difficulties and one quit because of reproductive problems in his flock.

Table 35. Results of survey of former sheep producers in south-central Kansas.

Cause of quitting sheep business	Number of times given as main cause	Number of times given as contributing cause but not main cause
Nearing or have reached retirement	31	15
Predator problems	26	17
Sheep production was unprofitable	6	12
Poor health	5	4
Switched to beef production	4	8
Taken other jobs	3	4
Switched to cash crop production	3	3
Switched to swine production	2	5
Difficulty in getting shearers	1	6
Labor requirements too high	0	4
Marketing difficulties	0	3
Difficulty in hiring qualified labor	0	1
Other	11	8

DISCUSSION

Sheep Numbers

The number of sheep and lambs in the study on 1 January 1976 was 19.0 percent of the 163,000 sheep and lambs in Kansas on that date, according to the Kansas State Department of Agriculture (1976). This number was 49.9 percent of the total sheep in the 9-county study area. Flocks in the study appeared somewhat larger than the average for the Plains Wheat-Corn subregion, according to Gee and Magleby(1976). They reported 11 percent of the commercial flocks as having 300 or more stock sheep, while 18 percent of the commercial flocks in this study were placed in this category.

Sheep Mortalities

Losses of sheep and lambs to predators were generally lower in this study (0.9 percent of stock sheep and 0.9 percent of lambs annually) than losses reported by other authors for the western United States. Magleby (1975) reported a loss of 2.2 percent of docked lambs and 3.8 percent of stock sheep in Kansas in 1974. He reported losses to predators of 6 percent of docked lambs and 2.5 percent of stock sheep in the 15 western states as a whole. Higher losses are generally reported in the mountain states than in the plains states. Early et al. (1974a) reported that farm flocks are less susceptible to predation than range flocks. Of the 15 western states, the lowest losses were recorded in Kansas, Nebraska, South Dakota, and North Dakota (Magleby

1975). In Iowa, an average predator loss of 2.8 percent of lambs marketed was reported by Boggess (1975). Reynolds and Gustad (1971) estimated an average predator loss for four western states to be 5.3 percent, with losses ranging from 3.6 percent in Texas to 7.9 percent in Wyoming. Early et al. (1974a) estimated predator losses to be 2.6 percent of ewes and 4.0 percent of lambs during 1970-71 in Idaho, with total losses amounting to 10.5 percent of ewes and 18.8 percent of lambs. The same authors (1974b) estimated 2.8 percent of ewes and 3.8 percent of lambs were lost to predators in 1972-73, with a total loss of 8.6 percent of ewes and 15.5 percent of lambs. Klebenow and McAdoo (1976) recorded a 9 percent total loss and a 4 percent predator loss on a band of sheep in Nevada. Dorrance and Roy (1976) reported predator losses of 1.6 percent and 2.8 percent for ewes and lambs, respectively, and total losses of 6.6 percent and 15.7 percent in Alberta. In two studies in Montana and New Mexico where very limited or no predator control was conducted, predator losses were reported to be quite high. In Montana, Henne (1975) reported a 29.3 percent loss of lambs and an 8.4 percent loss of ewes to predators. DeLorenzo and Howard (1976) reported lamb losses to predators of 15.6 percent and 12.1 percent in 1974 and 1975, respectively, in New Mexico.

Coyotes accounted for the majority of predator losses in this study (78.1 percent) as well as in most other studies. Proportions of predator losses attributed to coyotes in various studies amounted to 97.1 percent (Henne 1975), 91 percent (Klebenow and McAdoo 1976), 88 percent (Dorrance and Roy 1976), 81 percent (Nielsen and Curle 1970), 78.2 percent of lambs and 66.8 percent of ewes (Early et al. 1974a), 84.4 percent of lambs and 80.3 percent of ewes (Early et al. 1974b), 77.4 percent in 1974 and 100 percent in 1975 (DeLorenzo and Howard 1976). Bears, mountain lions, foxes, eagles, and bobcats were reported as predators on sheep in several of the above studies, but were not encountered in the study in Kansas.

Problems with dogs increase from west to east across the United States. Losses to dogs in the West are usually quite low (Nielsen and Curle 1970; Early et al. 1974a and 1974b; Henne 1975; Klebenow and McAdoo 1976), and usually make up less than 3 percent of the predator loss. Dogs accounted for 21.9 percent of the predator loss in this study. In Iowa during 1971-73, 38.9 percent of the predator losses of sheep were attributed to dogs (Boggess 1975). Dogs are the major predator on sheep in the eastern states (Denney 1974).

Reynolds and Gustad (1971) reported the percent of stock sheep losses by cause for Colorado and Texas. In Colorado, predators accounted for 25.6 percent of the losses; old age, 17.9 percent; bloat, 9.6 percent; disease, 9.5 percent; lambing complications, 6.7 percent; poison, 6.6 percent; and weather conditions, 5.1 percent. Unknown causes accounted for 16.7 percent of the losses. In Texas, old age was the major cause of loss (23 percent) followed by predation (15 percent), inclement weather (11 percent), parasites (11 percent), and poison (7 percent). Unknown causes (20 percent) and other factors (11 percent) were also important.

Predators have been reported to account for 24 percent (Early et al. 1974b) and 25 percent (Dorrance and Roy 1976) of ewe mortality in additional studies. These values are somewhat higher than the proportion of losses attributed to predators in Kansas (14.0 percent).

Several studies of lamb mortality have been conducted. Safford and Hoversland (1960) found that 16 percent of the lamb loss from birth to weaning was due to pneumonia; 15.8 percent had no visible lesions; 14.3 percent were stillborn; 13.8 percent of the loss was due to starvation; 11.8 percent to dysentery; 5 percent to delayed parturition; 5 percent to enterotoxemia; and 18.3 percent to other causes. Vetter et al. (1960) reported the leading causes of death in lambs to be stillbirth, "weak at birth", and pneumonia. Venkatachalam et al. (1949) stated that pneumonia, premature births, weak lambs, and stillbirths were the major mortality factors in their study. Wagner and Pattison (1973) reported major causes of lamb losses to be birth problems, exposure, and improper mothering which led to starvation. Rowley (1970) reported starvation to be a major cause of mortality in small lambs. Apparently, problems during and shortly after birth are the major causes of lamb mortality in other areas as well as Kansas.

Proportion of lamb losses attributed to predators has been reported in several recent studies. Values reported include 21 percent (Early et al. 1974a), 25 percent (Early et al. 1974b), 18 percent (Dorrance and Roy 1976), and 46 percent in 1974 and 67 percent in 1975 (DeLorenzo and Howard 1976). Magleby (1975) reported that over half of the lamb losses after docking were to coyotes. Davenport et al. (1973) stated that 30.1 percent of lambs necropsied on spring range were predator kills and on summer range, 62.1 percent of carcasses examined were predator kills. The value for undocked lambs in Kansas (6.1 percent) was lower than those reported above but the value for docked lambs (20.1 percent) was comparable with the above studies.

Most authorities report coyote losses to be highest during late spring and summer (Young and Jackson 1951; Gier 1968; Bowns et al. 1973; Early et al. 1974a and 1974b; Boggess 1975; DeLorenzo and Howard 1976). Pups are usually born in April and May (Gier 1968), and extra food is needed during late spring and summer to raise the young (Wade 1973b). Most lambing in the western states occurs from February through May (Gee and Magleby 1976) and small lambs are most susceptible to predation (DeLorenzo and Howard 1976). Lambing in Kansas occurs mostly from October through March, and few small lambs are available during the summer months. Klebenow and McAdoo (1976) report highest predator loss during late summer and early fall. Although Nielsen and Curle (1970) stated that lamb losses were highest during spring and summer, predator losses of ewes were highest during the winter months. The seasonality of losses to coyotes in Kansas is probably due in part to the reproductive biology of the coyote, and also to the confinement practices discussed below.

Seasonality of sheep losses to dogs has not been well documented. In Iowa, losses to dogs were highest from May through December with an extreme peak in December (Boggess 1975). The December peak was thought to be related to large kills in feedlot confinement situations under which dogs could easily kill a large number of sheep in a short period of time. However, the similar peak of dog losses in December in this study was due to high losses in pastures, not confinement situations.

Boggess (1975) recognized that sheep losses were not distributed evenly among producers——some producers suffered high losses. In an interview survey in New Mexico and Utah, about 50 percent of the sheepmen reported less than 5 percent predator loss; 25 percent reported 5 to 10 percent predator loss; and 25 percent reported loss as greater than 10 percent (Balser 1974a). Wagner and Pattison (1973) and Dorrance and Roy (1976) described the frequency distribution of losses among sheep producers as a Poisson distribution. In their study in Alberta, 39 percent of producers had no predator losses and 31 percent had a 3 percent loss or less. Results of the present study were similar to those cited above and suggest a Poisson distribution also.

The causes of loss among sheep necropsied by the investigator appeared similar to causes of loss reported by the sheepmen. There appeared to be no reason to doubt the validity of the sheepmens' reports of causes and extent of losses. Andelt (1976) reported close agreement between estimates of poultry losses made by the producers and actual losses found by him.

The major problem in conducting necropsies on sheep carcasses in this study was rapid decomposition due to warm temperatures during the summer, when much of the field work was conducted. This problem was also encountered by Bowns et al. (1973) and Davenport et al. (1973).

Value of Sheep Lost to Predators

The value of sheep lost to predators in Kansas is lower now than in the past, despite higher sheep and lamb prices.

Gier (1968) reported that in 1950, over $350,000 in losses of sheep and lambs to predators occurred in Kansas. This reduction in value of losses appears partially due to lower numbers of sheep and lambs (163,000 in 1976 compared to 800,000 in 1948), but also to a lower rate of loss to predators. Losses in Kansas ($70,000 annually) appear low when compared with the $1,109,374 reported for Utah in fiscal 1969 (Nielsen and Curle 1970) and the $16,955,820 reported for 16 western states in 1970 (Reynolds and Gustad 1971).

Management Practices

General Management Factors

Flock Size

The rate of loss to both coyotes and dogs appeared to vary inversely with the size of the flock, although absolute number lost varied directly with flock size. This relationship between rate of loss and flock size has not been reported in the literature. Gier (1968) stated that sheep losses in Kansas were nearly proportional to the number of lambs raised. Dorrance and Roy (1976) reported that larger flocks were more susceptible to predation than smaller flocks in their study in Alberta. Nielsen and Curle (1970) found no relationship between size of breeding flock and rate of loss to predators.

Many more sheep would have to be killed in large flocks than in small flocks for the rates of loss to be equal. Since coyotes typically kill only one or two sheep in a given attack (Kalmbach 1948, Gier 1968), large flocks would have to be attacked much more often than small flocks for the rates of loss to be equal. Large flocks are evidently being attacked only slightly more often than small flocks since absolute losses are greater in large flocks but rate of loss is not. Although dogs may often kill several sheep at once (Gier 1968), similar logic may be followed in rationalizing the difference in rates of loss to dogs.

Disposal of Carcasses

Several authors (Tiemeier 1955; Mathwig 1973; Gipson 1974; Boggess 1975; Lehner 1976) have suggested that improper disposal of dead livestock may lead to scavenging and subsequent predation on livestock, but little research has been conducted on the problem. Todd and Keith (1976) reported lower coyote densities on carrion-free areas than on areas where carrion was not removed. Depredations on livestock did not increase when carrion was removed.

The results of the present study suggest that making sheep carrion unavailable to scavenging coyotes does have merit in reducing losses to coyotes. Coyotes may acquire a taste for lamb and mutton, or at least learn the location of a flock of potential prey by scavenging on carcasses. The coyotes may turn to the live animal once the carrion is exhausted or as they learn that the sheep are easy prey. Proper disposal of carcasses will lower the number of encounters between predator and prey and in turn lower the chances for loss to occur.

No relationship was found between method of carcass disposal and losses to dogs. Dogs probably do not scavenge for food nearly as much as coyotes and do not return to the same place to feed as consistently. Most dog losses in the study were a one-time affair, as opposed to the habit of coyotes to return to the same farm and make subsequent kills at later dates.

Season of Lambing

Kansas differs from most of the other western states in having the majority of lambs born from October through December. Most of the lambs in the West are born from February through May, according to Gee and Magleby (1976). Iowa, a farm-flock state with sheep management similar to Kansas, also has the majority of its lambs born during the spring (Joe Schaefer, personal communication).

By having most of the lambs born in the fall, Kansas sheepmen do not have a large number of lambs on hand during the late spring and summer months when losses to coyotes are typically highest as discussed above. Early lambing is economically sound because the highest market prices for lambs typically occur in the spring, from March through May (McCoy 1972). The high losses of lambs to coyotes during lambing (Young and Jackson 1951, Early et al. 1974a) are avoided by lambing during the fall and winter months when the food demand of the coyote population is lower than during summer. Flocks are also more likely to be confined during lambing which further lowers the risk of predator losses.

Possession of Dogs

The possession of dogs by sheepmen influenced losses to both coyotes and dogs, but in opposite directions. Free-running or tethered pet dogs may chase coyotes away from the flock or bark enough to frighten or alert coyotes and prevent them from causing damage. Howard (1974b) reported the use of dogs to frighten coyotes and smaller predators away from poultry. Dogs appear to have a place in guarding sheep flocks from marauding coyotes.

This principle apparently did not work to frighten other dogs away from the sheep flocks. Sheepmen with dogs suffered higher dog losses than those without dogs. Denney (1974) reports that most of the problems with livestock come from free-running dogs (uncontrolled pets). These dogs may not be repelled from the flock as coyotes appear to be and may even entice the sheepmens' pets into joining the hunt. Female dogs (especially in heat) may lure male dogs into the vicinity of a sheep flock and further complicate the problem. Sheepmen with dogs must take care to guard against losses from their own or visiting dogs.

Distance to Towns or Settled Areas

Coyote losses in this study were roughly correlated with the distance of the sheep operation from a settled area. A discussion of this relationship was not found in the literature. One may expect the density of coyotes to increase as distance from settled areas increases and conflicts and confrontations with humans decrease.

Losses to dogs decreased markedly as distance from settled areas increased. As stated above, Denney (1974) attributed most dog-livestock problems to uncontrolled pets; most of these pets would likely originate from settled areas. The nearer a sheep operation is to a settled area, the more likely conflicts are to arise. Rowley (1970) and Bowns (1976) both reported that dogs were likely to cause problems near towns.

Predator Control

Removal of a small portion of the coyote population, the specific animals causing the damage, is often enough to stop losses of livestock and poultry (Bennitt 1948, Kalmbach 1948). This procedure may be quite efficient in reducing losses in certain instances, according to Gipson (1975). Missouri (Sampson and Brohn 1955) and Kansas (Henderson 1972) are the leading states in using this philosophy of predator damage control. A complete description of the damage-control program in Kansas in use during this study was given by Henderson (1972). He reported that 65 percent of the people who request training in animal damage control are able to stop their losses, and many others are able to reduce their losses substantially. Few producers in the study received training during the 15-month study period; however, many had received training at some time prior to the study. Sampson and Brohn (1955) reported an average catch of 9.2 predators per year by farmers that were trained in predator damage control under the Missouri system. They also reported an 81 percent reduction in the value of losses after training.

Apparently little incentive exists among Kansas sheep producers to conduct predator control before losses to predators occur; less than 5 percent of the producers in this study that had no losses to predators conducted any type of predator control while over 40 percent of the producers that suffered losses to predators conducted some type of control.

Location of Lambing

Nearly all (94.4 percent) of the sheepmen in the study lambed under confinement conditions. Wade (1973a) reported that lambing in sheds may reduce predator losses for farm-flock operators; however, he along with Gee and Magleby (1976) reported that shed lambing was not practical for the large range operations.

Kansas sheepmen have apparently taken the step of reducing predator losses by lambing under confinement conditions. In two studies in Idaho by Early et al. (1974a and 1974b), 85 and 81 percent of the lambing was done in sheds to discourage predation.

Season of Shearing

Long wool on the neck of a sheep may discourage predation by coyotes——Bowns (1976) reported that coyotes often attacked the hindquarters in late winter when the wool on the neck was long. Losses in this study were lower during winter and early spring before shearing was done——however, the cause of variation in losses between seasons was compounded by confinement practices and the reproductive biology of the coyote.

Breed of Sheep

Gilbert (1973) suggested that the breed of sheep may influence predator attacks; however, no studies were found in which breed was considered as a factor in losses to predators. No differences between breeds were observed in vulnerability to predators in this study. Size and behavior are apparently similar enough among breeds in Kansas to preclude selection by or resistance to coyotes and dogs on specific breeds.

Poultry Management

Gier (1968) reported high losses of chickens to coyotes during the 1940's, with most of the losses occurring in unconfined flocks. Management of flocks has changed since that time, with fewer, larger flocks being raised in total confinement and little loss to predators occurring today (Gier 1968, Henderson 1972). Production and management of poultry in association with sheep production apparently has little or no effect on losses of sheep and lambs to predators. Predation on poultry by coyotes has been greatly reduced and coyotes do not appear to turn to killing sheep and lambs after exposure to and possible predation on poultry.

Pasturing and Confinement Management Schemes

Confinement of sheep flocks at night was an important tool in reducing losses to predators. Since most losses to predators occur during the night (Bowns et al. 1973, Henne 1975), the practice of making sheep less accessible to predators (by confinement) during the night appears to be the key in reducing losses. Total confinement eliminated all daytime losses as well as reducing losses at night. Several authors (Coll 1922; Gier 1968; Huston and Shelton 1973; Mathwig 1973; Wade 1973a) have expressed the importance of confinement in reducing losses to predators; however, no documentation of actual loss reduction has been done. On the contrary, Dorrance and Roy (1976) reported the highest losses to predators in confined flocks, the next highest losses in semiconfined flocks (confined at night only), and the lowest losses in range flocks. This was due to very severe predation in confined flocks; many sheep were killed during each attack since they could not escape. However, predation was reported in only 17 percent of the confined flocks while losses to predators occurred in 81 and 93 percent of semiconfined and range flocks in their study, respectively.

The seasonality of losses to predators was described above under "Sheep Mortalities". These losses appear to be correlated with the availability of sheep on pasture as well as to the reproductive biology of the coyote. Losses were highest when most of the sheep were the most available to predators (on pastures) and lowest when the sheep were least available (confined).

Pasture Factors

Since approximately 80 percent of the losses to predators occurred while the sheep were on pasture, a close examination of the factors involved is warranted. A reduction of predator losses may best be accomplished by altering management of sheep during the time they are being pastured.

Flock size

The relationships between flock size and losses to coyotes in pastures were similar to those described above under "General Management". Larger flocks suffered greater absolute losses to coyotes than did smaller flocks, but the rate of loss tended to decrease as flock size increased. Larger flocks probably offered more opportunities for coyotes to attack sheep and this resulted in greater numbers of kills. Since coyotes typically kill only one or two sheep at a time (Kalmbach 1948, Gier 1968), the rate of loss is lower in larger flocks since number of attacks per flock apparently does not increase as rapidly as flock size.

No differences in loss rates were observed between categories of flock size in losses to dogs. Absolute number of losses appeared proportional to flock size. Nielsen and Curle (1970) found no relationship between flock size and losses to predators.

Pasture Size

Rates of loss to both coyotes and dogs increased with pasture size. This relationship is not well understood since larger flocks tended to be grazed on larger pastures and loss rate to coyotes decreased as flock size increased with no relationship noted for dog losses. Perhaps larger pastures provided more opportunities for kills or made cutting sheep from the flock and running them down easier.

Distance to Residence

Loss rates to coyotes did not differ between categories of distance from residence to center of pasture; however, the rate of loss to dogs tended to increase as this distance increased. One would expect the reverse to be true——dogs, being accustomed to close association with humans, would not be expected to be affected by distance from human activity, while coyotes would be expected to conduct the majority of their predation as far from human activity as possible. This was not the case in this study.

Interrelationships between the above three factors were difficult to understand in this study. Other factors may also have influenced the results in ways unknown at this time.

Type of Pasture

Losses to coyotes by type of pasture reflected the seasonality of food demand by the coyote population (Robinson 1962, Wade 1973a). Losses were typically higher in pastures grazed during the summer and fall (grass, grass-and-sudan, and milo stubble) than those grazed in winter (wheat and rye). An exception was sudan pasture which was grazed heavily during the summer but in which low losses occurred.

Losses to dogs appeared related to height of cover in pastures. Loss rates were highest in sudan and milo stubble, both of which tended to provide tall pasture cover. Loss rates were lower in grass and wheat-and-rye pastures, two cover types that provided much shorter pasture cover. Possible exposure to humans in short pasture cover may have some effect in deterring predation by dogs.

Height of Pasture Cover

Loss rates to both dogs and coyotes showed a tendency to increase as cover height increased within a given pasture type. This tendency was stronger for dogs than for coyotes. This relationship was most dramatic in sudan pastures; nearly all of the loss to dogs occurred in the tallest cover category. No mention of losses to predators among various heights of cover could be found in the literature.

Topography

Contrary to documented information, most losses in this study were reported in pastures of flat topography. Henne (1975) reported that 40 percent of the coyote kills observed were located in ditches, stream bottoms, and ravines. Bowns et al. (1973) and Davenport et al. (1973) reported finding many kills in rough areas where coyotes had chased sheep to make killing easier. Sheep flocks in this study may have been detected from greater distances in flat topography and predation thus increased. The steps in killing might possibly be easier in flat topography; cutting sheep from the flock, running them down, and attacking. Other unknown factors may also be involved in this relationship.

Streams

The loss rate to coyotes was higher in pastures with streams than in pastures without streams. This result appears to contradict the findings of the previous section in which the highest losses were in pastures of flat topography since pastures with streams were usually of rougher topography than those without. Coyotes may have been using stream courses as travel lanes or have been hunting other prey in cover along the streams and came into contact with sheep flocks which resulted in losses. Henne (1975) reported finding many coyote kills in stream bottoms and ravines; however, Davenport et al. (1973) reported most kills in open areas with few kills observed in timber. Many of the stream courses in this study were lined with riparian habitat.

Losses to dogs were significantly lower in pastures with streams than in those without. This apparently agrees with the results of the previous section in which most losses were in flat pastures. Dogs would not be as likely to follow stream courses as travel lanes or in hunting other prey and would be less likely than coyotes to encounter sheep flocks in these pastures.

Fencing Practices

The pasture fences in this study did not appear to be a factor in affecting predator losses. Construction of the fences was not aimed at excluding predators, but rather at confining sheep. Access into pastures over, under, and through the fences appeared easy for both coyotes and dogs.

Fencing has been used as a tool to deter coyotes since the 1890's (Thompson 1976). Lantz (1905b) described the use of fencing in Kansas to protect livestock from coyotes in corrals and small pastures. Jardine (1908 and 1909) cited a study in Oregon in which sheep losses were reduced after a fence was built to deter coyotes. Bauer (1964) and McKnight (1969) described the 5200-mile dingo fence in Australia; however, Fitzwater (1972) stated that fencing of that type would not be practical in the United States. Several authors described barrier fences used to deter coyotes in the United States including Coll (1922), Fitzwater (1972), and Shelton (1973a), but Young and Jackson (1951) and Robinson (1962) stated that these are not economical or practical on large pastures. They may be effective on small pastures near buildings, however. Electric fencing to deter coyotes has been described by McAtee (1939), Shelton (1973a), and Henderson (1974), but its use has not been widespread. Thompson (1976) conducted the most scientific study to date of fencing to deter coyotes and reported electric fencing ineffective. He also reported that fences must be at least 167.6 cm high with a mesh no larger than 15.2 x 10.2 cm to successfully deter coyotes.

No pasture fences in this study met Thompson's (1976) criteria for both height and mesh size. Very few fences met either one or the other. Coyotes and dogs appeared able to travel at will through the pastures with fences offering little resistance. The limited use of electric fences in the study did not appear effective in reducing losses, contrary to the three reports cited above.

It would be very expensive to build fences with the coyote-deterring qualities described above around pastures. Thompson (1976) reported the cost at $2,000 to $2,350 per mile for materials alone. Only very severe losses year after year could justify an expenditure of this amount to aid in reducing predator losses. Sheepmen in Kansas do not appear willing to use fencing of pastures as a means of protecting sheep and lambs from predation.

Bells

Although losses to coyotes and dogs occurred in flocks in which some or all sheep wore bells in equal proportion with flocks in which no bells were worn, the use of bells may hold some promise in reducing predation. No losses were reported or observed in which the animal attacked was wearing a bell. Hawbecker (1939) reported similar results in California with goats although it was not known whether it was the sound of the bell or the heavy leather strap shielding the throat that was deterring attack. The use of bells in corrals appeared more effective in reducing predator losses (see below under "Corral Factors") than their use in pastures. Coyotes and dogs may simply attack sheep in a different part of the pasture away from sheep wearing bells if they were disturbed by the noise of the bells. Closer confinement of sheep in corrals would make it more difficult for the predators to get away from this repelling noise.

Time Sheep Turned Out and Shut In

No relationships were found between predator losses and the times of day sheep were turned out to pasture in the morning and shut in corrals in the evening. The peaks of coyote activity have been reported as being near sunset and daybreak (Gipson and Sealander 1972) with the most intense daytime activity occurring during late afternoon (Chesness 1972). In Nebraska, coyotes were reported to be active from sunset until 1 to 2 hours after sunrise (Andelt 1976). Bowns et al. (1973) reported that most kills took place during late evening, night, or early morning. In Henne's (1975) study, most kills occurred just before dawn with a few occurring during the middle of the night. Very few kills took place during the day. Gier (1968) reported the practice of sheepmen not turning ewes with lambs out to pasture until after 8 a.m. in an effort to reduce predator losses. This practice does not appear necessary——some losses occur on pasture during the daytime regardless of the times sheep are turned out and shut in. Since most losses to coyotes occur between sunset and sunrise (Bowns et al. 1973, Henne 1975), the key in reducing losses appears to be confinement of sheep at night (see "Pasturing and Confinement Management Schemes").

Corral Factors

Only about 20 percent of the loss to predators occurred while the sheep were confined in corrals. However, three factors appeared very important in reducing these losses and are discussed below.

Lights

The most important factor in reducing coyote losses in corrals appeared to be the use of lights. Very few losses to coyotes occurred in corrals with lights. Only two reports on the use of lights above sheep corrals were found in the literature (Gier 1968, Mathwig 1973); no estimates of loss reduction were given. Losses to coyotes in corrals can apparently be nearly eliminated with only a moderate investment ($250 to purchase and install a mercury vapor light with electric-eye sensor). F. R. Henderson (personal communication) reported that if coyotes do begin to kill sheep under lights in a corral, they are fairly easy to see and shoot with a high-powered rifle. This is another benefit of using lights above corrals.

Losses to dogs in the study were higher in corrals with lights than in unlit corrals. Dogs may be more used to lights than coyotes because of the dogs' close association with humans, and instead of being repelled by lights, they may be able to catch and kill sheep more successfully in lit corrals. The small sample of dog kills in corrals may not be an accurate reflection of the true situation; however, the results suggest little value in the use of lights to prevent sheep predation by dogs.

Bells

Although the use of bells did not appear to reduce predator losses when sheep were on pasture, no losses to either coyotes or dogs were reported in corrals when bells were worn on a portion of the flock. Perhaps the closer proximity to sheep wearing bells in corrals was enough to discourage attacks on any of the flock. Hawbecker (1939) reported that coyotes avoided goats that were wearing bells. Again, the small sample of dog losses must be considered but the results suggest some benefit of the use of bells when sheep are confined in corrals.

Confinement

Losses to coyotes in corrals were higher in flocks that were confined at night only than in flocks confined at all times. Coyotes may have encountered flocks of sheep during the daytime in pastures and returned to the same flock at night. Predation may have occurred while the sheep were on pasture and this might have conditioned the coyotes to return to take advantage of the food supply. Whatever the mechanism, pasturing of sheep during the day increased the chances that losses to coyotes would occur in corrals. The same reasoning may be used to explain the slightly higher dog losses (not significant in this study).

Flock Size

No relationships were observed between flock size in corrals and rate of loss to coyotes. Losses appeared to vary with the size of the flock as the proportions of the flocks lost were nearly equal among the four categories. The relatively small sample of losses to coyotes may have prevented any trends in loss rates from showing up in this study.

Corral Size

As with flock size, no trends in rates of loss were observed among categories of corral size. Corral size was related to flock size with larger flocks being confined in larger corrals. Again, this relatively small sample may have prevented any trends in losses from being observed.

Distance to Residence

Although the results of this comparison did not show statistical significance, they suggest that losses to coyotes may be greater in corrals that are over 200 meters from a residence than in corrals that are closer. Human activity would probably be less in corrals that are farther from residences, and likelihood of detection by humans of any disturbance caused by coyotes would also be less. It appears that it would pay to take more care in preventing losses to predators in corrals far from residences than in those that are nearby.

Fencing Practices

Fences around corrals were generally better than pasture fences as far as offering resistance to passage by predators. However, dogs and coyotes could still enter most corrals with little effort. Very few corrals met Thompson's (1976) requirements of fence height and mesh size.

Although it is very expensive to fence pastures, a sheep flock can be confined in a good corral at night with little expense (Coll 1922). This practice would practically eliminate losses to predators in corrals. One hundred sheep could be confined (with 4 square meters per sheep) in a 20 x 20 meter corral at a calculated cost of $99.42 for materials, according to Thompson's (1976) cost of predator-deterring fence. Similarly, a flock of 500 sheep could be confined in a good corral (45 x 45 meters) for $223.70. This appears to be economical insurance against predator losses. However, sheepmen in this study appeared unwilling to make any unnecessary expenditures for corral fencing.

Total Confinement

Coyotes and dogs had little chance to be exposed to the flock owned by Mr. Marrs This probably prevented any conditioning of sheep-killing from occurring among potential predators of the flock. Several factors of management used with this flock may have prevented predator losses, even though no predator control was practiced and the fences around the corral were not predator-proof according to Thompson's (1976) criteria.

Little pasturing of sheep took place and it occurred only under supervision. Lights were used at night and carcasses were disposed of so as not to attract scavengers to the area. Lambing took place in confinement and occurred in the fall; few lambs were on hand during the summer months when predator losses are typically high. Dogs were often in close association with the flock to protect it from losses. These factors alone or in combination may have contributed to preventing losses to predators from occurring.

Predator Abundance

Losses of sheep and lambs to coyotes were much lower during the summer (June, July, and August) of 1976 (65) than during the summer of 1975 (151) as reported in Table 1. Coyote indices were also lower in 1976 (Figure 11) although not significantly.

The dog indices were considerably lower in 1976 than in 1975 (Figure 12). However, losses of sheep and lambs to dogs were only slightly lower during the summer of 1976 (23) than the summer of 1975 (26).

The results of the predator indices suggest a rough correlation between predator abundance and losses of sheep and lambs to predators, if indeed the scent-station method measures predator abundance. There is no method at present to relate index values to actual coyote numbers (Linhart and Knowlton 1975).

Conflicting ideas occur in the literature concerning the relationship between coyote abundance and the level of losses. Cain et al. (1972) and Wagner (1972) suggest a correlation between coyote population density and the level of sheep losses. Sheep losses to predators declined in the late 1940's coinciding with the introduction of 1080 and a reduction in coyote numbers. However, Bennitt (1948) reported that complaints of damage in Missouri showed no relation to coyote numbers——complaints were as numerous in areas of low coyote density as in areas of high density. Damage to livestock is done by only a small portion of the coyote population.

More care through management must be taken to protect sheep in Kansas from predators in localized areas of high coyote and dog abundance. Although losses occur in areas of low abundance as well as areas of high abundance, losses appear to occur more frequently in areas of high abundance.

Going-Out-of-Business Survey

Several factors have been suggested as causes in the decline of the sheep industry in the United States. These include declines in the demand for lamb and wool, competition from Australia and New Zealand, inadequate marketing practices (Early et al. 1974b), unfavorable market prices and rising production costs (Gee and Magleby 1976), labor problems, reduced grazing allotments on public lands, conversion to more profitable cattle industry (Pearson 1975), and heavy losses to predators (Johnson and Gartner 1975, Shelton 1973b). The present study concluded that old age of the sheep producers and predator problems were the main reasons for the decline recently in Kansas. Gee and Magleby (1976) stated that 20 percent of the sheep producers will face retirement in the next 10 years and few young people have been entering sheep production in the last 10 to 15 years.

Predators have often been implicated as causes in the decline of the sheep industry (Shelton 1973b; Early et al. 1974b; Johnson and Gartner 1975; Pearson 1975; Gee and Magleby 1976). The results of this survey agree with this observation. However, predators were not a major factor in the decisions of 11 of the 12 producers that sold out during the management-predation portion of this study. Predators may have been more of a problem in past years than they were during the time that field data were gathered in this study.

A number of sheep producers switched to other types of agricultural production. Surprisingly, from an economic standpoint, conversion to beef production ranked higher than conversion to cash crop or swine production. Market values for cash crops and swine were relatively higher than for cattle during the period of this study (Kansas State Board of Agriculture 1975 and 1976).

Several factors that seem important in the decline of the sheep industry in the United States as a whole are not important in south-central Kansas. These include difficulty in hiring qualified labor, marketing problems, and conflicts in use of public land. The farm-flock situation in Kansas is generally a one-man or one-family operation and hiring outside help is usually not required. The marketing structure in the Wichita area seems satisfactory for the sheep producers in south-central Kansas. All sheep production in the area is done on private land, thus avoiding conflicts over use of public land.

Management Recommendations

Two- and three-way analyses of variance (Snedecor and Cochran 1973) were attempted to determine the interactions between a number of variables. However, the limited number of observations of losses to predators made all multiple analyses of variance impossible due to the large numbers of empty cells. It must be recognized that the observed effects of a management factor on predator losses may not be due entirely to that factor. A combination of factors or other factors altogether may be responsible for observed predator losses.

A subjective description of factors is presented below in an effort to determine which of the management factors described above can be implemented to be effective, practical, and economical in reducing losses of sheep and lambs to predators. The first part of this discussion will be aimed at changing the management factors of a present sheep operation to reduce losses to predators; the second part will attempt to describe practices that can be taken to reduce losses to predators when starting a new sheep operation.

Factors to Change in Present Operation

Perhaps the simplest method of reducing losses to both coyotes and dogs in flocks on pasture is to confine the sheep at night in a suitable corral. Type of corral fencing and cost were described above (DISCUSSION: Corral Factors). Additional labor is required in confining and turning the sheep out each evening and morning but this requires a minimum of effort after the sheep become accustomed to coming in at night. A greater reduction in losses can be gained by confining the sheep at all times; however, this is not practical for most operations during the seasons when sheep are normally pastured.

The use of lights above corrals also appears to be an important factor in reducing losses to coyotes. This factor is applicable in flocks confined at all times or at night only, and may possibly have some utility for use in pastures with unconfined flocks if sheep can be conditioned to come in under the light at night. The cost of lights was discussed above (DISCUSSION: Corral Factors). Lights were not proven to be effective in preventing losses to dogs and care should be taken in the use of lights if dogs have been a problem in the past.

The use of bells on some or all sheep in corrals may be effective in reducing losses to both coyotes and dogs. Although only a small sample was examined in the study, no losses to either coyotes or dogs occurred in corrals in flocks in which bells were worn on a portion of the flock.

The method of disposal of sheep carcasses is an important factor in drawing coyotes into the vicinity of a sheep flock. Losses to coyotes can be reduced by removing carcasses from the area of a flock (have them picked up by a rendering plant) or burying carcasses.

Having dogs in the vicinity of a sheep flock is effective in reducing losses to coyotes. However, losses to dogs appear to increase when dogs are used in association with sheep flocks. Past losses in a flock can be used to determine whether or not a guard dog or dogs may be of benefit.

Predator control (usually trapping) is often effective in reducing losses to both coyotes and dogs by removal of problem individuals. Traps can be purchased for less than $5.00 apiece and when used correctly, are very efficient.

Losses to predators are lower in small pastures than in large pastures. This may be associated with the distance to human activity as small pastures typically are closer to farm buildings than large pastures. This relationship was shown for losses to dogs but not for coyotes. Losses may be reduced by moving sheep into smaller pastures that are closer to farm buildings.

The above methods of loss reduction will only prove economical if losses are moderate to high in extent. If losses to predators of only one or two sheep per year occur, these methods will not prove economical. The cost of implementing these factors will be higher than the value of sheep saved if losses are low.

Management of a New Operation

All of the factors described in the previous section can be used to prevent losses when setting up a new operation. Confinement at night, the use of lights and bells, method of disposal of sheep carcasses, possession of dogs, predator control, pasture size, and distance from pasture to farm buildings are factors that can be regulated to reduce losses to predators. In addition, several more factors are practical to use in association with a new operation.

Rates of loss to both coyotes and dogs are lower in larger flocks than in smaller flocks. Flocks of 300 or more stock sheep are the most efficient in relation to losses to predators. Losses occur in a greater percentage of large flocks than small flocks; however, the rate of loss is much smaller. It may prove beneficial to start a new operation with a large flock of sheep.

Two aspects of lambing appear important in relation to predator losses. Lambing in the fall makes it possible to have most of the lambs marketed in the spring leaving few on hand during the summer and fall when losses to predators are typically the highest. Commercial ewes (Columbia-Rambouillet cross) are suitable for fall lambing and are often used with Suffolk or Hampshire rams. Lambing in confinement is conducted by the majority of sheepmen in Kansas and appears necessary to keep losses to predators at a minimum.

New operations being started close to towns or settled areas are likely to experience problems with dogs. Sheepmen must keep this in mind and be ready to take appropriate actions when problems develop.

By taking a few precautions when starting a sheep operation, sheepmen should be able to keep losses to predators at a minimum. Losses are more likely to occur under certain conditions, and by avoiding these conditions, losses should be reduced considerably.

CONCLUSIONS

Based on data gathered during the study the following conclusions appear justified:

1. Losses of sheep and lambs to predators in Kansas are lower than in most other western states, with coyotes accounting for the majority of these losses.

2. Losses of stock sheep to predators occur primarily from June through September and losses of lambs occur primarily from June through December.

3. Losses to predators are not evenly distributed among sheep producers; most of the losses are absorbed by a small portion of the producers.

4. The value of sheep and lambs lost to predators in Kansas annually approximates $70,000.

5. General management factors that are important in affecting losses to predators include flock size, method of disposal of sheep carcasses, season of lambing, possession of dogs, distance of sheep operation from town or settled areas, predator control, and pasturing and confinement management schemes.

6. Pasture factors that are important in affecting losses to predators include size of flock pastured, size of pasture, distance from pasture to residence, type of pasture, height of pasture cover, topography, and the presence of streams.

7. Corral factors that are important in affecting losses to predators include the use of lights, the use of bells, and total confinement as opposed to partial confinement.

8. Losses to predators appear to be slightly correlated with predator abundance.

9. Old age of the sheep producers and predator problems are reported to be the major causes of Kansas sheepmen going out of business.

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APPENDIX

Cooperative
EXTENSION SERVICE
of Kansas State University

Division of Extension
Extension Wildlife
Ackert Hall
MANHATTAN, KANSAS 66506
Phone: 913 532-5784

"Taking the UNIVERSITY to the PEOPLE"

April 25, 1975

Dear Kansas Sheep Producer:

We, at Kansas State University Cooperative Extension Service, Department of Animal Science and Industy and Division of Biology, are initiating a survey to determine the extent of sheep losses in Kansas. We are interested in the numbers of sheep lost to various causes and the sheep husbandry techniques involved.

In order to determine accurately the extent of losses, your participation in this survey is needed, regardless of whether or not you have experienced losses recently. By learning the reasons for loss, we hope to help you, the sheep producer, reduce these losses.

All participating sheepmen will be asked to fill out a Sheep Loss Report card each month, an example of which is enclosed. A record will need to be kept of all sheep lost and the reason for the loss, beginning June 1, 1975 and continuing for 15 or 16 months. All reports of losses will be kept strictly confidential. We will be around to visit each participating sheepman's operation sometime this summer to observe the management practices.

We all know that methods are needed to reduce sheep losses. Your help on this survey will speed the research in this area and will benefit you and other sheep producers. Please return the enclosed postcard stating whether or not you will participate. If you agree to help, we will send you enough Sheep Loss Report cards to last for the duration of the survey.

If you have any questions or comments, please write to us at the address below. Thank you very much for your time and effort.

Sincerely,

F. Robert Henderson

F. Robert Henderson
Extension Specialist
Wildlife Damage Control
Ackert Hall
Kansas State University
Manhattan, Kansas 66506

Clifford Spaeth

Clifford Spaeth
Extension Specialist
Animal Science and Industry
Weber Hall
Kansas State University
Manhattan, Kansas 66506

Fig. 13. Initial letter of contact with sheep producers in study area.

Fig. 14. Example of "Sheep Loss Report Card" sent with initial letter of contact.

SHEEP LOSS REPORT CARD

EXAMPLE

NAME ____

ADDRESS ____

CITY ____________________ COUNTY ____________________ ZIP ____________

__________ No losses occurred during this month.

__________ Month

If you had sheep losses this month, answer the following questions.

	Numbers of Sheep Lost		
	Lambs		Sheep
	Before Docking	After Docking	
Weather Conditions:			
Diseases:			
Pregnancy disease			
Enterotoxemia (Overeating disease)			
Pneumonia			
Urinary calculi			
Other diseases			
Lambing complications:			
Old Age			
Theft			
Predators:			
Coyotes			
Dogs			
Bobcats			
Foxes			
Other Predators			
Poison			
Unknosn Causes			
Other reasons:			
Specify			
Totals			

COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
Kansas State University of Agriculture and Applied Science, County Extension Councils
and United States Department of Agriculture Cooperating.

__________Yes. I will cooperate in this survey.

__________No. I do not wish to take part in this survey.

__________I no longer raise sheep and so can be of no help in this survey.

Name____

Address______________________City_________________County______________Zip______

Location of home. (Give distance and direction from nearest town.)

Total Number of Sheep in Flock: Ewes________Lambs_______Feeder Lambs_______Rams___

Sincerely,

F. Robert Henderson

F. Robert Henderson
Extension Specialist
Wildlife Damage Control

Fig. 15. Postcard sent with initial letter of contact.

Cooperative
EXTENSION SERVICE
of Kansas State University

Division of Extension
Extension Wildlife
Ackert Hall
MANHATTAN, KANSAS 66506
Phone: 913 532-5784

"Taking the UNIVERSITY to the PEOPLE"

June 1, 1975

Dear Kansas Sheep Producer:

Thank you for agreeing to participate in our survey of sheep losses in Kansas.

Enclosed are the Sheep Loss Report Cards to be used in this survey. Beginning with the month of June, 1975, please record the number of sheep lost and the reasons for the losses. At the end of each of the next 16 months, fill out one of the Sheep Loss Report Cards and return it to us, regardless of whether or not any losses occurred. You will note that the card is self-addressed and stamped. If you did not have sheep in one or more of the next sixteen months, please return your report card anyway and make a notation on it that you did not have any sheep for that month.

Sometime during the summer, a graduate student here at Kansas State University, Bob Meduna, will be around to visit each participating sheep producer's operation to observe the management practices.

It is very important that you record all losses and send us a Sheep Loss Report Card each month during this survey. We would like to help you, the sheep producer, decrease losses through better husbandry techniques.

Thanks again for your help in this survey. With your help, we can make sheep husbandry a more profitable enterprise in Kansas.

Sincerely,

F. Robert Henderson
Extension Specialist
Wildlife Damage Control

Clifford W. Spaeth
Extension Specialist
Animal Science and Industry

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Fig. 16. Letter sent to cooperators at the beginning of the study.

SHEEP LOSS REPORT CARD

NAME____

ADDRESS__________________________CITY________________COUNTY________

ZIP__________

________No losses occurred during this month. ________________Month

If you had sheep losses this month, please answer the following questions.

	NUMBERS OF SHEEP LOST		
	Lambs		Sheep
	Before Docking	After Docking	
Weather Conditions:			
Diseases:			
Pregnancy disease			
Enterotoxemia (Overeating disease)			
Pneumonia			
Urinary calculi			
Other diseases			
Lambing Complications:			
Old Age:			
Theft:			
Predators:			
Coyotes			
Dogs			
Bobcats			
Foxes			
Other Predators			
Poison:			
Unknown Causes:			
Other Reasons: (Specify)			
TOTALS:			

Fig. 17. "Sheep Loss Report Card" used by sheepmen in the study.

Fig. 18. "Reminder" mailed to sheepmen each month of the study.

Cooperative
EXTENSION SERVICE
of Kansas State University

Division of Extension
Extension Wildlife
Ackert Hall
MANHATTAN, KANSAS 66506
Phone: 913 532-5784

"Taking the UNIVERSITY to the PEOPLE"

Dear Cooperating Sheep Producer:

We would like to remind you to please send in your Sheep Loss Report Card for last month, if you have not already done so. Drop the card in the mail regardless of whether or not any losses have occurred.

In future months, please indicate on the card the total number of ewes, lambs and rams that you have on hand on the first day of each month for which losses are reported. We need to know the number of sheep each producer has each month as well as the number lost.

To help in evaluating the causes of sheep losses, we will try to get around to producers who are losing sheep as often as possible. When a sheep death occurs, regardless of cause, please call 1 - 800 - 432-2780 during the evening after 5:00 p.m. This is a toll-free number and your message will be recorded and we will receive it the following morning.

Please call the above number each time a loss occurs and we will try to have someone there as quickly as possible to check it out.

The toll-free number is set up to receive information from county agents. The recorder will announce to you the following message: "This is Extension WATS Recorder. Please state name, title and name of county or area office, person to be called and question or item of call". Instead of the information requested by the recording, please give the following information:

Name
Address
Telephone Number
Kind of Loss
Date of Loss
Location of dead animal(s) in relation to your farmstead

As soon as you have given the above-listed information, please hang up and the recorder will disconnect from your phone line.

Sincerely,

F. Robert Henderson

F. Robert Henderson
Extension Specialist
Wildlife Damage Control

FRH:rn

COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
Kansas State University of Agriculture and Applied Science, County Extension Councils
and United States Department of Agriculture Cooperating.

Please put an X by each factor listed below that caused you to quit the sheep business. If you put an X by more than one reason, then also place a 1 by the most important reason.

____ Marketing difficulties
____ Labor requirements too high
____ Sheep production was unprofitable
____ Predator problems
____ Nearing or have reached retirement age
____ Difficulty in hiring qualified labor
____ Difficulty in getting shearers
____ Switched to beef production
____ Switched to swine production
____ Switched to cash crop production
____ Other (Explain)____

____

Signed____________________________________

Fig. 19. Postcard used in "Going-Out-of-Business Survey".

RELATIONSHIPS BETWEEN SHEEP MANAGEMENT
AND COYOTE PREDATION

by

ROBERT LEE MEDUNA

B. S., University of Nebraska, 1974

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

This study was conducted in an effort to determine the effects of a number of factors involved in sheep management in reducing losses of sheep and lambs to predators. Extent of losses to predators and the relationship with predator abundance were examined. Total losses to all causes and reasons for sheepmen quitting the business were also examined.

The management practices of 110 sheep producers in a 9-county area of south-central Kansas were examined. Losses were reported monthly from June 1975 through August 1976. Scent-lines to determine predator abundance were run during late August-early September of each year.

Losses of stock sheep to predators amounted to 0.9 percent annually while non-predator losses were reported to be 5.8 percent. Losses of lambs to predators were also 0.9 percent annually, and non-predator losses of lambs were calculated to be 7.0 percent. The major cause of mortality for stock sheep was old age while lambing complications accounted for the majority of lamb deaths. About 78 percent of the predator losses were attributed to coyotes. Losses of stock sheep to predators was highest from June through September, while losses of lambs were highest from June through December. Losses to predators were not distributed evenly among sheep producers with 80 percent of the losses being absorbed by only 22 percent of the sheepmen in the study. The value of sheep lost to predators was estimated to be over $70,000 annually in Kansas.

A number of factors were determined to be important in affecting losses to predators. General management factors that appear important include flock size, method of disposal of sheep carcasses, season of lambing, possession of dogs, distance of sheep operation from town or settled areas, predator control, and pasturing and confinement management schemes. Pasture factors that appear important include size of flock pastured, size of pasture, distance from pasture to residence, type of pasture, height of pasture cover, topography, and the presence of streams. Corral factors that appear important include the use of lights, the use of bells, and total confinement as opposed to partial confinement.

Predator abundance appeared to be slightly correlated with losses to predators.

Old age of the sheep producers and predator problems were reported to be the major causes of Kansas sheepmen going out of business from 1973-1975.

Losses of sheep and lambs to predators in Kansas appear to be lower than most other western states. The management schemes used by Kansas sheepmen may be responsible for this low level of losses to coyotes and dogs.