Fox-Prey Relationships in Eastern South Dakota

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FOX-PREY RELATIONSHIPS IN EASTERN SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

Relationships between red foxes (Vulpes fulva) and their principal prey, particularly ring-necked pheasants (Phasianus colchicus), were studied on four units in eastern South Dakota from December 1964 to September 1966. Each unit was composed of a 100-square-mile "reduction area," on which fox populations were reduced, and a 100-square-mile "check area," on which fox populations were not reduced for the study. Indices to populations of foxes, pheasants, mice, eastern cottontails (Sylvilagus floridanus) and whitetail jackrabbits (Lepus townsendi) were obtained and used to evaluate fox food habits and the effect of predator reduction on prey populations. Four-hundred seventeen stomachs and 104 female reproductive tracts from foxes taken in reduction areas and in or near check areas were examined.

Fox densities in the study areas in 1966 were low compared to past densities in certain other states. Aerial den counts showed that active fox dens were 67% fewer on the reduction than on the check areas in 1966. Fox reproductive rates increased in the year following population reduction. Soils, topography, and cover type were the most important factors determining the suitability of an area for denning. The breeding season of foxes in South Dakota began earliest in the southeastern part of the state and progressed northwestward.

Initially, high pheasant populations were present in Units

2 and 3, whereas Unit 4 was intermediate in pheasant numbers and Unit 1 was considered to be in marginal pheasant range. Summer indices of adult pheasants and of broods declined considerably in all but one instance on one unit from 1964 to 1965. Winter storm mortality contributed to further declines in adults in Units 1 and 2 from the summer of 1965 to the summer of 1966; however, indices for adults during this period increased in Units 3 and 4. Number of broods declined or remained the same from 1965 to 1966.

Results of night spotlight counts of jackrabbits and cottontails were highest in Unit 3 and the reduction area of Unit 4. Significant increases were observed in jackrabbit indices from 1965 to 1966 in the reduction area of Unit 3. Deer mice were the most abundant small mammal in the study units. Total numbers taken in the snap-trap surveys declined from 1965 to 1966, particularly in Units 3 and 4. Meadow voles were locally abundant, depending on the occurrence and distribution of suitable habitat. Frequency of meadow vole sign increased from 1965 to 1966 in all units except Unit 2.

Mice, pheasants, rabbits and insects were the most important fox food items. Mice and rabbits were staple foods at all seasons. Heavy predation on young rabbits during the denning season was noted. Pheasants were important in the diet in 1965 when the birds were fairly common. The high incidence of pheasant in fox stomachs from eastern South Dakota probably reflected the availability of the birds. It appeared that foxes had an easy time obtaining pheasants due to the low degree of competition between individual foxes and the large number of pheasants. The decline of pheasants from 1964 to 1965 was reflected by a considerable decrease in occurrence of pheasant remains in fox stomachs. A spring survey of food remains at active fox dens gave a biased impression of feeding trends as compared to results of stomach analyses. Mice, young rabbits and insects were under-represented or absent from den debris but were present in stomachs taken at this season.

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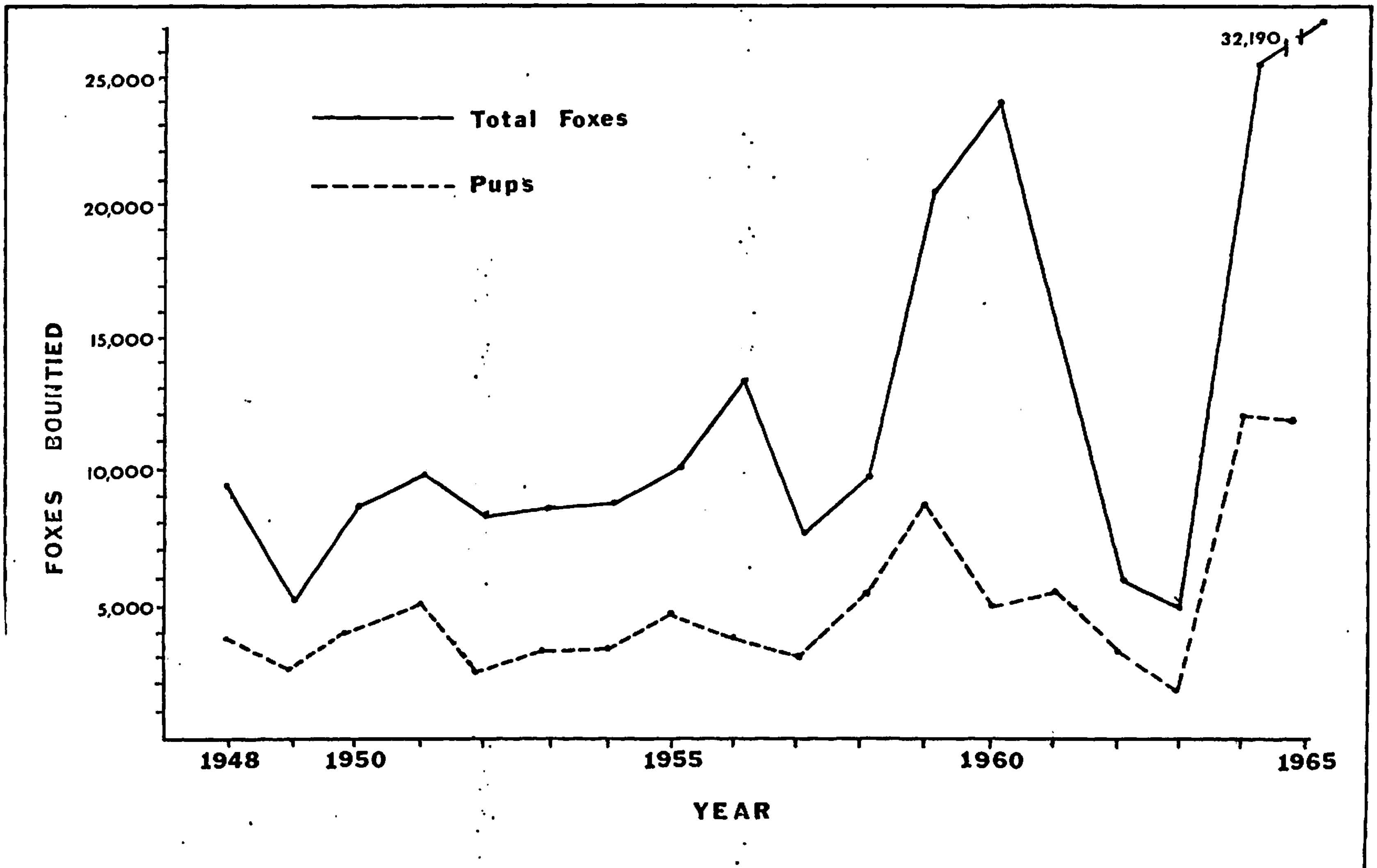
INTRODUCTION

Relationships between red foxes[1] (Fig. 1) and ring-necked pheasants have been the subject of considerable debate in South Dakota during the past few years. Money spent in pursuit of the pheasant, particularly by non-resident hunters, represents a considerable portion of the overall economy of eastern South Dakota. In 1962 approximately 60,000 non-resident pheasant hunters spent about $12 million, primarily in the eastern part of the state (Matson 1965). Annual cash receipts for tourism in that year were about $130 million for the entire state. Therefore, those factors which affect the welfare of the state's pheasant population are of major concern to a large segment of the public.

In 1961 the South Dakota State Legislature reduced the fox bounty from $7.50 to $2.50 per animal. Although this was acknowledged to be a wise move from a game management standpoint, the lower bounty combined with an increasing fox population as determined from past bounty records (Fig. 2) began to arouse sportsmen and landowners concerned about the effects on the state's number one game bird. The drastic decline in pheasant numbers from 10 million birds in 1963 to 4.7 million birds in 1964 (Trautman and Dahlgren 1966) helped precipitate a fox-pheasant controversy

[1] Common and scientific names of mammals and birds used in the text are listed in Appendix A.

Fig. 1. Juvenile male red fox.



'ig. 2. Foxes bountied in South Dakota from 1948 to 1965.

in newspaper headlines, political campaigns and advertising gimmicks. In spite of all this controversy, little scientific data concerning the importance of the red fox as a predator are available from South Dakota or any of the other Plains states.

The lack of reliable information on the fox-pheasant problem and the widespread interest in fox-control programs prompted the initiation of a long-term study of the relationships between populations of red foxes and their prey, particularly ring-necked pheasants. A cooperative study was begun during the summer of 1964 by the South Dakota Department of Game, Fish and Parks, the Division of Wildlife Services (formerly Branch of Predator and Rodent Control) of the Bureau of Sport Fisheries and Wildlife, the South Dakota Cooperative Wildlife Research Unit and the South Dakota State University. The main objective of the overall study was to determine the biological effects and cost of a large-scale fox-control program, with emphasis on the value of this procedure as a means of increasing pheasant numbers. In conjunction with this objective, the need for accurate estimation of populations of red foxes and their prey, particularly ring-necked pheasants, was recognized, and plans were made for obtaining the necessary indices.

An investigation into the food habits, reproductive characteristics and population dynamics of red foxes was considered to be an important part of the overall study. This phase of the investigation was chosen by the author for a thesis topic and constitutes the subject matter reported herein.

Sincere appreciation is expressed to Dr. Paul F. Springer, Leader of the South Dakota Cooperative Wildlife Research Unit[2], who was the author's major advisor and supervisor. Mr. Carl G. Trautman, research biologist of the South Dakota Department of Game, Fish and Parks, Drs. Donald R. Progulske, Ernest J. Hugghins, W. Lee Tucker, and Raymond L. Linder, all of South Dakota State University at Brookings, read the manuscript and made helpful suggestions and corrections.

Financial assistance, a vehicle, aerial photographs and other equipment and supplies were provided by the South Dakota Cooperative Wildlife Research Unit at South Dakota State University through funds supplied principally by the South Dakota Department of Game, Fish and Parks under Pittman-Robertson Project W-75-R-7, Job No. F-8, 2-7 but also by the Bureau of Sport Fisheries and Wildlife.

The cooperation of Mr. Joe Marbach, Game, Fish and Parks Department pilot, and Mr. Dean T. Badger and Mr. Robert F. Wahlin

[2] The South Dakota Department of Game, Fish and Parks, the South Dakota State University, the Bureau of Sport Fisheries and Wildlife, and the Wildlife Management Institute, cooperating.

of the Division of Wildlife Services, Bureau of Sport Fisheries and Wildlife, who acted as aerial observers during the May 1965 and May 1966 fox den surveys is greatly appreciated. Mr. William K. Pfeifer of the Division of Wildlife Services contributed considerable time as a pilot during the spring of 1966, when aerial photographs and reconnaissances of fox dens were made in the Brookings area. Other field personnel of the Division of Wildlife Services conducted the fox-reduction program and collected fox carcasses and/or stomachs and reproductive tracts.

Roadside pheasant surveys were conducted by temporary employees under the supervision of the Game Management Division, Department of Game, Fish and Parks. Personnel of the Game Management Division also made storm mortality and sex-ratio estimates. Personnel of the Division of Law Enforcement conducted night spotlight counts of rabbits. The author is grateful to the Department and the Division of Wildlife Services for permission to use results of the pheasant, rabbit and fox den surveys.

Part-time employees hired by the Department of Wildlife Management assisted with the removal and preservation of fox stomach contents. Reference collections at South Dakota State University were used to identify food remains in fox stomachs. Assistance in the identification of some difficult food remains was provided by Leroy J. Korschgen, biologist employed by the Missouri Conservation Commission.

Thanks are due to fellow graduate students at South Dakota State University for their assistance with many phases of the field work.

STUDY AREA

The study area consisted of four units located in different climatic and land-use regions in that portion of South Dakota lying east of the Missouri River (Fig. 3). These units were selected by personnel of the South Dakota Department of Game, Fish and Parks. Each unit was composed of two 10 x 10 - mile areas. One member was designated the "reduction" area, based on the fox-reduction program discussed in the Materials and Methods section of this report, and its counterpart the "check" area. Areas within a unit were located from 5 to 15 miles apart to minimize movement of red foxes from one area to another. Every effort was made to avoid major differences in climate, geography and land use between areas within a given unit. The locations of permanent study areas were not established until preliminary survey results indicated that both fox and pheasant populations between areas among the four units were acceptably comparable.

Unit 1 The reduction area in southcentral Campbell County and the check area in southeastern Walworth County and northern Potter County are located in the northern part of the "Coteau du Missouri" (Missouri Hills) in South Dakota. This is a gently-rolling region in northcentral South Dakota lying west of the "James Basin" (Fig. 3 and Appendix B). Annual precipitation varies from 16 to 18 inches, coming mostly as rain in spring

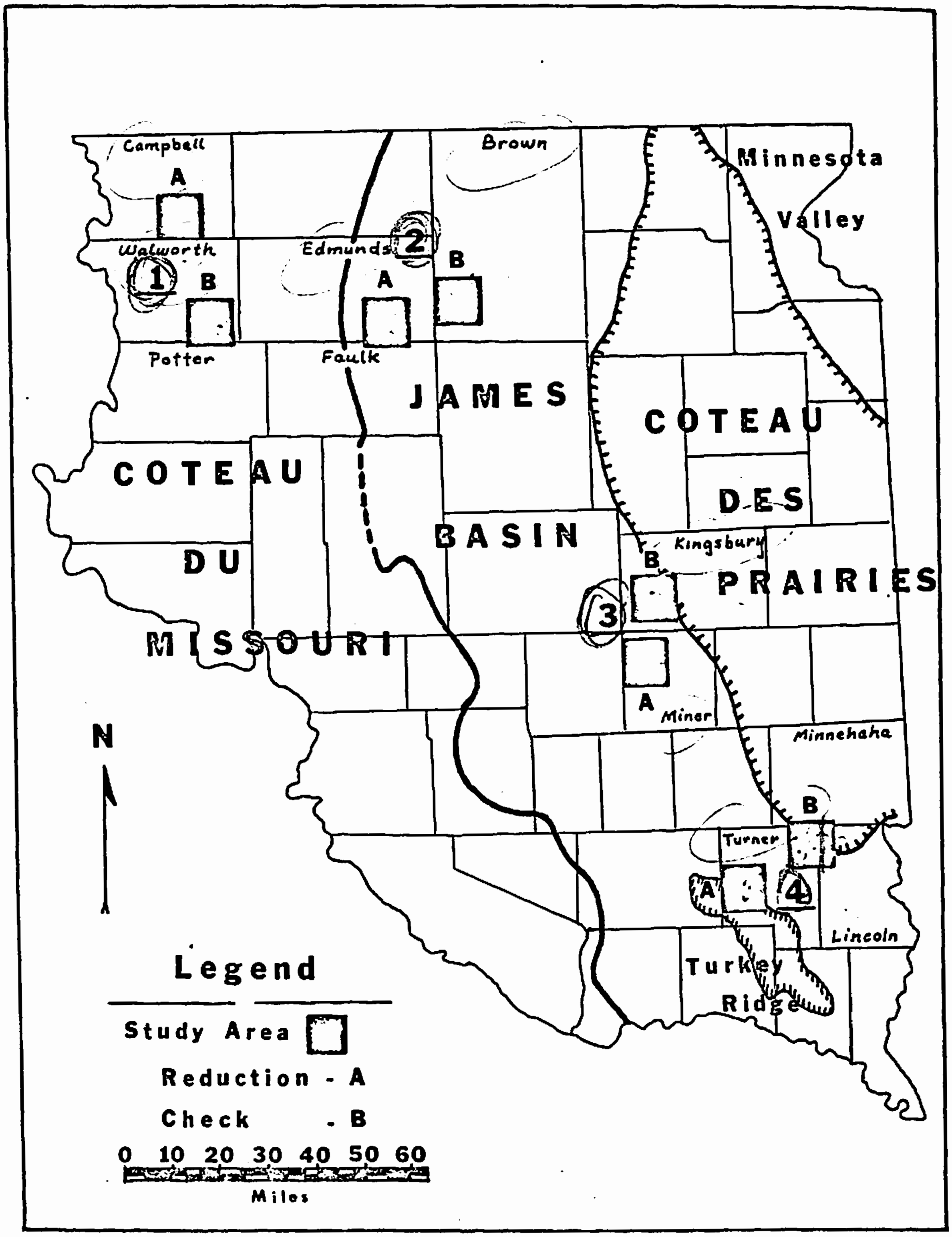


Fig. 3. Location of study units and physical divisions of eastern South Dakota.

and early summer (Flint 1955). The average growing season is about 130 frost-free days. The land surface reflects both stream carving by the Missouri River tributaries and recent glaciation. Both areas are underlain by extensive "outwash plains" draining west to the Missouri River. Gravel pits are abundant, particularly in the check area. Soils are well-drained Chestnut loams developed from glacial till, and eolian loams developed from loess deposits along the eastern bluffs of the Missouri River (Westin, Puhr and Buntley 1959).

The region where Unit 1 is located is typical of mixed-grass prairie (Shelford 1963). Native grasses once covering the unit include needle-and-thread (*Stipa comata*), western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), junegrass (*Koeleria cristata*) and buffalo grass (*Buchloe dactyloides*). Kentucky bluegrass (*Poa pratensis*) has replaced these species to a large extent on overgrazed pastures, and smooth brome (*Bromus inermis*) is prevalent in dry ditches and roadsides. Common and scientific names of grasses are after Hitchcock (1950). Trees are mainly restricted to farmyards, shelterbelts and stream banks. Cottonwood (*Populus deltoides*) is the dominant species on moist sites. Common and scientific names of trees are after Fernald (1950). The average farm in Campbell and Walworth Counties is nearly 790 acres (Westin et al. 1959). Most of the land is devoted to wheat and other small grains, pasture for livestock, and wild hay (Appendix C).

Unit 1 is located in marginal pheasant range. Severe winter storms occurring periodically where winter cover is at a premium act as a limiting factor to pheasant populations. Hungarian partridge are present in small, scattered coveys throughout the unit. Lark buntings, western meadowlarks, red-winged blackbirds, chestnut-collared longspurs and eastern kingbirds are common summer residents. Many species of waterfowl and marsh birds are present around the few large lakes and sloughs during the spring, summer and early fall. Snow buntings, horned larks and American rough-legged hawks are common in winter.

Common mammals in this unit include the deer mouse, meadow vole, masked shrew, thirteen-lined ground squirrel, Richardson ground squirrel, northern pocket gopher, whitetail jackrabbit, eastern cottontail, raccoon, striped skunk, badger, longtail weasel, red fox, coyote and whitetail deer.

Unit 2 The reduction area in southeastern Edmunds County and northeastern Faulk County and the check area in southwestern Brown County both occur in the "James Basin", an area approximately 50 to 60 miles wide and extending 200 miles from north to south in eastern South Dakota (Fig. 3 and Appendix B). Eastward toward this unit from the Coteau du Missouri, annual precipitation increases to 18 to 20 inches, and the average growing season increases to about 135 days (Westin et al. 1959).

Drainage is moderate to imperfect, streams are slow-moving and silt-laden, and shallow lakes and sloughs are present in the basin. The James River has an average gradient in South Dakota of only 5 inches to the mile (Flint 1955). Soils in the reduction area and the western two-thirds of the check area are Chernozem, dark grayish-brown, slightly acid loams developed from calcareous loam till. Soils in the southeastern one-third of the check area are Chernozem, dark grayish-brown, silt loams and silty clay loams developed from lacustrine silts and clays of the Lake Dakota plain (Westin et al. 1959).

Vegetation types in this unit are very similar to those found in Unit 1. Soils are higher in fertility, and a greater proportion of the total acreage is devoted to cash grain crops. The average farm in Brown and Edmunds Counties is about 652 acres. The production of wheat, oats and other small grains, and livestock are of greatest importance to the agricultural economy of this unit. More idle land is present, and a smaller portion of the area is devoted to rangeland in this unit as compared to Unit 1 (Westin et al. 1959).

Unit 2 supports a medium to high pheasant population. It appears that the lighter grazing and more diversified agriculture have contributed to a greater carry-over of winter cover than in Unit 1. Western kingbirds, mourning doves, eastern kingbirds, horned larks, red-winged blackbirds and marsh hawks are common summer resident birds.

Deer mice, grasshopper mice and meadow jumping mice appear to be notably common in this unit. Richardson ground squirrels are present, but they are not as common as in Unit 1. Meadow voles are locally abundant in and around marsh borders, ditches and undisturbed tracts of heavy grass cover.

<u>Unit 3</u> The reduction area in northwestern Miner County and the check area in southwestern Kingsbury County are found in the James Basin, mostly off the western edge of the "Coteau des Prairies" (Prairie Hills) in eastcentral South Dakota (Fig. 3 and Appendix B). Annual precipitation in this part of the state is 22 to 24 inches with a growing season of about 150 days (Flint 1955). Soils in both areas are well to moderately well-drained, dark grayish-brown, slightly acid loams developed from calcareous loam till (Westin et al. 1959).

Unit 3 is situated in that part of the state where mid and tall prairie grasses once flourished. Big bluestem (<u>Andropogon gerardi</u>), little bluestem (<u>A. scoparius</u>), western wheatgrass, sand dropseed (<u>Sporobolus cryptandrus</u>) and switchgrass (<u>Panicum virgatum</u>) along with upland and lowland forbs were the major species. Corn, oats and alfalfa are the most important crops. Farms are smaller (350 acres) in this unit than those in Units 1 and 2, and farming practices are more intensive (Westin et al. 1959).

Bird populations are similar in species composition to those in Unit 2. This unit occurs in the main pheasant range in eastern South Dakota, and it had the highest pheasant population of the four units. Other common birds include burrowing owls, upland plovers, western meadowlarks, mourning doves, eastern kingbirds, chestnut-collared longspurs and Swainson's hawks. Greater prairie chickens and bobwhites, once common in the region, are no longer present (Visher 1913).

The deer mouse, masked shrew, meadow jumping mouse, western harvest mouse and thirteen-lined ground squirrel are the most common small mammals. The plains pocket mouse was found only in this unit; however, it has been reported from other areas of the state (Over and Churchill 1941). Whitetail jackrabbits are relatively abundant in this unit, particularly in the reduction area.

Unit 4   This unit is located in extreme southeastern South Dakota. The heavily wooded portions of "Turkey Ridge" cover about nine sections of the southwestern part of the reduction area in western Turner County. The remainder of the reduction area lies in the southern James Basin. The check area in eastern Turner, western Lincoln and southern Minnehaha Counties lies partly in the southern James Basin and partly in the southern Coteau des Prairies (Fig. 3 and Appendix B). Annual precipitation in this region varies from 22 to 24 inches with a growing season lasting about 160 days (Flint 1955). Soils are Chernozem, dark grayish-brown, silty clay loams and clay loams developed from silty materials and glacial till of Wisconsin age. Soils in the northern end of the reduction area grade into very dark grayish-brown, slightly acid loams developed solely from glacial till (Westin et al. 1959).

The relatively warm, moist climate in this part of the state has contributed to the vigorous growth of tall prairie grasses with subsequent accumulation of large amounts of organic matter in the soil. Consequently, land in this region is more valuable than that in the other units, and it is more suited to the production of row crops, particularly corn and soybeans (Appendix C). Farms average about 207 acres. Small, scattered woodlots are present throughout the unit, and tree growth is present on floodplains adjacent to the larger streams. Common species of woody plants are the cottonwood, black willow (*Salix nigra*), green ash (*Fraxinus pennsylvanica*), hackberry (*Celtis occidentalis*) and American elm (*Ulmus americana*).

Common birds in this unit include the mourning dove, red-winged blackbird, eastern kingbird, eastern meadowlark, common grackle, red-headed woodpecker and dickcissel. Great horned owls are commonly seen hunting at dusk near timbered areas. The mockingbird was seen only in this unit.

The greater variety of birds and small mammals in this unit can be attributed to the greater interspersion of a wide variety of cover types and to the smaller fields. The deer mouse, meadow vole, house mouse, meadow jumping mouse, grasshopper mouse, western harvest mouse, masked shrew and shorttail shrew are represented. Thirteen-lined ground squirrels and signs of the plains pocket gopher are common along roadsides. Other mammals include the eastern fox squirrel, eastern cottontail, raccoon, striped skunk, mink, red fox and badger. Coyotes are relatively common, particularly in the Turkey Ridge area. Gray foxes are found near timbered areas. This species was not encountered in the other three units, although it may occur rarely. Opossums and woodchucks have been reported from southeastern South Dakota and probably occur rarely in this unit (Findley 1956b.).

MATERIALS AND METHODS

Fox Reduction

Beginning in January 1965 an attempt was made to reduce red foxes to a level of 15% or less of their former numbers in the fox reduction areas. In order to minimize the effects upon other predator species, reduction was conducted in the winters of 1964-65 and 1965-66 when these species were largely inactive. Placement of strychnine-treated drop-baits was the main reduction method. Foxes were also killed in the reduction areas in conjunction with aerial den counts in May 1965 and May 1966. Ground crews used a commercial liquid insect larvicide containing chloropicrin to gas foxes in their dens or to drive them out where they could be killed. Foxes in the check areas were not to be molested except for control on a landowner complaint basis.

Fox Population and Reproductive Studies

Aerial Den Counts

Indices to red fox populations have been obtained using several different methods. Scent stations (Richards and Hine 1953), landowner questionnaires (Lemke and Thompson 1960) and winter drives (North Dakota Game and Fish Department 1949) have been used with varying degrees of success. In this study, aerial counts of fox tracks in snow provided indices to fox activity; however, the results could not be converted to numbers of foxes per unit area.

It was hoped that an aerial count of active fox dens would be sufficiently reliable to provide estimates of the total fox population in each unit. During May 1965 and May 1966 active dens in the reduction and check areas were located from an airplane (Fig. 4). The pilot and observer noted the location of active dens and radioed the information to ground crews working in the area. Dens in reduction areas in 1965 and 1966 and in check areas in 1966 were visited by the investigator and examined to determine whether they were or were not occupied fox dens.

Analyses of Female Reproductive Tracts

Reproductive organs of 104 female red foxes taken in the study areas during 1965 and 1966 were examined by the investigator. The reproductive status of each tract based on the condition of the ovaries and the size and degree of turgidity of the uterus was recorded. Ovaries were grossly sectioned and examined for developing follicles and/or corpora lutea. Uteri were dissected and examined for fetuses or placental scars. Fetuses were measured (crown-vent length) and weighed (Fig. 5).

Fig. 4. Airplane and radio-equipped vehicles used to locate fox dens.

Fig. 5. Red fox fetuses at about 40th day of gestation.

The age of fetuses was estimated according to a weight curve established by Layne and McKeon (1956b) from New York foxes. Breeding dates were estimated from (1) fully turgid uteri in which the accompanying ovaries contained mature follicles or recently formed corpora lutea, and (2) backdating fetal age to approximate time of conception.

Fox Food Habits

General

Evaluation of the feeding habits of a predator such as the red fox involves a consideration of the population status of its prey. Scott and Klimstra (1955) working with Iowa red foxes concluded that:

> "this red fox, within the limits of its ability to take food, awareness of the availability of food and food preferences, is largely governed in its feeding by the relative availability of foods."

In the present study an attempt was made to obtain reliable estimates of principal prey animals in study areas during the period when foxes were collected. Results of preliminary fox stomach analyses and previous food habits studies in the Plains states indicated that pheasants, mice and rabbits were likely to be the most important foods of South Dakota red foxes (Dahlgren and Grondahl unpublished data, Findley 1956, and McKean 1947). Consequently, indices to populations of ring-necked pheasants, cottontails, whitetail jackrabbits, deer mice and meadow voles in the study areas were obtained.

Prey Populations

Ring-necked pheasant. During July and August 1964, 1965 and 1966, a summer roadside pheasant survey was conducted. Three 30-mile routes were established on all-weather roads to provide relatively complete coverage in each area. Routes were run beginning at sunrise on mornings when weather conditions conformed to the following: (1) wind velocity less than 12 miles per hour, (2) sky not completely overcast or clear in eastern portion and (3) storm conditions not prevailing or threatening. Observations were confined to an area within 200 feet of the road right-of-way. Cocks, hens and broods observed in each mile were counted. These surveys were intended to serve as an index to population density and to provide information on pheasant reproductive success. A similar roadside survey was conducted in all areas during May 1965 and May 1966 to obtain indices to pheasant breeding populations. Data from the spring and summer surveys except those in 1966 were statistically analyzed by the Experiment Station Statistician at South Dakota State University.

Rabbits. Indices to populations of jackrabbits and cottontails were obtained by night spotlight counts conducted during the spring and fall of 1965 and 1966. Routes were run for about 4 hours beginning one-half hour after sunset. Preliminary work in January 1965 in Unit 3 by Cooperative Wildlife Unit personnel suggested that jackrabbits and cottontails were most active during this time of night. Lord (1963) also concluded that the peak of cottontail activity is nocturnal during most of the year. James (personal communication, letter Feb. 17,1965) reported success using night spotlight counts as a method of obtaining indices to jackrabbit populations in North Dakota. In this study, one 50-mile route along all-weather roads was established in each area to provide as complete a coverage as possible. Routes in the reduction and check area of a unit were run the same night to eliminate day-to-day variations in rabbit activity. Two spotlights were used, one mounted on each side of a vehicle, except for the counts in March 1965 when only one spotlight was used. Two observers recorded all jackrabbits and cottontails noted within the effective range of the spotlights (150 feet of the road right-of-way).

Small mammals. A snap-trap survey of small mammal populations was conducted in all areas to establish (1) indices of abundance useful in interpreting fox food habits, and (2) the extent to which these animals might buffer the impact of fox predation on pheasants. The four units were sampled separately between June 15 and July 22, 1965, and between July 6 and July 29, 1966. A total of 288 mouse-size snap traps was set for 4 days and nights in each reduction and check area and tended daily. Six sections of land were randomly selected for sampling from the inner 36 sections of each area. Two of the four corners of each section were randomly selected, and a line of 24 traps set 50 feet apart was established in the first homogeneous stretch of fence-row cover encountered.

When it became apparent that the snap-trap survey would not provide a reliable estimate of change in vole populations, a survey of meadow vole sign was conducted by the investigator between October 30 and November 21, 1965, and between September 3 and September 11, 1966. Six sections of land were again randomly selected for sampling from the inner 36 sections of each area. Ten plots, 0.1-meter square, were laid out in the first permanent fence-row cover encountered after proceeding from a randomly selected starting point on each of the six sections. Only relatively undisturbed grass cover with a medium to heavy layer of surface litter was selected. Fresh sign of meadow voles (runways, droppings and cuttings) was recorded. An overall rating was then assigned to each of the 60 sample plots, similar to the system used by Hayne in Michigan and Wisconsin (Hayne and Thompson 1965). Ratings were assigned according to the following scheme:

Rating	Description
1	Indistinct runway system, few droppings, no cuttings.
2	Well-developed runway system, moderate accumulation of droppings, cuttings present.
3	Well-developed runway system, heavy accumulation of droppings, cuttings abundant.

Stomach Analyses

Stomachs of 417 red foxes taken in the reduction areas and in or near the check areas from December 1964 to September 1966 were analyzed for food remains by the investigator. Of these, 378, or 90.6%, contained food. Most animals were taken at strychnine-treated draw-stations in the winter and at dens in spring by District Field Assistants of the Division of Wildlife Services. Some foxes were taken by the investigator to supplement food habits collections and to provide information concerning the feeding behavior of foxes in captivity.

In most cases stomachs were removed in the field, labelled, wrapped in cheesecloth and preserved in 10% formalin to facilitate handling. Food habits analyses were made in the laboratory by washing stomach contents over a fine-mesh sieve and placing them in a beaker of water to allow bones, teeth and other heavy materials to settle. Hair, feathers and other bouyant items were floated off and the entire contents spread out on a white porcelain pan for separation and identification of the various food remains. Small items such as feather parts, rodent teeth and insect parts were examined with the aid of a 3X binocular scope. The identification of certain types of mammal hair often required examination under greater magnification. Food items which could not be identified by the investigator were saved for future reference. Stomach contents were then squeeze-dried and oven-dried at 130 F for about 2 hours. The volume of each item was measured to the nearest 0.5 cc. by water displacement in a graduated cylinder.

Food items were tabulated by frequency of occurrence (number of stomachs containing that item divided by the total number of stomachs) and by average volume (volume of that item in all stomachs divided by the total volume of the contents of all stomachs).

Food Remains at Active Dens

During the den survey in May 1965 and May 1966 a total of 52 active red fox dens in the four units was visited by the investigator. Den sites and the immediate surrounding areas were searched thoroughly, and food remains present were identified and counted. Parts of birds and mammals were pieced together using such criteria as species, size, age, degree of wear and right vs. left appendages. Counts for all items represent minimum estimates.

RESULTS AND DISCUSSION

Fox Populations

Aerial Den Counts

Scott and Selko (1939) obtained a count of rearing dens on 5% of the area of two Iowa counties by a systematic ground search of likely denning areas. They multiplied the results of the count by a factor approximating the average size of a fox family to arrive at an estimate of fox density. The reliability of this technique depends on the ability of the observer to detect "active" or "occupied" fox dens and to distinguish them from temporary retreats or "clean-out" holes, recently abandoned fox dens and dens of other animals, particularly badgers.

Results of the den survey method used in this study showed that active fox dens could be distinguished with sufficient reliability to permit estimates of fox populations in 10 x 10 - mile areas. Of 159 dens observed from the air in May 1965 and May 1966, 57 were checked from the ground; of these, 52 were active red fox dens. Of the remainder, two were recently abandoned fox dens, two were occupied badger dens and one was a clean-out hole attended by an adult fox. Unfortunately, no estimates could be made of the number of active dens overlooked. However, this number was believed to be small due to the (1) conspicuous appearance of active fox dens as seen from the air (Fig. 6), (2)

Fig. 6. Red fox den in soilbank (note food remains and trampled vegetation).

scarcity of woodlots and other forested areas which would have restricted observer visibility, and (3) previous experience of the pilot and observer in locating dens. In the opinion of the investigator, an aerial count of active fox dens conducted during clear, bright weather provides a useful basis for estimating fox populations occupying large open areas in eastern South Dakota. Flights are best made as early and late on calm days as light conditions will permit since this is the time when pups are most likely to be above ground and easiest to detect. Generally, this is from sunrise to about 4 hours after, and from about 3 hours before sunset until sunset. In addition, the count must be made after the majority of the fox pups in an area are old enough to be active above ground (Fig. 7) but before they reach the age at which vixens begin moving them to new dens. This period extends from the time the pups are about 4 weeks to 8 or 9 weeks old. Prior to this time, an occupied den would not appear active and a considerable number would probably be missed. Counts made after fox families had begun using more than one den would result in an overestimate of the population. A summary of the results of the aerial den counts is shown in Table 1.

Fig. 7. Red fox pup 3 to 4 weeks old.

Fig. 8. Red fox pup at den in small-grain stubble.

Table 1. Distribution by cover type of 159 active red fox dens located in the study areas during May 1965 and May 1966.

Unit	Area	Pasture '65	Pasture '66	Soilbank§ '65	Soilbank§ '66	Hay§§ '65	Hay§§ '66	Stubble '65	Stubble '66	Other '65	Other '66	Total '65	Total '66
1	Red.		3	3								3	3
	Chk.	2	6	5			1				1	7	8
2	Red.		2	1	4				1			1	7
	Chk.	3	5	5	4	3	3	2	1			13	13
3	Red.	3	1	1		1	1	1				6	2
	Chk.	8	3	7	7	6	1	3				24	11
4	Red.				1	1			1			1	2
	Chk.	5		21	2	20	4	2	2		1	48	9
		21	20	43	18	31	10	8	5		2	103	55

§Includes wild hay.
§§Alfalfa and red clover.

Pasture, soilbank and hay were the most important cover types for denning (Table 1). Small grain stubble (Fig. 8) was less important when consideration is given to the substantial acreages present in all units (Appendix C). Scott and Selko (1939) working with Iowa foxes found a positive correlation between fox populations and land of 5 to 10% slope. Most dens in this study were situated on a hill, slope or other well-drained site. The number of entrances ranged from 2 to 14 with 2 or 3 usually showing heavy use. Most dens visited by the investigator were located in sandy soil. This was evident from the conspicuous mounds of sand marking den entrances.

Den counts in the check areas in 1965 were made by a different observer than in 1966 and were not checked from the ground; consequently, no estimates of reliability could be placed on the results. The high counts obtained in the check areas of Units 3 and 4 were not believed to be representative of the fox populations actually present. They may have been due to differences in interpretation of dens between the two aerial observers.

Comparisons of numbers of fox dens between reduction and check areas in 1966 provide estimates of the degree of reduction achieved. Estimates of reduction were as follows: Unit 1 (63%); Unit 2 (46%); Unit 3 (82%); Unit 4 (78%). The average for all units was 67%.

Breeding Season

During 1965 and 1966 the breeding season of red foxes began in early January and extended until the middle of March (Table 2). Eighty-eight percent of female foxes examined were estimated to have been bred from about mid-January to the end of February. There was no significant difference in time of breeding between years. These findings agree with those of Sheldon (1949), who found that the peak of fox matings in New York state occurred about the end of January. North Dakota foxes begin mating in January or early February (North Dakota Game and Fish Department 1949). In general, the breeding season in eastern South Dakota began in Unit 4 (southeast) about 3 weeks earlier than in Units 1 (northwest) and 2 (northcentral). Unit 3 (central) was intermediate in this respect. These results suggest that the aerial den count should begin in Unit 4 and progress northwestward to coincide with the chronological delay in fox reproductive activities.

Table 2. Estimated time of breeding of 42 female red foxes taken in the reduction areas during the winters of 1964-65 and 1965-66 as determined from fully turgid uteri and backdating from size of fetuses.

Unit	Jan.1-15	Jan.16-31	Feb.1-15	Feb.16-28	Mar.1-15	Total
1			3	6		9
2			1	5	2	8
3		3	3	1		7
4	2	7	6	2	1	18
	2	10	13	14	3	42

Table 3. Mean numbers of corpora lutea, placental scars and fetuses from female foxes taken in the reduction areas during 1965 and 1966.

	Corpora lutea			Placental Scars			Fetuses		
	1965	1966	Diff.	1965	1966	Diff.	1965	1966	Diff.
All Units	5.2	7.9	2.7§§	4.7	7.6	2.9§§	4.6	7.0	2.4§§
	(31)§	(26)		(12)	(8)		(16)	(11)	

§Sample size in parentheses.
§§Difference significant at 0.01 level.

Litter Size and Productivity

Use of aerial den counts as a basis for estimating fox populations made it necessary to obtain an estimate of litter size. Forty-seven uteri containing fetuses or placental scars were available from foxes taken in the reduction areas in 1965 and 1966. Litter size estimates based on fetal counts averaged 4.6 in 1965 as compared to 7.0 in 1966. The difference was significant at the 0.01 level (Table 3). Apparently, the reduction in fox numbers through control operations contributed to an increase in the number of young per female the following year. Schofield (1958) also found a direct relationship between man-caused mortality and the reproductive rate of red foxes in Michigan. Counts of corpora lutea exceeded placental scar counts by 4 to 10% and fetal counts by 11%. This difference included ova which were ovulated but failed to become fertilized or implanted in the uterine wall. Several instances of trans-uterine migration of ova were noted, similar to the findings of Layne and McKeon (1956a). This phenomenon undoubtedly accounted for some of the observed ova mortality. Only one case of embryo resorption was noted; however, the number of gravid uteri examined were not sufficient to permit a thorough evaluation of this and other pre-partum losses. For these reasons the litter size estimates of 4.6 and 7.0 are maximum figures.

Fox Density

The size of a typical fox family was calculated to consist of 3 adults and 4.5 pups. Scott and Selko (1939) estimated that only two-thirds of adult foxes contribute to the breeding population. For purposes of this study, an extra adult was attributed to each den to account for non-breeding individuals. An average of 4.5 pups per family was derived from the litter size data from the reduction areas prior to control as noted above.

An estimate of fox populations can be made for the check areas in the spring of 1966 (Table 4) when data from the last column in Table 1 are used.

Table 4. Calculated fox densities by unit in May 1966.

Unit	Dens		Foxes/Den		Foxes	Fox/ Square Mile
1	8	x	7.5	=	60	60/100 = 0.60
2	13	x	7.5	=	98	98/100 = 0.98
3	11	x	7.5	=	83	83/100 = 0.83
4	9	x	7.5	=	68	68/100 = 0.68
	10.3	x	7.5	=	77	77/100 = 0.77

Since other investigators were primarily interested in detecting relative changes in fox populations, only a few comparisons can be made with fox-per-square-mile data from other states. Information on fox densities in the Plains States is available from North Dakota (North Dakota Game and Fish Department 1949). Although estimates from that study were based on the results of winter fox drives, the findings agree closely with those from the present study (Table 5). Kilburn (unpublished data) summarized the results of 23 fox drives covering 239 sections of land conducted during the winter of 1965-66 in eastern South Dakota. An average of 0.8 fox/mile^2 was seen during these drives (Table 5). Estimates of fox numbers based on the den counts represent maximum annual population densities. Mortality factors affect juvenile foxes in particular and tend to cause a steady reduction in the

Table 5. Summary of the results of red fox population density studies conducted in the United States.

Foxes/ Square Mile	Type of Census	Season	Location	Reference
10.6	Active dens	Spring	Virginia	Swink 1952
4.8	Active dens	Spring	Iowa	Scott 1947
4.5	Track count, trapper interview	Winter	New York	N.Y. Cons. Dept. 1951
4.0	Head count	Winter	New York	Bump et al. 1947
1.6	Active dens	Spring	Ohio	Mitchell 1941
1.5	Active dens	Spring	Michigan	Shick 1952
1.2	Active dens	Spring	Iowa	Scott 1947
0.8	Winter drives	Winter	North Dakota	N.D. Game and Fish Dept. 1949
0.8	Winter drives	Winter	South Dakota	Kilburn unpublished data
0.8	Active dens	Spring	South Dakota	This study
0.6	Active dens	Spring	Iowa	Scott and Selko 1939
0.2	Active dens	Spring	Iowa	Scott and Selko 1939

population through summer and fall months to a low point just prior to the next denning season.

An evaluation of South Dakota bounty records over the past 18 fiscal years (South Dakota Department of Game, Fish and Parks 1961, 1962, 1963, 1964 and 1965) indicates that the number of foxes bountied had generally increased from 1948 through 1965 (Fig. 2). From 1963 to 1965 the number of foxes bountied increased considerably. Pelt prices and the dollar value of the bounty remained unchanged during these years; consequently, this increase in bounty receipts could reflect an actual increase in fox numbers, although the use of bounty records as an index to fox numbers can be misleading. Actual fox population levels in 1964 and 1965 may have exceeded the 18-year average. However, fox densities in South Dakota were low compared to other regions of this country, particularly the northeast (Table 5). There was no evidence of storm mortality of foxes during the winter of 1965-66.

Fox Food Habits

Prey Populations

Ring-necked pheasant. Past pheasant densities in South Dakota have been the highest of any state in the United States. The pheasant population of South Dakota's 50,000-square-mile range was estimated at 30 million to 40 million birds in 1945 (Dale in Allen 1956). The present investigation was initiated at a time when the pheasant population in South Dakota was undergoing a drastic reduction. An estimated pre-hunt population of 10 million birds in 1963 declined to an estimated 4.7 million in 1964 (Trautman and Dahlgren 1966). By 1965 the population consisted of about 3.5 million pheasants prior to the hunting season. A comparison with data from past years showed that the 1965 pre-hunt population was the lowest since 1950, when an estimated 3.2 million pheasants were available (Dahlgren 1963).

Results of spring and summer roadside pheasant surveys conducted in the study areas are summarized in Table 6. A comparison of July-August adult and brood counts between 1964 and 1965 generally reflects a decline in pheasant numbers comparable to that which was occurring elsewhere in the state. This decline was most striking in the high population areas of Units 2 and 3. Significant declines (0.05) of adults occurred in the reduction areas of Units 2, 3 and 4, and the check area of Unit 2 (0.01). There appears to be a direct correlation between the initial adult-bird-per-mile indices and the rate at which the populations declined from 1964 to 1965 (Fig. 9). Counts in the spring and summer of 1966 compared to those in 1965 showed that adult pheasants generally increased in Units 3 and 4 but continued to decline in Units 1 and 2. The further decrease in adult- and brood-per-mile indices for Units 1 and 2 from 1965 to

Table 6. Summary of the results of pheasant roadside surveys conducted in the study areas during 1964, 1965 and 1966.‡

		Adults/Mile					Broods/Mile		
		May		July-August			July-August		
Unit	Area	1965	1966	1964	1965	1966	1964	1965	1966
1	Red.	1.10	.32§	.59	.41	.10§	.21	.17	.04§
	Chk.	1.03	.52	.56	.46	.15	.15	.10	.04
	Avg.	1.07	.42	.58	.44	.13	.18	.14	.04
2	Red.	4.74	2.75	2.66	1.46§§	.81	.75	.78	.35
	Chk.	4.98	2.57	3.07	1.21†	.80	.82	.50	.36
	Avg.	4.86	2.66	2.87	1.34†	.81	.79	.64	.36
3	Red.	7.22	9.19	4.06	1.50§§	2.09	1.31	.97	.68
	Chk.	5.39	4.38	††	1.62	1.90	††	.46	.39
	Avg.	6.31	6.79		1.57	1.99		.72	.54
4	Red.	2.44	2.72	1.23	.70§§	.92	.30	.24	.21
	Chk.	1.94	2.94	.85	.54	.96	.24	.14	.17
	Avg.	2.19	2.83	1.04	.62§§	.94	.27	.19	.19
Avg. of All Units		3.61	3.18	2.14	.99§§	.97	.64	.42†	.28

§Necessary delays prevented statistical analysis of 1966 data.

§§Difference between 1964 and 1965 significant (0.05 level).

†Difference between 1964 and 1965 significant (0.01 level).

††The original check area in Unit 3 was not comparable to the reduction area. A new check area was selected, but July 1964 counts in this area are not available for comparison.

‡Number of runs ranged from 28 to 74 (avg. = 47.8).

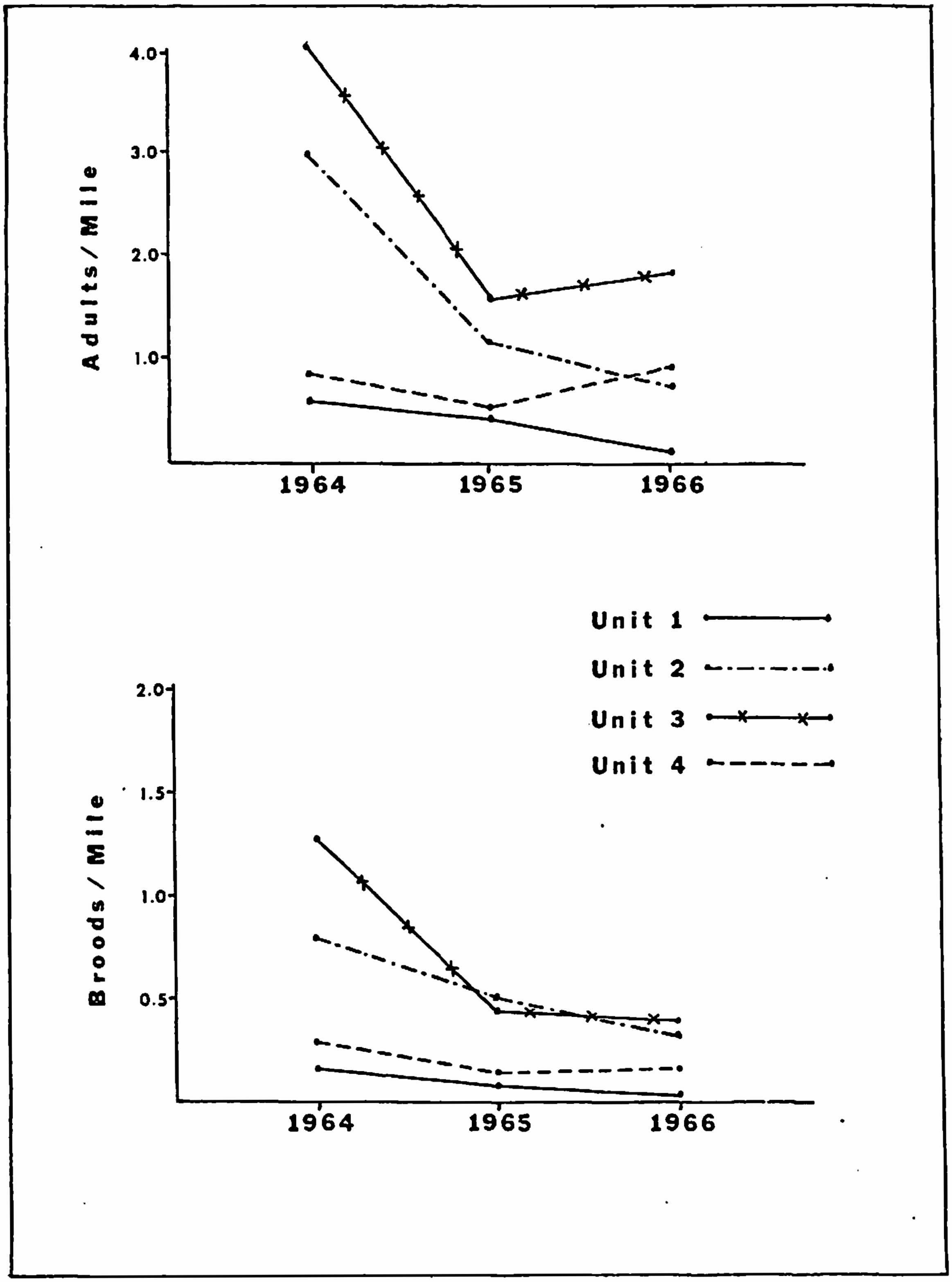


Fig. 9. Comparison of summer roadside pheasant indices among units.

1966 was attributed primarily to a severe blizzard which occurred from March 3 to March 5, 1966. Average mortality estimates based on pre- and post-storm aerial counts of live and dead pheasants were 85% for Unit 1, 30% for Unit 2 and 5% for Unit 3.

Throughout the study period the highest adult- and brood-per-mile indices were obtained in Unit 3. Indices were lower in Unit 2; however, Units 2 and 3 were both situated in high-density pheasant range. Unit 4 ranked third in adult pheasant numbers until the summer 1966 counts when it surpassed Unit 2. Unit 1 was located in marginal pheasant range, and it had the lowest bird-per-mile indices of the four units.

A valid comparison can not be made between May and July-August counts within a given year because of major differences in observability of pheasants between these two periods. Territorial cocks with their harems tend to be overly conspicuous in spring, particularly due to the sparse cover conditions which prevail at that time of year. However, a glance at Table 6 indicates that spring-to-spring and summer-to-summer comparisons between 1965 and 1966 usually reflect relative changes of the same direction and general magnitude.

Rabbits. Whitetail jackrabbits and eastern cottontails were present in all study areas. To eliminate seasonal variations in rabbit activity, comparisons between years were based on

October counts only. Indices to jackrabbit populations were highest in Unit 3 and the reduction area of Unit 4 (Table 7). A significant increase (0.05) in jackrabbit indices occurred in the Unit 3 reduction area from 1965 to 1966. A similar increase occurred in the Unit 4 reduction area.

Indices to cottontail populations were highest in Unit 3 (Table 8). No cottontails were seen during the October 1965 and 1966 counts in the Unit 1 reduction area or in the October 1965 counts in the Unit 4 check area. A significant decline (0.05) in cottontail indices from 1965 to 1966 occurred in the check area of Unit 2. A comparison of combined cottontail data from all units revealed that the increase from October 1964 to October 1965 was not significant.

Small mammals. The deer mouse was clearly the most abundant small mammal trapped in the study areas (Table 9). A few known specimens of the white-footed mouse were taken in Unit 4, but because of the difficulty of distinguishing this species from the deer mouse, all *Peromyscus* were classed as deer mice for purposes of this study. A reduction was observed in the number of deer mice taken in 1966 compared to 1965 (Table 10). This was due to large declines in Units 3 and 4. Indices remained essentially unchanged in Unit 2 but increased in Unit 1 from 1965 to 1966. There was little or no evidence that deer mice were more abundant in reduction areas as compared to check

Table 7. Average numbers of whitetail jackrabbits seen along 50-mile routes in the study areas.

Unit	Area	1965 Mar.	1965 Oct.	1966 May	1966 Oct.	Diff. between Oct. 1965 and Oct. 1966
1	Red.	10.0 (1)§	10.5 (2)	8.8 (5)	11.5 (4)	+ 1.0
	Chk.	7.0 (1)	10.0 (2)	9.0 (5)	9.5 (4)	- 0.5
	Avg.	8.5	10.3	8.9	10.5	+ 0.2
2	Red.	3.5 (2)	13.0 (3)	12.8 (5)	16.4 (5)	+ 3.4
	Chk.	3.5 (2)	4.0 (3)	3.4 (5)	7.2 (5)	+ 3.2
	Avg.	3.5	8.5	8.1	11.8	+ 3.3
3	Red.	10.0 (2)	44.7 (3)	80.8 (5)	103.0 (5)	+58.3§§
	Chk.	6.0 (2)	22.3 (3)	23.4 (5)	22.6 (5)	+ 0.3
	Avg.	8.0	33.5	52.1	62.8	+29.3
4	Red.	7.0 (1)	34.5 (2)	21.2 (5)	53.4 (5)	+18.9
	Chk.	1.0 (1)	3.0 (2)	2.2 (5)	1.8 (5)	- 1.2
	Avg.	4.0	18.8	11.7	27.6	+ 8.8
Avg. of All Units		6.0 (1.5)	17.8 (2.5)	20.2 (5)	28.2 (4.8)	+10.4

§Number of runs.
§§Difference significant at 0.05 level.

Table 8. Average numbers of cottontails seen along 50-mile routes in the study areas.

Unit	Area	1965 Mar.	1965 Oct.	1966 May	1966 Oct.	Diff. between Oct. 1965 and Oct. 1966
1	Red.	2.0 (1)§	0.0 (2)	1.0 (5)	0.0 (4)	---
	Chk.	1.0 (1)	0.5 (2)	1.8 (5)	0.5 (4)	---
	Avg.	1.5	0.3	1.4	0.3	---
2	Red.	2.0 (2)	2.7 (3)	6.0 (5)	2.8 (5)	+0.1
	Chk.	1.0 (2)	4.3 (3)	10.0 (5)	0.8 (5)	-3.5§§
	Avg.	1.5	3.5	8.0	1.8	-1.7
3	Red.	21.5 (2)	11.0 (3)	53.6 (5)	17.4 (5)	+6.4
	Chk.	3.0 (2)	3.3 (3)	19.9 (5)	7.8 (5)	+4.5
	Avg.	12.3	7.2	36.8	12.6	+5.4
4	Red.	5.0 (1)	2.0 (2)	19.9 (5)	4.2 (5)	+2.2
	Chk.	2.0 (1)	0.0 (2)	3.4 (5)	0.4 (5)	+0.4
	Avg.	3.5	1.0	11.7	2.3	+1.3
Avg. of All Units		4.7 (1.5)	3.0 (2.5)	14.5 (5)	4.3 (4.8)	+1.3

§Number of runs.
§§Difference significant at 0.05 level.

Table 9. Distribution of the small mammal catch by unit.

Species	Unit 1 1965	Unit 1 1966	Unit 2 1965	Unit 2 1966	Unit 3 1965	Unit 3 1966	Unit 4 1965	Unit 4 1966	All Units 1965	All Units 1966
Deer mouse	54	94	62	63	123	37	192	28	431	222
13-lined ground squirrel	13	7	12	27	7	20	8	28	40	82
Meadow vole	8	4	3	20		4	7	8	18	36
Masked shrew	1		7		5		3		16	
Grass-hopper mouse	1	1	3	4	1		6	2	11	7
House mouse	2	2	1	1	1		7		11	3
Meadow jumping mouse			5	3	3	2	2	3	10	8
Shorttail shrew							1	2	1	2
Plains pocket mouse					1				1	
Western harvest mouse							2		2	
	79	108	93	118	141	63	228	71	541	360

Table 10. Distribution of the deer mouse catch by area.

Unit	Area	1965	1966	Diff. between 1965 and 1966
1	Red.	16	40	
	Chk.	38	54	
	Avg.	27.0	47.0	+20.0
2	Red.	50	30	
	Chk.	12	33	
	Avg.	31.0	31.5	+ 0.5
3	Red.	69	29	
	Chk.	54	8	
	Avg.	61.5	18.5	-43.0
4	Red.	93	12	
	Chk.	99	16	
	Avg.	96.0	14.0	-82.0
Avg. of All Units		53.9	27.8	-26.1

areas following fox reduction (Table 10). The numbers in Tables 9 and 10 reflect trends in abundance and are not convertible to numbers of mammals per acre or square mile.

The thirteen-lined ground squirrel was the second most abundant small mammal trapped. This animal was frequently seen scurrying across roads or standing upright along roadsides during late spring, summer and early fall. Only museum special and mouse-size snap traps were used in the survey; thus, it was possible that a significant number of adult ground squirrels escaped the traps. Young-of-the-year, however, were usually caught and held. If this bias was essentially constant between years, a substantial increase in numbers of thirteen-lined ground squirrels occurred from 1965 to 1966. This species was not expected to be an important item in the fox diet in spite of its abundance in the study areas. Ground squirrels hibernate during the cold months of the year at which time they are invulnerable to fox predation. During the spring, summer and fall when they are active above ground, their period of daily activity is during the daylight hours, whereas foxes hunt almost exclusively at night. Storm (1965) radio-tracked foxes in Illinois and found that they began moving no earlier than 2 hours before dark, continued through most of the night and ceased activity no later than 4 hours after dawn.

All vole specimens taken during the snap-trap survey were meadow voles. They were taken most frequently in undisturbed stands of lowland grass cover in roadsides and adjacent to wetlands. The relative scarcity of good vole habitat apparently accounted for the low trapping success for this species. The prairie vole was taken elsewhere in eastern South Dakota, usually in undisturbed stands of upland grass cover. Intensive grazing and haying operations may have been a detriment to this species.

Because of the small number of voles taken, the snap-trap survey was not considered a sound basis for detecting changes in their populations. Table 11 presents a summary of results of the vole sign survey conducted in the study areas during November 1965 and September 1966. Indices to vole abundance increased from 1965 to 1966 in Units 1, 3, and 4, and decreased in Unit 2. The average difference for all units between years was not significant (Table 11). The amount of fresh sign was similar in Units 1, 2, and 3, but was generally more than twice as abundant in Unit 4. The frequency of vole sign was fairly comparable between areas within a given unit.

A comparison of snap-trapping results between units (Table 9) indicates a general increase in the variety of species from Unit 1 (northwest) to Unit 4 (southeast). This is believed to be in response to the greater interspersion of different cover types under the more intensive agriculture of southeastern

Table 11. Results of a meadow vole sign survey conducted in the study areas during October 1965 and September 1966.

		Frequency of Sign		Overall Rating	
Unit	Area	1965	1966	1965	1966
1	Red.	7.0	16.0	9.0	17.0
	Chk.	14.0	18.0	20.0	20.0
		10.5	17.0	14.5	18.5
2	Red.	14.0	11.0	23.0	15.0
	Chk.	12.0	12.0	15.0	13.0
		13.0	11.5	19.0	14.0
3	Red.	2.0	13.0	3.0	15.0
	Chk.	6.0	11.0	9.0	12.0
		4.0	12.0	6.0	13.5
4	Red.	20.0	29.0	29.0	43.0
	Chk.	17.0	26.0	20.0	32.0
		18.5	27.5	24.5	37.5
Grand Avg.		11.5	17.0	16.0	20.9

South Dakota. Smaller farms and fields and more frequent wooded areas contribute to an increase in the amount of "edge."

Masked shrews were taken in the snap traps with about the same frequency as meadow voles in 1965 (Table 9). The following year none were taken. This is indicative of a probable decline in numbers of this species. The remaining mammals listed in Table 9 are included only to illustrate their minor status in the overall small mammal complex.

Stomach Analyses

Results of the analyses of 378 red fox stomachs that were taken in or adjacent to the study areas during 1965 and 1966 and that contained food (Fig. 10) are presented in Tables 12 and 13. To facilitate comparisons among seasons and between years, data from all units are grouped in these tables. Determinations for summer and fall were based on a relatively small number of stomachs; consequently, inferences based on winter and spring data are the strongest. Since only 29 stomachs were taken in or near the check areas, no comparisons could be made between areas within units.

When consideration is given to broad food groups, mammals were most important throughout the year. Birds ranked second in importance except during the spring of 1965 when they surpassed mammals in frequency of occurrence and average

Fig. 10. Food remains in a fox stomach collected during the winter of 1964-65.

Table 12. Fox stomach analyses, December 1964 to November 1965.

	Season and Sample Size							
	Winter (120)§		Spring (46)		Summer-Fall (21)		Annual Average (187)	
Food Item	Freq.§§	Vol.+	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.
MAMMALS	85	53	73	28	86	56	79	47
Mice	55	16	39	11	57	13	52	14
Deer mouse	42	11	27	9	10		36	9
Meadow vole	10	4	2	1	29	10	11	4
Harvest mouse	1						1	
House mouse	1		5	1			2	
Meadow jumping mouse			2					
Grasshopper mouse	1						1	
Unidentified	8	1	5		29	3	10	1
Rabbits	21	27	30	13	19	6	23	22
Cottontail	6	9	10	5	5		7	7
Whitetail jackrabbit	11	16	10	6			10	12
Unidentified	4	2	10	2	14	6	7	3
Shrews	6		9		14	2	7	
Ground squirrels	3	3	2		5		3	2
Red fox	8		10	1	5		8	
Skunk	1	3					1	2
Livestock (cow, pig, sheep)	2						1	
Other mammals	3	1	1		5	30	4	4
Unidentified	12	3	10	3	28	5	13	3

Table 12. (continued)

Food Item	Winter (120)§ Freq.§§	Winter (120)§ Vol.+	Spring (46) Freq.	Spring (46) Vol.	Summer-Fall (21) Freq.	Summer-Fall (21) Vol.	Annual Average (187) Freq.	Annual Average (187) Vol.
BIRDS	77	39	78	64	76	36	77	45
Ring-necked pheasant	46	34	52	55	52	18	49	38
Cocks	8		7		10		8	
Hens	26		32		33		28	
Unidentified	12		14		14		13	
Songbirds	10	2	20	5	19	1	14	3
Meadowlark	1		2		5		2	
Longspurs	2		2	1			2	
Horned lark	3	1	2	2			3	1
Other song-birds								
Unidentified	4	1	14	2	14	1	8	2
Chicken	6	2	7	3	5	12	6	3
Ducks								
Eggshells	5		2		19		6	
Unidentified	11	1	16	1	14	5	13	1
UNIDENTIFIED VERTEBRATES	12	3	18	2			12	2
INSECTS	14		32	1	57	3	23	1
Grasshoppers	13		22	1	19		16	
Beetles	1		2		33	3	5	
Other insects			4		19		3	
Unidentified	3		8		33		8	

Table 12. (continued)

Food Item	Winter (120)§ Freq.§§	Winter Vol.+	Spring (46) Freq.	Spring Vol.	Summer-Fall (21) Freq.	Summer-Fall Vol.	Annual Average (187) Freq.	Annual Average Vol.
PLANTS	81	3	80	2	90	1	82	2
Grasses	64	1	61	1	76	1	65	1
Corn	14	2	9	1	19		13	1
Weed seeds	1		4		5		2	
Fruits (wild plum, rose hips)	1		2		10		2	
Unidentified	16		8		19		14	
UNIDENTIFIED	18	2	21	3	25	4	20	3
		100		100		100		100

§Number of fox stomachs examined which contained food.

§§Percent frequency of occurrence (rounded to nearest whole number).

+Average volume in percent (rounded to the nearest whole number).

Table 13. Fox stomach analyses, December 1965 to November 1966.

	Season and Sample Size							
	Winter (124)§		Spring (38)		Summer-Fall (29)		Annual Average (191)	
Food Item	Freq.§§	Vol.+	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.
MAMMALS	96	63	97	74	81	63	95	67
Mice	81	26	59	21	46	32	73	25
Deer mouse	46	13	18	3	15	15	37	11
Meadow vole	39	10	38	18	31	17	34	12
Harvest mouse	9	1			4		6	1
House mouse	1	1					1	1
Meadow jumping mouse	4						3	
Grasshopper mouse								
Unidentified	14	1	7		8		11	
Rabbits	33	27	50	30	19	22	40	28
Cottontail	15	6	15	11	12	18	15	9
Whitetail jackrabbit	13	16	8				12	11
Unidentified	6	5	32	19	7	4	13	8
Shrews	4				4		3	
Ground squirrels			22	16	4	3	6	4
Red fox	3		2		23		9	
Skunk	5	2	3	2	4		5	2
Livestock (cow, pig, sheep)	2				12	3	2	1
Other mammals	3	1	13	4	4		5	2
Unidentified	7	7	17	1	12	3	10	5

Table 13. (continued)

	Season and Sample Size							
	Winter		Spring		Summer-Fall		Annual Average	
	(124)§		(38)		(29)		(191)	
Food Item	Freq.§§	Vol.+	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.
BIRDS	59	28	77	22	46	24	69	25
Ring-necked pheasant	35	19	21	21	11	7	28	18
Cocks	15		9				13	
Hens	12		12		4		11	
Unidentified	6				7		4	
Songbirds	7	1	38	1	18	16	17	3
Meadowlark	1		7		7	5	3	
Longspurs	3	1	1	1			2	1
Horned lark	2						1	
Other songbirds			5		14	11	3	1
Unidentified	4		18		12		8	1
Chicken	3	2					2	1
Ducks	2	5	6				3	3
Eggshells	3		7		12	1	5	
Unidentified	15	1	13		12		7	
UNIDENTIFIED VERTEBRATES	19	4	22	2	4		19	2
INSECTS	18	2	19		71	4	23	3
Grasshoppers	15	2	2		43	1	16	1
Beetles	2		10		32		8	
Other insects	3		1		36	2	5	1
Unidentified	3		4		21	1	4	1

Table 13. (continued)

Food Item	Winter (124)§ Freq.§§	Winter Vol.+	Spring (38) Freq.	Spring Vol.	Summer-Fall (29) Freq.	Summer-Fall Vol.	Annual Average (191) Freq.	Annual Average Vol.
PLANTS	87	2	96	1	100	5	92	2
Grasses	74	1	93	1	93	4	84	1
Corn	8	1	3		3		6	1
Weed seeds	8		2				6	
Fruits (wild plum, rose hips)	1		2		8		3	
Unidentified	1		18		25		9	
UNIDENTIFIED	17	1	26	1	32	4	19	1
		100		100		100		100

§Number of fox stomachs examined which contained food.

§§Percent frequency of occurrence (rounded to nearest whole number).

+Average volume in percent (rounded to nearest whole number).

volume. Plants were a frequent item in the stomachs; however, they composed a very small portion of the total volume. Insects were frequently found in stomachs collected during summer and fall, but they were a minor item the remainder of the year.

Mammals. Mice, as a group, were the most important mammals in the diet by frequency of occurrence (Tables 12 and 13). Deer mice and meadow voles were the most frequent small mammals in the stomachs; they were also the most abundant species taken by snap trapping. The different species of voles could not be distinguished in the stomachs; consequently, all remains of *Microtus* were classed as meadow voles. A considerable increase in the frequency of mice in the stomachs occurred from 1965 to 1966 (Tables 12, 13 and 14). This was due to a higher occurrence of meadow voles in the winter of 1965-66 and the spring of 1966. Vole populations were up in 1966 in Units 1, 3 and 4 (Table 11), and it appeared that foxes responded to this increase. The catch rate for deer mice in 1966 declined from 1965 (Table 10); however, this reduction was not reflected by a greater decline in the occurrence of this species in the diet (Table 14). Occurrences of deer mice were highest in winter and lowest in summer and fall (Tables 12 and 13). Scott et al. (1955) found a similar pattern for utilization of deer mice by foxes in Iowa. Observations made while following fox trails in snow during the winter of 1964-65 indicated that foxes spent much of their time hunting mice around

Table 14. Comparison of bird and mammal remains among units by their frequency of occurrence in fox stomachs.

	1965 Winter-Spring-Summer-Fall (187)§					1966 Winter-Spring-Summer-Fall (191)				
	1	2	3	4	Avg.	1	2	3	4	Avg.
Mice	44§§	42	43	67	52	79	59	63	93	73
Deer mouse	44	30	33	60	36	29	32	37	38	37
Meadow vole	14	2	18	7	11	35	24	32	60	34
Rabbits	29	14	30	24	23	20	46	27	38	40
Cottontail	6	7	7	15	7	3	11	16	18	15
Whitetail jackrabbit	17	7	7	6	10	12	15	6	8	12
Unidentified	6		16	3	7	6	20	6	12	13
Ring-necked pheasant	44	68	50	58	49	15	37	33	23	28
Songbirds	12	11	15	20	14	15	15	11	30	17

§Number of fox stomachs examined which contained food.

§§Percent frequency of occurrence (rounded to nearest whole number).

sloughs and haystacks and in fencerows. The increased availability of other foods, particularly fruits and insects, during the summer and fall probably lessened feeding pressures on deer mice and other vertebrate prey as well.

Rabbits, as a group, were second to mice in importance by frequency of occurrence in fox stomachs. The availability of mice was much greater than that of rabbits; however, the greater size of a cottontail or jackrabbit as compared to a deer mouse or meadow vole provided foxes with considerably more bulk at a given feeding. Thus, rabbits composed a larger volume than mice during most of the year. This large difference in prey size was reflected in the volume determinations in spite of the fact that (1) foxes may kill and eat several mice in a night, and (2) there is a tendency for a fox to cache a rabbit for future use or to utilize only a portion of the carcass (Murie 1936).

Increases in jackrabbit and cottontail indices from 1965 to 1966 in Units 3 and 4 (Tables 7 and 8) were not reflected in increased occurrences of rabbit in stomachs from Unit 3 although some increase occurred in Unit 4 (Table 14). Changes in the relative availability of vertebrate foods tended to mask relations between the abundance of an individual species and its occurrence in the diet. Jackrabbit and cottontail remains were frequently indistinguishable during the warm months of the year. In winter the white hair of jackrabbits was easily distinguished from cottontails; consequently, only winter data were used for comparing relative occurrences of these two species. Jackrabbits and cottontails were taken with roughly equal frequency, although jackrabbit remains composed a larger volume due to the larger size of this animal (Tables 12 and 13). Rabbits occurred most frequently in stomachs collected at dens in spring, particularly in 1966. Nineteen of 44 stomachs taken at the dens in 1966 contained baby rabbits. On two occasions in 1966, adult foxes carrying two or more baby cottontails in their mouths were shot near active dens. These findings suggest that foxes exerted considerable pressure on baby rabbits during the time when pups were being reared at the dens.

Shrews were not an important fox food in the study areas. Masked shrews were fairly common in 1965 (Table 9), but none were taken in snap traps in 1966. Other workers report that foxes frequently kill shrews and leave them uneaten on the trails (Scott 1947, Murie 1936); consequently, results of stomach analyses are probably not an accurate indication of the predation pressure exerted on shrew populations by foxes.

With the exception of the spring of 1966, ground squirrels occurred infrequently in the stomachs. Possibly, a larger sample of stomachs during summer and fall would have revealed a greater utilization of ground squirrels. However, Scott (1947) found that ground squirrels were not an important item in the diet of foxes in Iowa although this prey was abundant in the areas under study. Apparently, the greater demand for food during the spring when pups are at the dens may force adult foxes to hunt during daylight hours when they are otherwise inactive. As a result they would encounter and kill a larger number of ground squirrels at this season.

The remaining mammals listed in Tables 12 and 13 were of minor importance in the diet. Remains of raccoons and skunks were probably from animals poisoned at winter draw stations. Of 234 stomachs examined from foxes killed at draw stations, 85, or 36%, contained remains of the sheep, cow or pig used as station bait. This suggests that carrion food of a variety of types may be important to foxes in winter if it is available.

Birds. Throughout the study period ring-necked pheasant composed the majority of the bird remains and was an important item in the fox diet. In 1965, pheasant ranked first with mice in frequency of occurrence, but surpassed them in average volume (Table 12). There was a considerable decline in the incidence of pheasant remains from 1965 to 1966, particularly in stomachs from Units 1, 2 and 4 (Table 14). In 1966, pheasant was generally surpassed by mice and rabbits in both average volume and frequency of occurrence. This decline of pheasant remains in the fox diet coincided with a decline in adult-bird-per-mile and brood-per-mile indices from 1964 to 1966 (Table 6 and Fig. 9). In addition the utilization of pheasants may have been "buffered" somewhat as a result of greater utilization of meadow voles during 1966.

Pheasant remains declined considerably in the diet of foxes in Unit 1 from 1965 to 1966 (Table 14). The estimated 85% storm mortality occurring in an area of marginal pheasant range evidently reduced the birds below a "threshold of security" from fox predation (Fig. 11). A similar reduction of pheasants in Unit 2 was accompanied by a decline in pheasant remains in fox stomachs from that unit. Pheasant populations in Units 3 and 4 began a slight decrease in 1966. Correspondingly, there was relatively less change in the occurrence of pheasant remains in stomachs from Unit 3 in 1966; however, fewer pheasant remains were found in stomachs from Unit 4 in 1966 as compared to 1965. The larger increases in occurrences of meadow voles in this unit may have had a buffering effect on the extent of pheasant utilization by foxes. Wagner et al. (1965) point out that it is difficult to demonstrate direct correlations between fluctuations in pheasant numbers and the frequency of occurrence of pheasants in fox stomachs because of variations in the relative availability of other prey. Scott and Klimstra (1955) emphasized the importance of the relative availability of foods in influencing the feeding behavior of foxes. In spite of the lack of precise adjustment of feeding responses to fluctuations in prey populations, variation in pheasant numbers appears to be an important factor to consider in evaluating the impact of fox predation. This is particularly true in an area of marginal

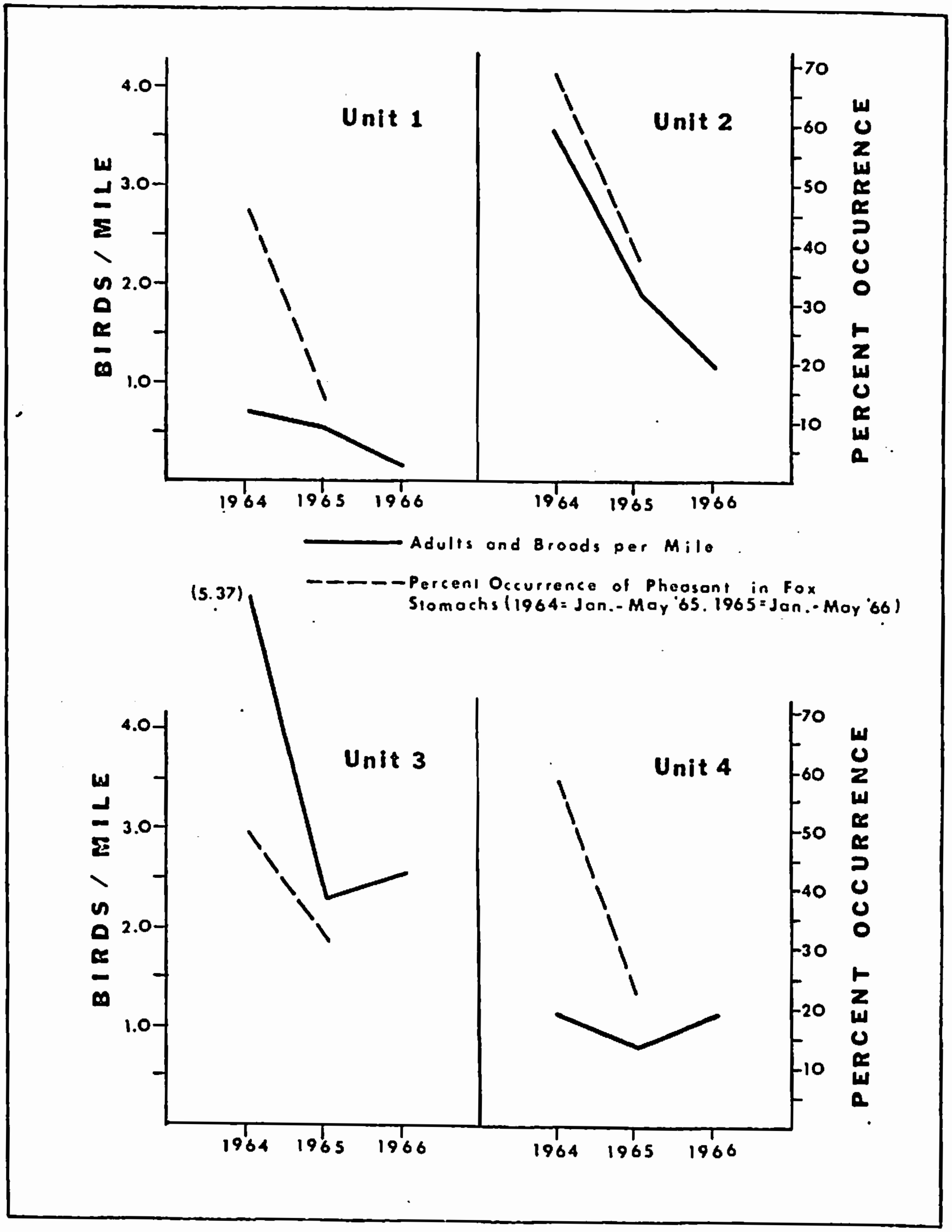


Fig. 11. Comparison between summer pheasant indices and frequency of occurrence of pheasant remains in fox stomachs.

pheasant range, such as Unit 1.

Seasonal differences in frequency of occurrence of pheasant remains were slight in 1965; however, stomachs collected in the winter of 1965-66 had a considerably higher frequency of pheasant than those from the following spring and summer. During the winter, insects and fruits are less available and foxes must rely more heavily on vertebrate prey. In addition, storm-killed pheasants are available as carrion during this season. Definite evidence of carrion feeding by foxes on pheasants was found. In two instances maggots were found associated with pheasant remains in stomachs which had not been allowed to spoil. The results of a study conducted in North Dakota suggest that this manner of feeding may account for a large proportion of the pheasant remains found at fox dens. Of 71 pheasant carcasses scattered randomly over a 5-square-mile area, 14 (about 20%) were recovered at three fox dens on the area (Grondahl 1958). Foxes had picked up some of these birds at distances up to one-half mile from their den. Findley (1956a) also found a high occurrence (65%) of pheasant remains in fox stomachs collected in the winter of 1954-55. He concluded, on the basis of the analysis of 26 stomachs, that pheasants in Spink County, South Dakota were very vulnerable to foxes during that season. In his study tall grass adjacent to sloughs was virtually the only winter cover available to pheasants, and it was also the cover from which most foxes were taken by aerial gunning.

In the spring the increased demand for food by fox pups undoubtedly results in a significant increase in fox predation pressure upon prey populations, including pheasants. The period of major pheasant nesting effort from May 1 through June (Trautman et al. 1958) coincides with the peak of fox denning in eastern South Dakota. There has been considerable interest in the ability of foxes to locate and destroy nesting pheasant hens. A comparison of the ratio of cock to hen pheasants in the stomachs (Tables 12 and 13) with the sex ratios (cocks per 100 hens) in the study areas (Table 15) suggests that foxes were not selective for either sex in 1965. There appeared to be some selectivity for cocks in the winter-spring 1966 data; however, sex ratios showed an increase in cocks in 1966 compared to 1965 (Table 15). Dahlgren and Grondahl (unpublished data) found an over-representation of cock pheasants as compared to hens in fox stomachs collected from some southern South Dakota counties in winter. If there was increased pressure upon nesting hens during the spring months, it was not reflected in the ratio of cock to hen pheasants in the stomachs or in the den remains (see next section).

Songbird remains were found in fox stomachs at all seasons, particularly in spring (Tables 12 and 13). These were largely meadowlarks, longspurs and horned larks which spend considerable time on the ground where they would be vulnerable to foxes. Fox predation on domestic chickens did not appear to be impor-

Table 15. Pheasant sex ratios (cocks per 100 hens) in the study areas as determined from aerial surveys.

Unit	Area	Winter 1964-65		Winter 1965-66	
1	Red.	24	(50+)§	53	(20)
	Chk.	23	(50+)	46	(21)
	Avg.	23.5		49.5	
2	Red.	26	(70)	34	(62)
	Chk.	22	(60)	32	(61)
	Avg.	24.0		33.0	
3	Red.	16	(50+)	32	(59)
	Chk.	26	(113)	39	(76)
	Avg.	21.0		35.5	
4	Red.	44	(37)	82	(29)
	Chk.	41	(33)	61	(30)
	Avg.	42.5		71.5	
Avg. of All Units		27.8		47.4	

§Figures in parentheses indicate number of pheasant groups surveyed.

tant based on the stomach analyses. However, the local importance of a few problem foxes raiding chicken houses is not revealed in a large-scale study. Egg-shell fragments were found most frequently during the summer, when birds are nesting and eggs are most available. Little or no evidence of fox predation on young pheasants was found.

Insects. Remains of insects were found at all seasons but were most frequent during the summer and fall (Tables 12 and 13). Grasshoppers and beetles were the principal groups taken. Several insects were identified to species; however, no one species appeared to be particularly important.

Plants. Grasses composed the majority of plant occurrences. They were a frequent item but were a minor portion of the total volume. Much of the grass may have been taken incidentally with mice or insects although foxes will eat grass for roughage. Corn and weed seeds were often associated with pheasant or chicken remains and probably represented the crop contents of the bird. Nevertheless, a few stomachs taken in winter consisted wholly of corn in substantial volume, indicating that foxes will gorge themselves on this food at times. Wild fruits, mainly wild plums and rose hips, were taken most frequently during summer and fall at their time of greatest abundance. These items were relatively scarce in the study areas, occurring mostly in shelterbelts.

Food Remains at Active Dens

Food items found at active fox dens in the study areas during the spring of 1966 are presented in Table 16. A comparison of these data with results of stomach analyses of foxes taken at dens in that year (Table 13) reveals some major inconsistencies. Remains of birds, particularly the wings and feet of pheasants and songbirds, were the major items recorded at dens (Table 16), whereas, mammals were the most frequent food in stomachs (Table 13). Differences in results of the two methods were apparently due to an under-representation of mice, baby rabbits and, to some extent, ground squirrels in the den remains. All of the 43 occurrences of rabbits at the dens were adults or young near their full growth judging from the size and development of the hind legs. However, it was apparent from the results of stomach analyses that foxes were feeding heavily on baby rabbits during the denning season. Usually, mice and baby rabbits were completely eaten since many stomachs contained whole animals and virtually no trace remained at the dens. Jackrabbits were recorded more often at the dens than cottontails; however, the difference was slight.

Since stomach analysis is the most direct method of evaluating fox food habits short of actual observations of

Table 16. Food remains found at 34 active red fox dens in the study areas during May 1966.

	Unit				
	1	2	3	4	Total
Food Item	(8 dens)	(13 dens)	(7 dens)	(6 dens)	(34 dens)
Birds	31	49	21	32	133
Ring-necked pheasant	9	31	14	18	72
Cocks	(3)	(11)	(7)	(5)	(26)
Hens	(6)	(19)	(7)	(13)	(45)
Unidentified		(1)			(1)
Songbirds	12	16	4	11	43
Chicken	3	1	1	3	8
Ducks	2		2		4
Other	5	1			6
Mammals	14	20	20	26	80
Rabbits	5	10	13	15	43
Cottontail		(4)	(6)	(5)	(15)
Whitetail jackrabbit	(3)	(5)	(6)	(8)	(22)
Unidentified	(2)	(1)	(1)	(2)	(6)
Ground squirrel	3	4		2	9
Mice	4	2	4	4	14
Livestock	1	3	2	1	7
Pocket gopher	1			2	3
Other		1	1	2	4
Reptiles and Amphibians	2		1		3
Snake			(1)		(1)
Frog	(2)				(2)

prey kills, discrepancies between results from the two methods were probably due to biases in the manner and length of accumulation of den remains. Errington (1937) recorded prey or food items from fox dens and concluded that "the larger carcasses, being more conspicuous and less likely to be eaten entire, are much more likely to be listed out of proportion to the frequency with which they may be brought in." Feeding experiments with captive adult foxes revealed that the wings of a pheasant, chicken or songbird were never utilized, but the remainder of the carcass was usually completely eaten. Legs of both pheasants and rabbits were often eaten depending upon how hungry the fox was. Pups were not as capable as adults in utilizing the less digestible parts of large vertebrate prey.

No remains of invertebrate or plant food were recorded from the dens although these items were detected in stomachs. It appears that a survey of food remains at fox dens is incomplete at best and of little value by itself as a method for assessing the food habits of foxes during the spring months.

CONCLUSIONS

It is difficult to make definite conclusions on fox-prey relationships based on the first 2 years of a 4- to 5-year study. When results of the fox-reduction experiment are finally considered and compared with changes in pheasant indices, a more thorough evaluation of fox predation on pheasants in South Dakota will be possible. Conclusions drawn in this report concerning fox-prey relationships are based on only the results of the food habits segment of the overall study.

Aerial den counts provide a method for estimating fox populations in eastern South Dakota. Timing of the count is important. Significant increases in fox reproductive rates were noted following intensive fox-reduction operations.

Results of the majority of fox food habits studies conducted in South Dakota and other states are presented in Table 17. The work of Englund (1965a, 1965b) and McIntosh (1963) is included to allow comparisons among fox feeding trends on different continents. Since regional differences in weather, soil, vegetation, topography, land use and other factors can exert major effects on the kinds and numbers of potential fox prey, the variety of principal food items is not surprising (Table 17). Major trends are apparent, however. Among the 28 studies mice were one of the principal food groups in 22 and rabbits in 24. Clearly, these species

Table 17. General summary of results of red fox food habits studies (modified from Korschgen 1959).

Region	State	Number and Type of Sample	Principal Food Items	Reference
Northeast	New York	206 stomachs	Mice, rabbits, grasses	Hamilton 1935
	New York	313 scats	Field mice, rabbits	Eadie 1943
	New York	134 stomachs	Rabbits, mice	Darrow (in Seagears 1944)
	New York	537 scats	Cottontail, fruits, mice	Cook and Hamilton 1944
	New York	400 scats	Deer mice, fruits	Schueler 1951
	Maryland	100 scats	Voles, muskrat	Heit 1944
	Pennsylvania	147 stomachs	Cottontail, woodchuck, deer	English and Bennett 1942
	Pennsylvania	147 stomachs	Chicken, rabbits, pheasant	Latham 1950
	Virginia	549 scats	Voles, cottontail, opossum	Swink 1952
	Ohio	89 stomachs	Opossum, rabbits, squirrels	Gier and Gale 1946

Region	State	Number and Type of Sample	Principal Food Items	Reference
Midwest	Iowa	2,110 scats	Mice, cottontail	Errington 1937
	Iowa	1,454 scats	Cottontail, mice	Scott 1943
	Iowa	991 scats	Cottontail, rodents	Scott 1947
	Iowa	1,450 scats	Rabbits, birds	Scott and Klimstra 1955
	Indiana	211 stomachs	Rabbits, mice	Kase 1946
	Michigan	300 scats	Mammals, birds, insects	Dearborn 1932
	Michigan	768 scats	Cottontail, insects, voles	Murie 1936
	Minnesota	92 stomachs	Rabbits, mice	Hatfield 1939
	Missouri	1,170 stomachs	Rabbits, rodents, poultry	Korschgen 1959
	Wisconsin	59 stomachs	Rodents, rabbits	Richards and Hine 1953
	Wisconsin	2,400 stomachs	Mice, cottontail	Besadny 1964

Region	State	Number and Type of Sample	Principal Food Items	Reference
Plains States	North Dakota	200 stomachs	Mice, game birds, rabbits	McKean 1947
	South Dakota	29 stomachs	Pheasant, mice, rabbits	Dahlgren and Grondahl 1949
	South Dakota	26 stomachs	Pheasant, mice, rabbits	Findley 1956
	South Dakota	378 stomachs	Mice, pheasant, rabbits	This study
Sweden	Island of Gotland	178 stomachs	Mice, rabbits, pheasant	Englund 1965
Sweden	Mainland	1,131 stomachs	Mice, garbage	Englund 1965
Australia	Canberra District and New South Wales	378 stomachs	Carrion sheep, rabbits	McIntosh 1963

are staple foods of red foxes. Of interest is the fact that the food habits of foxes in Sweden were very similar to those in South Dakota.

The high incidence of pheasant remains in fox stomachs from eastern South Dakota compared to other states appears to reflect the availability of the birds. It does not necessarily constitute evidence that foxes are a depressive influence on pheasant populations. Wagner et al. (1965) concluded that predation on pheasants is likely to be most severe in the poorer pheasant range characterized by low numbers of birds. However, research in states with considerably fewer pheasants than South Dakota has failed to yield incriminating evidence against foxes. Arnold (1952) found no statistical relationship between curves of abundance for foxes and pheasants. He concluded that foxes in Michigan have little or no effect on pheasant populations. A large-scale fox-control experiment in New York state did not benefit pheasant populations (New York State Conservation Department 1951). Besadny (1964) examined over 2,400 fox stomachs from 1955-62 and found no evidence that foxes adversely affected game populations in Wisconsin.

The larger pheasant populations in South Dakota produce correspondingly greater annual surpluses as compared to other states; consequently, more pheasants are available to foxes, both as live and carrion birds. The data suggested that when pheasants declined below certain levels in the study areas, their occurrence in fox stomachs also declined. Other factors which affected the frequency of occurrence of pheasant remains in fox stomachs included (1) changes in numbers of other prey, particularly mice and to a lesser extent, rabbits, and (2) season of the year. Little evidence of fox predation on pheasant young was found.

In general, it appeared that foxes had a relatively easy time obtaining pheasants due to the low degree of competition between individual foxes, and the large numbers of pheasants. This situation probably tends to over-dramatize the effect foxes may have upon pheasants. However, the question of whether or not foxes are a limiting factor to pheasant populations in eastern South Dakota can not be fully answered until results from the entire study are available for analysis.

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APPENDICES

Appendix A.	Common and scientific names of birds and mammals mentioned in the text.
Appendix B.	Locations of the four corner sections of each study area in eastern South Dakota.
Appendix C.	Major cover types in the study areas.

Appendix A

Common and scientific names of birds and mammals mentioned in the text.

The common and scientific names of birds were taken from the American Ornithologists' Union Check-list (1957); the common and scientific names of mammals were taken from Burt and Grossenheider (1964).

BIRDS

American rough-legged hawk	Buteo lagopus
Bobwhite	Colinus virginianus
Burrowing owl	Speotyto cunicularia
Chestnut-collared longspur	Calcarius ornatus
Common grackle	Quiscalus quiscula
Dickcissel	Spiza americana
Eastern kingbird	Tyrannus tyrannus
Greater prairie chicken	Tympanuchus cupido
Great-horned owl	Bubo virginianus
Horned lark	Eremophila alpestris
Hungarian partridge	Perdix perdix
Lark bunting	Calamospiza melanocorys
Marsh hawk	Circus cyaneus
Mockingbird	Mimus polyglottos
Mourning dove	Zenaidura macroura

Appendix A (continued)

Red-headed woodpecker	*Melanerpes erythrocephalus*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-necked pheasant	*Phasianus colchicus*
Snow bunting	*Plectrophenax nivalis*
Swainson's hawk	*Buteo swainsoni*
Upland plover	*Bartramia longicauda*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*

MAMMALS

Badger	*Taxidea taxus*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Eastern cottontail	*Sylvilagus floridanus*
Eastern fox squirrel	*Sciurus niger*
Gray fox	*Urocyon cinereoargenteus*
House mouse	*Mus musculus*
Longtail weasel	*Mustela frenata*
Masked shrew	*Sorex cinereus*
Meadow jumping mouse	*Zapus hudsonius*
Meadow vole	*Microtus pennsylvanicus*
Mink	*Mustela vison*

Appendix A (continued)

Northern grasshopper mouse	*Onychomys leucogaster*
Northern pocket gopher	*Thomomys talpoides*
Opossum	*Didelphis marsupialis*
Plains pocket gopher	*Geomys bursarius*
Plains pocket mouse	*Perognathus flavescens*
Prairie vole	*Microtus ochrogaster*
Raccoon	*Procyon lotor*
Red fox	*Vulpes fulva*
Richardson ground squirrel	*Citellus richardsoni*
Shorttail shrew	*Blarina brevicauda*
Striped skunk	*Mephitis mephitis*
Thirteen-lined ground squirrel	*Citellus tridecemlineatus*
Western harvest mouse	*Reithrodontomys megalotis*
White-footed mouse	*Peromyscus leucopus*
Whitetail deer	*Odocoileus virginianus*
Whitetail jackrabbit	*Lepus townsendi*
Woodchuck	*Marmota monax*

Appendix B

Locations of the four corner sections of each study area in eastern South Dakota.

Unit	Area	Township	Range	Section	County
1	Red.	126 N	76 W	17	Campbell
		126 N	75 W	14	Campbell
		125 N	76 W	32	Campbell
		125 N	75 W	35	Campbell
	Chk.	122 N	75 W	20	Walworth
		122 N	74 W	23	Walworth
		120 N	75 W	6	Potter
		120 N	74 W	3	Potter
2	Red.	122 N	68 W	19	Edmunds
		122 N	67 W	22	Edmunds
		120 N	68 W	6	Faulk
		120 N	67 W	3	Faulk
	Chk.	123 N	65 W	30	Brown
		123 N	64 W	27	Brown
		121 N	65 W	7	Brown
		121 N	64 W	10	Brown
3	Red.	108 N	58 W	18	Miner
		108 N	57 W	15	Miner
		107 N	58 W	31	Miner
		107 N	57 W	34	Miner
	Chk.	111 N	58 W	34	Kingsbury
		111 N	56 W	31	Kingsbury
		109 N	58 W	15	Kingsbury
		109 N	56 W	18	Kingsbury

Appendix B (continued)

Unit	Area	Township	Range	Section	County
4	Red.	99 N	55 W	19	Turner
		99 N	54 W	22	Turner
		97 N	55 W	6	Turner
		97 N	54 W	3	Turner
	Chk.	101 N	52 W	35	Minnehaha
		101 N	50 W	32	Minnehaha
		99 N	52 W	19	Turner
		99 N	51 W	22	Lincoln

Appendix C

Major cover types in the study areas.

	Percent of Land Area											
	Unit 1			Unit 2			Unit 3			Unit 4		
Cover Type	Red.	Chk.	Avg.	Red.	Chk.	Avg.	Red.	Chk.	Avg.	Red.	Chk.	Avg.
Permanent pasture	40§	26	33	17	18	18	19	21	20	11	9	10
Hay (Tame)	18	16	17	16	12	14	15	13	14	12	9	11
Corn	7	9	8	9	13	11	21	19	20	37	37	37
Soybeans	--	--	--	--	--	--	--	--	--	3	5	4
Wheat	14	14	14	15	14	15	1	5	3	1	1	1
Oats	7	9	8	10	10	10	14	10	12	22	20	21
Other small grain	3	3	3	5	10	8	3	9	6	--	--	--
Slough	3	4	4	1	1	1	--	--	--	--	--	--
Soilbank	8	8	8	5	9	7	5	12	9	3	3	3
Total	100	89	95	78	87	84	78	89	84	89	84	87

§Figures determined from aerial photographs, ground reconnaissance and South Dakota Crop and Livestock Reports.