Some Life History and Ecological Activities of the Richardson Ground Squirrel In South Dakota

Dean Robert Gunderson

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SOME LIFE HISTORY AND ECOLOGICAL ACTIVITIES OF THE
RICHARDSON GROUND SQUIRREL
IN SOUTH DAKOTA

BY
DEAN ROBERT GUNDERSON

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of
Entomology-Zoology, South Dakota
State College of Agriculture
And Mechanic Arts

December, 1961
This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and 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.
ACKNOWLEDGMENTS

The author wishes to express his appreciation to the people who helped and guided him during the course of his study.

To Dr. J. A. Rogulski, assistant professor of Zoology and Wildlife Conservation and the author's major professor for his constructive criticism and supervision of this manuscript.

To Hadine Henderson who typed the manuscript and who helped with the construction and grammar.

To Terry L. Cummings who helped with the care and feeding of the caged animals.

S.R.J
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INTRODUCTION

Wherever man has gone he has changed his environment to suit his needs. Because of his need for food, man has plowed up the prairies and converted the grasslands to grain fields. Before white man settled the Great Plains, range rodents such as the prairie dog and the ground squirrel existed undisturbed and unmolested except by their natural predators. With the advent of cultivated crops, the range herbivorous found a new and tasty source of food. Among these primary consumers which took advantage of man's interference with the natural prairie was the Richardson ground squirrel, Citellus richardsoni (Figure 1).

During the past few years, the Richardson ground squirrel has been found in increasing numbers in the central part of South Dakota. There has been very little investigation of this species of ground squirrel in the United States although some work has been done in Canada.

The purpose of this study is: (1) to determine the habits and activities in the life cycle of the Richardson ground squirrel; and (2) to compare this data with that indicated by other authors.

Richardson ground squirrels do considerable damage to grain crops, soil, forage crops, and farm lands, and they are also a potential reservoir for bubonic plague.

The Study Area

The study was conducted in the north central part of Hyde County, South Dakota, approximately 12 miles north and three miles west of the City of Highmore.
Figure I. The Richardson ground squirrel, *Citellus richardsoni*
Soils

The Wisconsin ice sheet covered this area of the Great Plains, and the debris left when the ice receded affected the physiographic features of the entire county, except the southeastern part.

The soils in the study area have developed over glacial drift, a dark-colored shale, and alluvial deposits consisting of sediments derived from the two materials. These soils are of the Williams loam series.

Hachliss and Williams (1925) gave the following description of the soils of this area:

The surface soil of Williams loam, to a depth ranging from seven to 12 inches and averaging about eight inches consists of loose, friable very dark grayish-brown or nearly black loam of finely granular structure. The surface soil is underlain to a depth varying from 16 to 20 inches, by dark-brown or brown, heavier-textured loam or clay loam which contains some glacial pebbles. The next layer, which reaches a depth of about 30 inches is friable or slightly compact yellow or grayish-yellow silty clay or clay loam. Below this layer is pale-yellow or yellow friable silt; the glacial till from which this soil was derived.

Climate

The climate of the general area is typical of the plains region. The summers are short, with hot days and cool nights, and the winters are long and often severe. The mean winter temperature is 16.2°F and that of the summer is 69.5°F. The latest recorded killing frost was June 6, and the earliest was Sept. 5. The mean annual rainfall recorded is 13 inches. The heaviest precipitation takes place during the spring or summer and the lightest during the winter (Hachliss and Williams, 1925).
The study area consisted of approximately 25 acres of alfalfa and about five acres of a buffalo-blue-grama grass association (Figure II). The area was divided into two main divisions designated A and B. Area A consisted of alfalfa and was bounded on the north and south by prairie grasses, on the west by ranch buildings, and on the east by cultivated land. Area B was bounded on the north by a prairie slough, on the south by alfalfa, on the east by a gravel road, and on the west by a slough. Both areas contained gravelly ridges in which the majority of squirrel burrows were located (Figures III and IV).
Figure II. Map of study area

- Trees
- Slough
- Prairie
- Ridge
- Old burrow systems
- New burrow systems

200 Feet
REVIEW OF LITERATURE

DESCRIPTION OF THE ANIMAL

The Richardson ground squirrel, *Citellus richardsoni* (Sabine), is often called the prairie gopher. It also is known as yellow gopher, flicker tail, and "picket pin" gopher. The color varies from tawny to a near white. Brown and Hoy (1943) stated that: "There is a vast variation in size and color in different areas and the variation is likely due to the soil type and kind of food available."

Howell (1938) describes the color as "... a nearly uniform buffy or drab with a slight dappling with the under parts a deep buff in summer."

The first recorded specimen of Richardson ground squirrel was collected by Sir John Richardson at Carlton House, Saskatchewan, in 1822. The animal was first described by Sabine in 1822 who named it *Arctogale richardsonii*, but the name was changed to *Citellus richardsonii* by Richardson in 1829 and was finally changed to *Citellus richardsoni* by Trouessart in 1904 (Howell, 1938).

Bailey (1926) described the ground squirrel in his biological survey of North Dakota. He measured sixteen adults and obtained the following measurements: total length 265.4 mm. (277-306), tail vertebrae 73.3 mm. (65-83), hind foot 44.9 mm. (43-47). He found the weight in the spring to average 364.4 grams and in the fall 448 grams. In the current study the adults weighed from 245 grams to 356 grams, and the crown-rump length varied from 213 mm. to 250 mm.
Range

In 1933 Howell described the range of the animal as follows:

From the plains of southern Alberta, southern Saskatchewan, southwestern Manitoba, northern and central Montana, North Dakota (except southwestern part) and northeastern South Dakota; north to the North Saskatchewan river; east to the Red River valley, North Dakota, Big Stone Lake, South Dakota, and the western edge of Minnesota; south to east-central South Dakota, and southwestern Montana; west to the foothills of the Rocky Mountains in Alberta and Montana.

Over and Churchill (1941) stated:

It has migrated from farther north into South Dakota within the past twenty-five or thirty years. As late as 1915 the senior author could find very few specimens along the coastline of the Milwaukee railroad. Specimens were taken in 1903 in Walworth county by Mr. Fred W. Smith. This ground squirrel or gopher has never been found west of the Missouri River, but since 1915 it has spread southward rapidly and by 1926 has reached the northern limits of Hughes, Jerauld, Sanborn, Minne, and Moody counties.

Life History

The habitat of the Richardson ground squirrel has been generally discussed by Bailey (1926), Brown and Roy (1943), Howell (1935), and by Seaton (1923).

The food habits of this animal were studied by Howell (1935), Brown and Roy (1943), and Bailey (1926).

The burrow systems were studied by Brown and Roy (1943).

Errington and Creckenridge (1936), in their studies of predation by such hawks, found many traces of ground squirrel remains. Errington (1936 and 1937), made studies of predation by the badger and fox upon ground squirrels. Bailey (1926) gives a general account of enemies of the Richardson ground squirrel. Fitch, et al. (1946) made studies of predation on the California ground squirrel. Brown and Roy (1943) also
listed important predators of the Richardson squirrel.

Hibernation and aestivation of the Richardson ground squirrel
were described by Jowls (1943), Bailey (1926), and Brown and Roy (1943).

Loorn (1940) conducted hibernation studies of the Mule ground squirrel
by measuring the fat content of the body to determine hibernation.

Wade (1927-1928) made studies of the effect of temperature and weather
conditions affecting hibernation of ground squirrels.

Gestation and reproduction were discussed by Brown and Roy (1943),
Howell (1938), and Bailey (1926). Dickerman (1939) studied mating habits
of the Richardson ground squirrel under laboratory conditions. Dem-
nison (1957) made studies on the size of newly born young, and on the
length of the gestation period. Surrall (1949) made a comprehensive
study of the growth of young ground squirrels of the spilosoma species.

Fitch and Bentley (1949) and Linsdale (1946) conducted studies
of the California ground squirrel in relation to forage crops, and
Phillips (1936) made studies of ground squirrels on grazing lands.

Daily and seasonal activities of ground squirrels were studied
by Shaw (1949), Wade (1927), and Fitch (1948).

Parasites of the Richardson ground squirrel were studied by
Furgess (1955), and by Brown and Kromman (1952). Brown and Roy (1943),
in their study of Rocky Mountain spotted fever in Alberta, found numer-
ous fleas, ticks, and mites on squirrels.

Studies on the control of ground squirrels were made by Linsdale
(1931) and Lockmann (1957). Brown and Roy (1943) made a complete study
of the control of this squirrel in southern Alberta as a result of a
bubonic plague scare in Canada.
METHODS USED FOR COLLECTING DATA

Nearly all of the data collected concerning the food habits, behavior, and daily and seasonal activities were made from observations in the field. Observations were made from March 15, 1960 to Sept. 15, 1960, and from March 1, 1961, to June 15, 1961.

Observations

Observations were mainly made from a blind located on the highest point of land in the study area. As the height of the vegetation increased, it became increasingly difficult to see individual animals. Notes on the daily activities and movements of the animals were made as the season progressed until the animals could no longer be observed from the observation point. Slower growth of vegetation on area B allowed a longer period of observation than on area A. Observations of daily activities were concluded on June 15, 1961. Observations on the behavior of the animals were made from animals in the field by using binoculars, and food habits were determined to some extent by feeding and watching the caged animals.

The caged animals were kept in a wooden box (24 inches x 24 inches x 48 inches) covered with 4-inch hardware cloth. The top of the cage was covered with a lid made of 4-inch hardware cloth with a 12-inch square cut in the top for food and water placement. The cage was divided into two sections with a nest box in each section. One section was dark at all times and served as a refuge for the animals. A two-inch hole was cut near the bottom of the partition to allow the animals to go back and forth.
Trapping

The traps used were made from \( \frac{1}{2} \)-inch pine with \( \frac{1}{8} \)-inch hardware cloth covering the top. A trigger mechanism was made out of wire and the door constructed of tin with a weight soldered to the back. The traps proved effective in the early season with ground oats and corn used as bait; however, after vegetation became plentiful, the traps were ineffective. A commercial wire box trap was also used in the early spring. Later in the season a snare tied of nylon fish line was used to trap the young squirrels.

Only one live trap fatality occurred when a young squirrel which was left in the trap for 24 hours died, probably as a result of the temperature which had reached 95°F during the day.

Snap rat traps (size 1) proved ineffective against the squirrels. The traps were sprung, but all of the squirrels had escaped. One young squirrel approximately two months old was seen crawling along with its hind quarters dragging as a result of being injured by a trap.

Marking

Captured squirrels were weighed to the nearest gram and their measurements were recorded to the nearest millimeter. Some of the young squirrels were marked with Indigo and Malachite green dyes, but these dyes proved to be ineffective for after approximately two weeks, the dyes had entirely disappeared. The squirrels were also marked by toe clipping to make identification possible from season to season. Toes were numbered so that not more than one toe was removed from each foot. Some bleeding was observed but the toe soon healed.
**Mapping**

The two study areas were marked off in 200-foot square quadrats by using a chain and compass. Burrows were located during April, 1960, and again in April, 1961, so that all new burrows could be plotted on the map. The corners of the quadrats were marked with three-foot stakes.

**Parasites**

Both external and internal macro-parasites were collected from animals which were removed from the live traps. The external parasites were placed in Hood's solution for later identification; the internal parasites were placed in FAA solution.
ENVIRONMENT

Burrows

Burrows are an important part of the environment of the ground squirrel. Including hibernation and aestivation, a squirrel spends almost 90 per cent of his lifetime in the burrow.

Location

The selection of the site of the burrow seems to be controlled by the soil type and elevation of the land. The ground squirrel seems to prefer the more gravelly type of soil for the burrow. Food availability also seems to play an important part in its location. The burrows in the study areas were for the most part located on the ridges and higher elevations, probably because of drainage more than any other factor.

Construction

Burrows vary in depth and length depending upon the soil type and the time of year. Brown and Hoy (1943) found that the winter burrows are usually very deep and approach 20 feet in length, while the summer burrows are shallow and eight to ten feet long. One of the burrows excavated on March 23, 1961, measured five feet at its greatest depth and contained approximately 27 feet of subterranean connections. It contained 10 openings, the diameter of which varied from two to four inches (Figure 7). Each summer burrow had an average of eight openings scattered over an area ten to fifteen feet in diameter. Brown and Hoy (1943) noted that the winter burrow has only one opening, which is plugged
Figure V. Map of excavated burrow
from the inside by the ground squirrel when it goes into hibernation.

The usual burrow entrance consists of an opening on one side of the mound of soil removed from the burrow. This mound serves as a protection for the burrow entrance and as an observation post for the animal. The amount of soil raised by a ground squirrel in the construction of a burrow may vary considerably. The amount of soil from one freshly dug burrow entrance weighed 100 pounds, or contained approximately five cubic feet of earth. This unusually large mound of earth measured three feet in diameter and was 24 inches high (Figure VI).

**Types of Burrows.**

The Richardson ground squirrel constructs three types of burrows:

1. **home burrows of adults;**
2. **auxiliary burrows at feeding places;** and
3. **home burrows of young.** Adult squirrels have auxiliary burrows leading to feeding places. Such auxiliary burrows are usually not over ten feet long although one measured over 20 feet in length; this burrow had its entrance near an old oat straw pile where the adult fed on the grain.

The existence of subterranean connections between the main burrow and the auxiliary burrows could be confirmed by watching a marked squirrel go into one entrance and appear at another.

Sometimes in the spring of the year a small round hole can be seen near the entrance of an adult burrow. The hole made by young ground squirrels leads from the nest to the ground surface, and because they are dug from the inside of the nest all of the dirt is pushed back into the winter burrow.

Each squirrel has one burrow in which it spends most of the day.
and night. Usually the mated male and female live together in one bur- row until after the young are born; then the male moves to another bur- row. Occasionally the female leaves the old burrow taking some of the young with her and leaving some of them behind. By the middle of June, the young have relocated to either newly constructed or old burrows.

Nests

Nest building usually takes place in June or July in preparation for hibernation. The nests are built out of available materials such as dried grasses, feathers, oil straw, and weeds. Material gathered for nests is carried in cheek-pouches which sometimes are so full that the material hangs out the sides of the mouth. On May 3, 1961, a male was observed carrying grasses from one burrow to another. Evidently he was moving to a new home and was taking his nest with him.

The winter nest of the burrow that had been excavated was located four feet below the surface. It was built of dried grass and chicken feathers. The female that had lived in this burrow was one that had been live trapped and held in a cage. The nest building activities of this female were observed after she was put into the cage. Some dried prairie hay was put into the cage, and the squirrel pulled the hay into the nesting box with her feet. After the hay was pulled into the box the squirrel proceeded to cut it into smaller pieces with her teeth. The stems were cut into clippings approximately 1/4 inch long. The squirrel would use her nose and body to arrange the clippings and then would turn around and around in a small circle, pushing and moving her body against the hay until she had a nest of approximately three inches
in diameter. Upon returning to the nest, she would close the opening with her nose by pushing against the outer clippings.

**Runways**

Runways are paths through the vegetation worn by the squirrels going from burrow to burrow (Figure VII). Runways were noticed a few days after the squirrels emerged from hibernation. They were usually two inches wide and sometimes over 200 feet long. Squirrels seldom ventured from the runways except for foraging purposes. The runways connected auxiliary burrows and neighboring burrow systems. An average of six runways would lead from the home burrow. Sometimes ear tracks and cattle trails were used as runways by the squirrels. When danger threatened, the squirrels ran to the nearest runway and then to the burrow entrance. Only by standing on their runways between the animals and the burrow entrance, would the author be able to get them to leave the runway. Their reluctance to leave the runway resulted in a means of trapping them. A wire live trap open at both ends was placed on the runway, and when they were frightened the squirrels would run along at top speed into the trap.

**Home Range and Territories**

The home range of a ground squirrel contains several burrow systems usually used by members of the same squirrel family. There is usually an exchange of animals between home ranges. A squirrel may travel from two to four hundred feet visiting other burrow systems (Figure VIII). The home range is limited by certain geographical areas such as the slough area to the north of area B. When the squirrels first emerge
Figure VIII. Movements of an adult male squirrel from 8:15 A.M. to 9:00 A.M., March 19, 1961
they do considerable exploring, and their range is much larger than
later in the season.

During the breeding period, the male establishes a territory and
defends it against all members of the species. On April 5, 1960, a male
was observed defending his territory from another male. The male ap-
proached the intruder with his tail raised and his mouth open. Then he
started chasing the intruder but could not catch him. His burrow
was approximately one hundred feet from the edge of the slough, The male
tried to drive the intruder into the water by herding him toward the
water's edge. He succeeded in driving the intruder onto a small knoll
about three feet from the water's edge where he kept watch for about
five minutes.

The average squirrel territory covers an area approximately one
hundred feet on all sides of the home burrow. After the young are born
and the male has left the burrow, the female is the territory guardian
and will not let the male approach except in times of danger, and then
he uses the burrow for a retreat. The female defends her territory
against other females and against all strangers. After the young have
emerged, the territory expands or is lost completely, and there is again
a freedom of movement between the colonies.
ASSOCIATED ANIMALS

Lives of ground squirrels are interrelated with the lives of other members of the animal community. Some of the animals are predators, others are parasites, and others merely associate using the squirrel's burrow as a home.

Ground Squirrels and Mice

Some animals compete with the Richardson squirrel for food and a few use the burrow as a place of refuge. In two different occasions thirteen-lined ground squirrels (*Citellus tridecemlineatus*) which had been using the burrow for a place of refuge were trapped. Home ranges of the thirteen-lined ground squirrel and Richardson overlapped to some extent, especially in the natural prairie vegetation. The thirteen-lined squirrels did not construct burrows in the alfalfa or cultivated soils, but usually in fence rows and close to farm buildings. They would not enter a Richardson's burrow unless there was a need for quick refuge from danger. Since insects are the principal food of the thirteen-lined ground squirrel, the squirrel may go into the Richardson burrow to feed on insects which use the burrow for a home. Thirteen-lined ground squirrels are not a serious competitor for food except during an extremely dry spring when all vegetation is scarce.

Another insectivorous rodent found near the burrows was the grass-hopper mouse (*Ochrotomys leucogaster*). These rodents probably go down into the burrows in search of insects. Harvest mice (*Reithrodontomys*) and deer mice (*Peromyscus maniculatus*) were also trapped near the burrows. Deer mice are partly dependent on Richardson burrows as refuges.
Cottontails and Jackrabbits

Ranges of the plains cottontail (Sylvilagus audubonii baileyi) and the blacktail jackrabbit (Lepus californicus) extended throughout this area. There was little or no competition for food between these rodents and the ground squirrel, but it is possible that the rabbits could use the mound of dirt near the burrow as a refuge in the winter.

Small Birds

Among the small birds that are common near the burrows were the horned larks (Eremophila alpestris), meadow larks (Sturnella neglecta), lark bunting (Calamospiza melanocorys), killdeer (Charadrius vociferus), and upland plover (Bartramia longicaudis). A pair of plovers nested in alfalfa near the squirrel territory. Squirrels and plovers fed within a few feet of each other seeming entirely compatible. The plovers fed on insects, and they frequently fed near the burrows where some ant mounds were found. Killdeer and horned larks also were found nesting near the burrows.

Arthropods

Among the arthropods most noticeable near the burrows were the agricultural ant (Pogonomyrmex barbatus) which apparently preferred making their nests in the mounds near the burrow entrance. The ants gathered seeds of weeds and grasses and stored them underground. It is possible that the ants compete for the stored food with the ground squirrels. Other arthropods noticed near the burrows were various species of grasshoppers (Locustidae). The squirrels were observed catching grasshoppers and feeding on them. Various members of the Order Coleoptera
were found living in the burrows. In the excavated burrow were found
crickets (Gryllidae) and a nest of thirty centipedes (Scolopendra
morsitans).

Predators

Hawks

The Richardson ground squirrel is an important food for many
predators that prey on ground squirrels. Marsh hawks (Circus cyaneus),
prairie falcons (Falco mexicanus), red-tailed hawks (Buteo jamaicensis),
and Swainson’s hawks (Buteo swainsoni) are enemies of the ground squir-
rel. The potential effect of these hawks is illustrated by studies of
their predation on California ground squirrels (Pitch, et al., 1946).
During one year, a single pair of red-tailed hawks took from an area of
half a square mile an estimated 100 squirrels.

Brown and Roy (1943) list the following predators of the Richar-
don ground squirrel in the following order of importance: hawks, owls,
vessels, badgers, coyotes, snakes, dogs, and domestic cats. Bailey (1926)
found that the ferruginous rough-legged hawk (Buteo regalis) feeds al-
most exclusively upon the squirrel. He also lists the Swainson and
marsh hawks as predators. Bailey states that “even the bird-catching
sharp-shinned (Accipiter striatus valox) and Cooper’s hawk (Accipiter
cooperii) may take one.” The marsh hawk was the most frequent hawk
species found near the study area althoughErrington (1936) did not men-
tion finding Richardson ground squirrel remains from marsh hawk galleys
collected in the North Central United States. On one occasion during
the current study, a marsh hawk was seen sitting on a trap trying to
get to the live trapped squirrel. The hawk sat on the trap for about ten minutes before flying off. Other hawks identified in the vicinity of the study area were the red-tailed hawk and the rough-legged hawk. Most of the hawks were observed during their migration in March and early April. Rough-legged hawks would frequently hover over burrow entrances for a few moments although no actual attack on a squirrel was noticed.

**Fox and Coyote**

Bailey (1926) mentioned the fox as a predator of the Richardson squirrel although Errington (1936) found no remains of Richardson ground squirrel in 1,175 fecal samples and from the 913 dens that he examined. This was probably because his study was east of the present range of the Richardson squirrel. Although fox have been seen near the study area, the author did not have an occasion to observe any of the fecal samples or dens.

Today, coyotes (*Canis latrans*) are so few in number that they have little effect on squirrel populations. It is possible that in the period when coyotes were more common ground squirrels were their chief source of food.

**Domestic Cats**

The author found that the domestic cat is an important predator of the squirrel, especially where the vegetation is high. The majority of squirrels taken by domestic cats were young squirrels which came out of the natal dens for the first time. Domestic cats were seen taking as many as six young from one family of squirrels.

On one occasion, the author, while sitting approximately 200 feet
from a burrow, had the opportunity to watch a cat approach and stalk an adult ground squirrel. There was not enough vegetation near the burrow for the cat to use as cover. The squirrel was about ten feet from the burrow when it noticed the cat approaching. The cat crept to within about 20 feet of the squirrel before the squirrel ran to the burrow entrance. The cat crouched low and observed the squirrel from this position. Then the squirrel stood on its hind feet watching the cat. These positions were maintained for about five minutes; then the cat started a slow run toward the burrow. The squirrel let the cat approach to within ten feet and then, with a flick of its tail, disappeared into the burrow. After crouching low behind the burrow mound out of sight of the entrance for about seven minutes, the cat then came around the mound and examined the burrow before moving off in search of other prey.

With the increased growth of vegetation cats have an easier time approaching squirrels. Young squirrels are easy prey because of their lack of fear, especially when the mother is not above ground. The author has seen female cats bring in young squirrels to the kittens and also witnessed a large male squirrel being brought in by a domestic cat (Figure 11). The domestic cat was by far the most important predator of the Richardson ground squirrel.

Parasites

No specific effort was made to collect all parasites from the dead animals. Only those parasites noticed while the reproductive organs were being examined were collected. Fleas (Siphonoptera) proved to be the most numerous ectoparasite on the squirrels. The fleas were identi-
Figure IX. A male domestic cat dragging a large ground squirrel
fied as belonging to the genus Spicocrastes. Burgess (1955) in his examination of 1,762 squirrels found 1,461 fleas while Brown (1944) in his examination of 6,264 squirrels found 1.7 fleas per animal.

The Anoplura (lice) found on the squirrels were identified as Hoplopleura hirsuta. Only one animal was infested with lice. Burgess (1955) found 171 lice on the 4,461 squirrels which he examined. The lice which he found were identified as Neoboe matopinus laevasculus.

One mite belonging to the genus Haemolaelaps was found on the squirrels examined. Burgess (1955) found 5,011 scabies on the 1,763 squirrels which he examined.

Brown and Irannan (1952) found chiggers (Imschongastia) on squirrels during their studies in Alberta.

The only internal parasites noticed in examining the 18 squirrels was a species of tapeworm belonging to the class Cestoda. The largest of the three worms, all found in the large intestine, measured 37 mm. in length. Internal parasites found by Brown and Hoy (1943) included Capillaria hepatica, Spirura spp., and Myxaloptera spp.
PERIODS OF ACTIVITY

**Daily Activity**

During most of the early spring days, the ground squirrels remained out of the ground most of the time. As the days became warmer, the time spent out of the burrows decreased until aestivation and hibernation. During the first part of May, the squirrels started to remain underground during the hot part of the day. The maximum time spent out of the burrows was about ten hours per day during the peak of activity. Shaw (1943) found during his studies of the Columbian ground squirrel, that the daily appearances from the burrows is greatly influenced by sunrise and sunset. He stated that, "The Columbian ground squirrel is definitely diurnal and sun-loving--its activities largely controlled by seasonal and daily activities of the sun, wind, temperature, and climatic conditions generally." The factors influencing activities of the Columbian squirrels seem to be identical to those which influence the Richardson squirrel.

The activities of a male squirrel were recorded during the 17th of March, the 1st of May, and the 1st of June, 1961. On March 17, the squirrel spent approximately 130 minutes of the time above ground in exploring while it spent only a third as much time feeding. On May 1, this squirrel spent only 50 minutes exploring and 30 minutes feeding, while 65 minutes were spent in nest building. On June 1, only 30 minutes were spent in exploring while 160 minutes were spent in feeding and about 40 minutes were spent in nest building. By these observations it can be seen that the exploring activities of the squirrels decreased
as the feeding and nest building activities increased. When the squirrels first emerged from hibernation, approximately 75 per cent of their daily activity was spent in exploring.

The wind seemed to have little or no effect on the daily activities of the squirrels. Squirrels were observed feeding near their burrows when the wind was blowing 30 miles per hour with gusts up to 50 miles per hour. However, when the wind was high the squirrels tended to remain nearer the burrows.

Rainy and cool damp weather drove the squirrels into their burrows. Sowls (1945) observed that his captive Franklin ground squirrels remained in their den boxes all day during cold, damp weather. The squirrels were observed to come out of their burrows about an hour after a rain.

Air temperatures influenced activities of the squirrels. In early spring when the temperature was below 35°F, there was very little activity above ground, but when the temperature reached 35°F, almost all of the squirrels retreated underground.

As with other animals, the climatic elements affect the activities of the squirrels. Although the various factors were not measured, the temperature seemed to be a major influence on squirrels.

**Seasonal Activities**

**Emergence from Hibernation**

Apparently the dates of entering and leaving the hibernation dens vary considerably with local conditions. Howell (1936) reported that
ranchers in central Montana found the squirrels appearing in February, and Seaton (1928) found they came out during February in the country around Dawson, Manitoba. Howell (1938) stated that, "at Condo, North Dakota, they were first observed in 1915, on March 1."

Weather conditions seemed to determine the time of leaving the hibernation dens. The first squirrels observed in 1960 were seen on April 15, and, in 1961, almost a month earlier on March 17. Snow covered the study area until the first week in April in 1960. The temperature at this time was below freezing but as soon as the snow melted the squirrels appeared. In 1961, there was a week of above normal temperatures. From March 8 to March 15 the temperatures reached the 60-degree mark. There was no snow on the ground at this time. It appears that the unseasonal rise in temperatures brought the squirrels out of hibernation. This is apparently the same conclusion made (1928) reached when he stated:

That frozen soil presents a barrier through which ground squirrels cannot dig their way, thereby holding them imprisoned until sufficient thawing and loosening of the soil makes digging out possible. Since these conditions vary widely with the years in the region, and are correlated with annual spring-emergence dates, it is reasonable to assign to this factor great importance in any explanation of the fact that ground squirrels emergence dates do vary so widely.

When the squirrels first emerged from the burrows in the morning they would spend a few minutes sunning themselves. This was accomplished by lying out flat on the mound with the hind legs extended or by sitting on their haunches with their backs to the sun. Very little sunning was observed among the adults, while the young seemed to partake of this activity almost every morning.
The maximum number of squirrels seen at one time occurred around 7 A.M. and 5 P.M. The earliest time of the day a squirrel was observed was at 6:30 A.M. on May 2, 1961. Sunrise on this particular day was at 5:22 A.M. On most occasions, under favorable weather conditions, the squirrels came out about one hour after sunrise. The latest time in the evening that a squirrel was noticed above ground was at 8:00 P.M. on June 10, 1961. Sundown on that day was at 8:09 P.M.

Most of the squirrels were out of their hibernation dens by March 23. Males were the first to emerge, followed by the females about a week later. All of the animals that were shot the first week were males. The year-old young emerged after the females.

Preparation for Aestivation and Hibernation

The squirrels began preparation for aestivation the last week in May. A male was observed gathering nesting materials on May 3rd. The squirrel was transferring nesting materials from one den to another. He would disappear into the old burrow and return about five minutes later with cheek-pouches full of old hay and grass. He carried the nesting materials to the new burrow which was about 100 feet away. On June 2, 1961, a squirrel was observed collecting dandelion (Taraxacum) seeds. The squirrel would run from one dandelion to another pulling off the complete heads until the cheek-pouches were full. The seeds were probably eaten during the summer period of inactivity.

During the summer of 1960, the majority of squirrels were inactive after July 15th. They went into a state of aestivation at that time, and only the young remained out of the burrows.
Entrance into hibernation

In 1960, the latest date that squirrels were observed above ground was on September 15. As previously stated, these were the young squirrels which were identified as young by the smaller size and weights.

The males were the first to go into hibernation, followed a week later by the females. Animals which were shot were examined to determine the sex and, of 13 animals shot, there were no males identified after September 1st.

Sovls (1949) stated that, "the flickertail remains out much later than the Franklin's. Many flickertails are still active in early October on the posture plains and during mild autumns a few are seen as late as the first week in November."

Fat content seems to be an important factor which causes hibernation. Akeron (1949) found that the fat content in the body of the Prute ground squirrel caused hibernation. He found that it took 100 days for the males to become fat and 135 days for the female to become fat; these days corresponded to the entrance into hibernation. Suarell (1949) found that Citellus spilosoma began to store fat after the testes had withdrawn into the abdomen. He found that young animals began storing fat after they weighed about eighty grams.

The layer of fat along the back of a male captured on April 12 was measured and was found to be 60 mm. by 30 mm. by 10 mm. in thickness. On June 19th a male of approximately the same size was killed and the fat content along the back measured 75 mm. by 43 mm. by 17 mm. All of the squirrels had some amount of fat stored even after coming out of hibernation. The fat is stored around the reproductive organs, under
The Richardson ground squirrel evidently enters into hibernation when the fat content has reached a certain amount and when the climate becomes unsuitable for the activity of the squirrels.
Behavior

The Richardson ground squirrel exhibits certain behavioral habits which establish them as an organized society. The behavioral patterns of individual squirrels and the society as a whole was observed in the field and from animals in the cage.

Positions

There are numerous positions assumed by the animals when they are not moving about. When the squirrels are running they usually sit on their haunches with their fore feet on the ground. The head is held high with the back horizontal to the ground and the tail lying flat on the ground (Figure 1A). Some animals will lie flat on the ground with their front and hind legs stretched out.

A feeding animal may use more than one position when eating. Usually the feeding animal sits on his haunches and holds the food in his fore paws (Figure 1B). At other times he may stand on all four feet and pluck the grass with his teeth without using his feet to put the food into his mouth (Figure 1C).

A comfortable and favorite position seems to be the so-called "picket" position (Figure 1D). The body is held straight and in a vertical position with the fore feet folded across the chest. Ground squirrels were seen holding this position for as long as 15 minutes with hardly any movement. In this position, the weight of the animal is supported by the hind feet. Sometimes the animal will stretch out to its full height using its toes as a support; however this position is used for only short periods of time. The tail is not used to support the animal.
Figure X. Typical positions of ground squirrels.
A. Sunning position; B. Feeding position;
C. Feeding position; D. "Picket" position
in this position.

**Locomotion**

The ground squirrels had three different gaits that were used at different times depending on whether they were feeding, frightened, or exploring. When feeding, the animal would move in a fast trot from one spot to the nest, nibbling as he went, and taking only a bite from each plant. Only when they were feeding in a small area, would the squirrels resume a walking gait. Sometimes the squirrels would use a running-jumping gait. This gait was observed during the gathering of seeds and when the animals were exploring. The animal would run at a fast trot and then make a small jump into the air. When angry, the squirrel would run rapidly toward the intruder with the tail raised in a vertical position. When frightened, the animal would break into a fast run. The body and head was held low to the ground and the gait was very rapid, breaking from a sort of gallop at first, into full running position. When exploring, the squirrel moved at a trotting gait, stopping at intervals to use the "picket" position. Figure VIII shows the number of "picket" positions assumed during the movements of a male squirrel.

**Colony Integration**

The Richardson ground squirrel does not have the close colony integration of the prairie dog although their colony integration is more complex than that of other rodents. The burrow systems are not arranged in any special order although there is communication between burrow systems.
There is cooperation among the squirrels when danger threatens. The burrows are so arranged that a squirrel's warning whistle can be heard by other members of the system. There is no noticeable division between members of families as there are in prairie dog systems. A ground squirrel may make his burrow near the burrow systems of unrelated animals without interference. Once the young have left the home burrow the family ties are broken.

Cooperation also exists during nest building time. Squirrels have been observed assisting each other in the nest building activities. Squirrels were also observed helping each other in the construction of a burrow; however the above cases are rare as most of the squirrels lead independent lives.

**Social Organization**

There was little evidence of dominance among members of the community. There was some dominance of one male over another during the mating season and during the defense of a territory. There was sexual aggression of the male toward the female during the breeding season. The adults were dominant over the young to a certain degree, but the young usually were free to do as they pleased.

There was some dominance observed between caged males and females. The male would crowd the female away from the feeding pan and also try to crowd her out of the nest. The female would growl and try to push her way into the nest. The male seemed to be the most passive of the two animals. He would never growl or bite the female but would simply push her aside with his body. Sometimes the female would bite and strike at the
male with her fore feet but the male paid little attention to her.

There was no dominance displayed among the young. They would engage in mock fighting and chase each other around but no one individual was dominant over another.

A young ground squirrel approximately three months old was placed in the cage with an adult male and female to see what the reaction would be. As soon as the male saw the young squirrel he approached in the typical fighting attitude with his tail arched over his back and a sideways movement of the body. As soon as he approached the young squirrel he attacked, jumping onto the back of the young squirrel. The young squirrel turned over on his back in the typical defensive attitude. The male tried to bite the young squirrel around the genital region. The young squirrel growled and squealed and tried to escape, but his feet held him down. The male held the young squirrel in this position for about three minutes before leaving to resume his feeding. The female also attacked the young squirrel in the same manner as the male. About thirty minutes later the young squirrel had joined the male and female in the nesting box and the adult squirrels completely ignored him.

**Reactions to Observer**

The curiosity of the squirrels enabled the observer to approach to within a few yards of the burrow where the squirrel was located. The young squirrels which had just emerged from the hibernation dens were the easiest to approach. They showed very little fear and could be approached with ease.

When the adults had just emerged from hibernation, they were dif-
difficult to approach. The observer could approach no closer than one hundred yards from the burrow before the squirrel disappeared. An automobile or other vehicle could approach to within a few feet of them without difficulty. If, however, some of the squirrels had been shot from a vehicle they soon learned to recognize the vehicle as a danger symbol and would stay underground.

As the season progressed the adults seemed easier to approach. During nest building activities, they could be approached to within a few feet without showing fear. The instinct to gather nesting materials seemed to overcome the danger instinct.

When the observer approached the squirrel and the squirrel had disappeared, it was usually about 15 to 20 minutes before the squirrel reappeared. One squirrel remained out of sight in the burrow for one hour before reappearing. The squirrel would stick its head cautiously above the ground and remain in this position for varied lengths of time.

Some young squirrels of approximately one month's age came out of the burrow when the observer was standing within five feet of the entrance. Abrupt movements caused them to run back into the burrow, but unusual noises would attract both the young and adult squirrels. A whistling noise would cause the young squirrels to stand up straight near the burrow entrance for a better look.

The squirrels which were being held in a cage turned over on their backs in the defensive position when the author tried to pick them up, although eventually they allowed themselves to be picked up by the nape of the neck and they remained relatively calm. When squirrels were first put into the cage, they curled up into a ball with their head between the
hind legs and pretended to be asleep. This position was observed on
several occasions when a squirrel was extremely frightened.

The adult squirrels continued to remain very wild even though
kept in a cage for three months; however, they took alfalfa from the
author's hand, biting off pieces of the alfalfa and retreating back
into the seclusion of the nesting box.

Climbing and Jumping

The caged squirrels proved to be excellent jumpers. They would
jump a vertical distance of 24 inches and grab the wire top of the cage
with their fore feet. They would swing the hind feet up and hook all
four feet onto the wire with their toenails. They could move along the
top hanging upside down. The squirrels could stay in this position for
as long as ten minutes. While in this position, they would lick the
wire rapidly with their tongue. This behavior was observed in all squir-
rels when they were trying to escape. This "tongueing" procedure was
used by the squirrels to soften the material so it could be pulled apart
with the incisors. The tongue was moved rapidly over the material until
it had softened sufficiently to gnaw. They would continue this "tongue-
ing" technique until at times the tongue would bleed profusely. Both
adults and young were observed engaged in this activity. About 50 per-
cent of the caged squirrels' activities were spent trying to escape by
this method. As soon as the squirrels were fed, they would begin the
"tongueing" action, either on the cover of the cages or on the wooden
sides.
Scrubbing and Grooming

Squirrels spent a considerable portion of each day scratching and grooming themselves. They could scratch almost all areas of the body using the hind feet. The area scratched most of the time was the chest and head areas. The face and head were groomed by using the fore feet. They would lick the front feet and then rub the back of the head and cheeks with the feet in very rapid movements. The underparts of the body were groomed by pushing and combing with the nose and licking the fur with the tongue. Grooming was usually done intensively when they first came out of the nest box in the morning, although they have been seen grooming themselves at all times of the day.

Communication

Communication between animals may be divided into three types of stimuli. These are: (1) vocal, (2) olfactory, (3) tactile, and (4) visual.

Vocal communications were divided into the following categories: (1) warning whistle, (2) fear whistle, (3) fighting growl, and (4) tooth chattering.

The warning whistle is a sound lasting from two to five seconds. The whistle starts out in a low note, rises to a level tone, and then dies off in a plaintive tone. It is given by the squirrel when he is usually in the "picket" position. This whistle is used to warn other members of the community of danger. The first squirrel noticing the danger gives the whistle and then all members within hearing distance will respond with answering whistles.
The fear chirp or whistle is used when the squirrel is frightened. It is a short bird-like chirp and is usually given just before the squirrel enters the burrow. Sometimes the chirp is prolonged into a series of rapid notes starting at a high pitch and descending to a low tone.

The fighting growl is used when a squirrel is quarreling, at which time the squirrel gives a series of whistles and growls which vary in length and duration.

Tooth chattering occurs when a squirrel is challenged by another squirrel or when the squirrel is experiencing a situation which he does not like. When the squirrel was first put into a cage the tooth chattering occurred, and it also occurred when the squirrel was first trapped.

When a squirrel is giving the warning whistle, its mouth is open and the lower jaw vibrates (Figure XI). The whistle may be heard as far as two hundred yards. When the young squirrels are about a month old they can whistle as loudly as the adults.

What degree the olfactory stimuli had concerning communication between the squirrels is not known. The squirrels emit a strong musky odor when certain stimuli occur. The squirrel has three anal papillae located in the folds of flesh near the rectum. When everted the papillae are 2 mm. long and ½ mm. wide. The papillae are everted when the squirrel is handled and when the squirrel is advancing toward another in a threatening manner. Whether the smell is used only as a warning to the intruder is not known.

Tactile contact occurs when the squirrels approach each other. This is accomplished by one squirrel touching the other squirrel's mouth with his mouth. They will approach each other open-mouthed and bend
Figure XI. A ground squirrel giving the warning whistle
their heads sideways so that the mouths will meet. This contact occurs between all of the squirrels regardless of age or sex. Whenever two individuals meet, this contact will occur. The “mouthing” technique is probably used as a means of identification.

Visual stimulation occurs when a squirrel sights a strange object or before he makes any other form of contact. When a squirrel sees another squirrel running from danger he is instantly alerted. Also if he sees a hawk or hawk-like silhouette overhead he is alerted and the danger whistle is given. Tail flicking may also convey a message between two squirrels. When the squirrel sights an enemy, the tail is flicked rapidly. Also, the tail is flicked before a squirrel disappears into the burrow.

**Reaction to Trapping**

When traps were first set out in the spring, just after the emergence from hibernation, the squirrels were trapped very easily. The trapping success was due to a shortage of food. As the season progressed and food became plentiful the adult squirrels completely ignored the live traps. After April 20, it was extremely difficult to live trap adult squirrels.

With tests on 14 species of small mammals, Pitch (1954) found that baits are least attractive at times when natural foods are abundantly available and most attractive when natural foods are scarce. He states:

> that best catches are most likely to be made at the season when preferred food sources are in short supply even though the population may be at its annual low point. The annual maximum population ordinarily corresponds with a time of food surplus when animals tend to be indifferent to baits, and when adults obtain
their maximum weights. In each case bait acceptance tends to conform to the same seasonal pattern from year to year altered somewhat by the population density and the food supply.

Baits that were used for this study were peanut butter and whole oats, ground oats and corn, and rolled oats. The bait which proved to be the most effective was a ground oats and corn mixture. Horn and Fitch (1946) found that wheat seemed to be the most logical bait for use in trapping the California ground squirrel.

The traps used were made of wood with a sensitive pendulous trigger. A commercial wire box trap was also used. Young ground squirrels showed very little fear of box traps (Figure XII). They would go into the trap even when there was no bait used. One young squirrel was caught four different times in a box trap. Some adult squirrels were caught more than once during the first two weeks after they were out of hibernation, but after food became available, no squirrels were retrapped.

Both adults and young were snared with nylon fish line. The fish line proved to be a very effective snare. Once there was tension on the line, the squirrel could not escape. Some were caught by only one leg and escape was impossible. During one day, seven young squirrels were captured and marked in a period of two hours using the snare.

Cannibalism

An experiment was conducted to determine the cannibalistic tendencies of the Richardson squirrel. A young thirteen-lined ground squirrel (wt. 1.3 gms.) was placed into the cage with an adult male and female. At first the Richardson squirrel did not notice the young thirteen-lined squirrel. The young squirrel seemed very frightened and he ran to a cor-
Figure XII. A young ground squirrel about to enter a trap
ner of the cage. The male squirrel seemed to be attracted by the scent of the young squirrel. He ran rapidly toward the young squirrel, grabbed it with his front feet, as a cat would capture a mouse, and bit the young squirrel repeatedly in the head until it was dead. After dragging it to another corner he proceeded to devour the squirrel starting at the anterior end of the body. The female came out of the nest box and tried to grab the dead squirrel from the male, but he pulled it away. It took approximately fifteen minutes for the squirrel to consume the young animal. After eating the squirrel, the male started digging into the dirt at the bottom of the cage. He kept rubbing his nose in the dirt as if trying to clean himself.

An adult mouse (*Pteinodon tomas*) was put into the cage with the squirrels. The mouse seemed very frightened as soon as he sighted the squirrels; the squirrels seemed equally frightened of the mouse. They ran into the nest box and the mouse dug down under the dirt. Evidently the squirrels will not kill or eat this species of animal.

A pregnant female was kept in the same cage with a male. One morning it was noticed that the female had had young sometime during the night. None of the young could be found in the nest box and it was concluded that the male had eaten the young.

Brown and Hoy (1934) observed ground squirrels feeding on the carcasses of dead squirrels but in the present study no evidence that they would eat the dead of their own species was found.
FOOD HABITS

Most of the information concerning the food habits of squirrels was obtained by observing animals in the field. Other information was obtained by examining plants near the burrow systems and by observing animals feeding in captivity. The squirrels were timed as they fed on various plants but as more time was spent in some areas than in others, an accurate evaluation cannot be made by this method.

Brown and Aey (1943) stated that, "The Richardson's ground squirrels are mainly vegetarians feeding on seeds and roots, with wild onion being one of their favorite foods and they are also fond of insects such as crickets, grasshoppers, caterpillars, and cutworms."

Howell (1935) states that, "These squirrels subsist on the native grasses and flowering plants. They also consume seeds of various plants including bindweed and sagebrush, and capture many grasshoppers and caterpillars."

When the squirrels first emerged from hibernation, there was no green vegetation available for food. The squirrels depended upon plant seeds and plant debris for food. They were observed eating alfalfa (Medicago sativa) seeds and the seeds of Russian knapweed. The first vegetation to appear in Area A was the young alfalfa shoots which proved to be the favorite food of the animals. The alfalfa shoots first appeared about April 1, 1961. The animals also ate the roots and leaves of this plant. When eating, the squirrels would grasp the stem of the plant with the front feet and bite off a section of the stem and hold the alfalfa between their feet, guiding the stem and leaves into the mouth.
with the front feet.

Figure XIII shows a young ground squirrel eating alfalfa from the author's hand. This squirrel lived in Area B and had never been exposed to the alfalfa, but as soon as the squirrel scented the alfalfa, it completely disregarded any danger and tried to pull the food out of the author's hand.

A plant which grew in abundance wherever the alfalfa was thin was the Russian knapweed. The squirrels were observed eating this plant along with the alfalfa.

The plant life in Area B was much more extensive, consisting of many of the short, medium, and tall prairie grasses as well as many species of weeds. The first plants to emerge in this area in the spring were the tall grasses consisting mainly of reed canary grass (Phalaris arundinacea), switchgrass (Panicum virgatum), Indian grass (Sorghastrum nutans), big bluestem (Andropogon gerardii), and bluegrass (Andropogon nallii), and reedgrass (Calamagrostis spp.). The grasses preferred by the squirrels in the early spring (April) were the big bluestem (Figure XIV) and reedgrass.

During the early summer months the following plants were available for food in the study area: Western wheatgrass (Agropyron smithii), green needlegrass (Stipa viridula), Canada wildrye (Elymus canadensis), slender wheatgrass (Agropyron trachycaulum), suttle alkali-grass (Juncellaria aridina), little bluestem (Andropogon scoparius), side-oats grass (Bouteloua curtipendula), sand lovegrass (Fragrasic pentinacea), blue grass (Bouteloua gracilis) and buffalo grass (B. dactyloides). The squirrels were observed feeding the majority of the time on little
Figure XIII. Young ground squirrel eating alfalfa
Figure XIV. A ground squirrel eating big bluestem grass
bluestem, western wheatgrass, and blue grass.

Some of the natural broad-leaved plants that the squirrels preferred were the Russian knapweed (Centaurea repens), thistles (Cirsium), and dandelions.

During the late summer and fall, the seeds of certain plants were eaten. These plants included the dandelion, Russian knapweed, and alfalfa.

**Types of Animal Food Eaten**

Twelve stomachs were examined for animal remains. Grasshoppers proved to be the most numerous insect found in the stomachs. Other insects identified were crickets and beetles. Bits of hair from some animal were found but were not identified. All of the stomachs contained unidentified green material. Three of the stomachs contained grasshopper remains and one stomach contained cricket and beetle remains.

Ground squirrels probably eat many other varieties of plant and animal materials which were not observed by the author. No attempt was made to identify every food item eaten by the squirrels, thus only general food habits were noted.

**Foods Eaten by Caged Animals**

A few of the foods eaten by the caged animals were ground corn and oats, bread, cooked and raw potatoes, alfalfa, blue grass, and dandelion heads and stems.

Some of the animal materials eaten by the squirrels consisted of grasshoppers, crickets, beetles, and meat scraps. A large ground beetle (Carabidae) was put into the cage. The male squirrel did not see the
beetle but followed the beetle's path much in the same manner as a hunting dog follows the prey. As soon as he came within a few inches of the beetle he pounced on it and grabbed it with his front feet. He carried the beetle into the nest and devoured it in a matter of seconds.

The caged squirrels drank water freely by lapping the water with their tongue in the manner of a domestic cat. In the wild the squirrels probably get enough moisture from the plants they eat and from dew to satisfy their needs.
REPRODUCTION AND DEVELOPMENT OF YOUNG

The reproductive cycle of the ground squirrel is seasonal, with only one breeding season per year. Wade (1927) working with the thirteen-lined ground squirrel, found that the males were sexually active for only a short time in the spring and that regression of the reproductive system was rapid. Shaw (1925) found the same to be true of the Columbian ground squirrel.

Mating

Mating takes place during the first two weeks after the squirrels have come out of hibernation. At the time of emergence, the testes are enlarged and descended. The females are pursued above the ground as well as in the tunnels. There were no matings observed by the author either among the caged or wild animals, although Dickerman (1959) observed copulations among Richardson squirrels in captivity. He states that,

On March 17, 1959, a male and female squirrel (Citellus richardsoni) were removed from nest boxes and a week after the male and female were removed from the boxes they mated several times. This was accomplished with both animals lying on their sides curled in the flamed position, the male curled around the posterior end of the female much in the position used by forms that copulate in the standing position.

A male was observed chasing a female on March 21, 1961. The female ran for about 200 feet before going into a burrow. The male was about three feet behind her when she went into the burrow. The squirrels did not reappear again for 30 minutes.

Gestation Period

Brown and Ray (1943) found that the period of gestation is about
27 days, and Howell (1938) stated that, "the period of gestation appears to be about 28 to 32 days." However, Jenniston (1937) found that the period of gestation was only 18 days at the most. He placed a healthy active male with a female on April 9, and on April 26, seven newborn pups were observed.

A male was placed with a female on March 23, 1961, but no copulation was witnessed, although the female did have young on April 15. Whether the female was pregnant before the male was placed in the cage is not known. The first implantation sites on the uteri of the females were observed on March 25. The female's emergence from hibernation seems to determine the breeding season, because during 1960 no pregnant females were captured until April 22, and that date of emergence was on April 15.

**Number of Young per Litter**

The average number of embryos found in six pregnant females was eight, with the minimum number found to be seven and the maximum number twelve. A female examined on March 27 had 12 follicles which were 1.0 mm in diameter. A female examined on March 31 had seven follicles which averaged eight mm in diameter.

Howell (1938) found that the average litter of a series was 7.5 young, numbering from six to 11 and Brown and Hoy (1943) found that the litters varied from six to eight in number.

Counts on the number of young per litter were made in the study area whenever possible. The maximum number found in one litter was nine.

**Care Given Young by Parents**

When the young first emerged from the hibernation dens, the mother
stayed close to them and would give a warning whistle when danger was near. Upon hearing the warning whistle, the young would stand up to observe, and, if the fear chirp was given by the mother, the young would scurry to the burrow. On one occasion, after the author had snared a young squirrel, the mother came running up to within a distance of three feet, whistling loudly. The mother allowed the young to bite and crawl over her when they were playing. At no time was a mother squirrel observed punishing or mistreating her young. As the squirrels grew older, the mother strayed farther and farther from the young. When the young were approximately two months old, the mother was seldom near them except during times of danger.

**Early Development of Young**

No observations were made of new-born young because the male had killed the young before steps could be taken to save them. Brown and Roy (1943) found that the young are born covered with hair. Dennis-ton (1957) found that the average young weighed 5.96 grams and that they were 45.96 mm. long (crown-rump length).

A pregnant female was captured and marked on April 8, 1961. When observed again on April 11, the young had been born. The young from this particular female were first observed on May 9 (Figure X). There were nine young in this family. One of the young was caught and weighed and a toe clipped for later identification. The month-old squirrel weighed 90 grams and he was 150 mm. in length (crown-rump length). The hind foot measured 30 mm. and the tail 40 mm. in length.

Eight of the nine young were trapped, weighed, and marked during
Picture XI. Young ground squirrels, one month old, emerging from a burrow.
the first week they were out of the dens. Figure XVI shows the gain in weight of a young male ground squirrel over a period of 30 days. The squirrel was recaptured six different times and the weight recorded. The squirrel gained approximately 4 grams per day during the first 15 days and 2 grams per day the last 15 days. At a rate of 2 grams per day it would take the squirrel approximately fifty more days to reach the average adult size of 300 grams.

Three young ground squirrels were captured on June 13, 1961, and they were fed for 20 days to determine their gain in weight and the amount of alfalfa they would consume. The squirrels were fed only the leaves of alfalfa. The alfalfa was weighed and the weight recorded before it was placed in the cage. Figure XVII shows the total amount of alfalfa consumed each day by the three squirrels and the average gain in weight of each squirrel. The average gain in weight of the caged squirrels compares with the gain of the young in the wild state. Water was the only other food placed in the cage. The animals' weight averaged 107 grams at the start of the test and 193 grams at the end of the test. Each animal consumed about 26 grams per day of alfalfa at the start of the test and approximately 85 grams daily at the end of the test.

When the young first emerged, their radius of activity was very limited. Figure XVIII shows the radius of activity of the young squirrels the first week after they had emerged from hibernation.

On the first day, the young stayed on the mound or within five feet of the mound. They would nibble at the alfalfa but hardly any of them consumed any vegetation. They were first noticed at 8:30 a.m. on May 9, 1961. Most of the activity of the first day was spent in sunning
Figure XVI. Weight gain of young ground squirrels under natural conditions
Figure XVII. The average weight gain of three young ground squirrels and the total amount of alfalfa eaten.
Radius of activity at the end of the first week of emergence

Radius of activity the first day of emergence

Radius of activity the second day of emergence

Underground connections

 Stake

 Main burrow

 Auxiliary burrow

Scale: One inch equals approximately ten feet

Figure XVIII. Radius of activity of young ground squirrels
and exploring near the burrow's edge. Some of them would engage in
wrestling matches or chase each other down into the burrow. They could
emit small bird-like chirps only much weaker in volume than the adults.
They could move rapidly even though they were only a month old. They
were lighter in color than the adults and the guard hairs were quite
noticeable. The pelage was much softer in texture than the pelage of
the adults. The head was large compared to the rest of the animal's
body as is typical of the young of the genus Citellus.

On the second day the young came out of the burrow at 7:30 A.M.
They ran to an auxiliary burrow about ten feet from the main burrow
using both the runways and underground passages. Their radius of ac-
tivity was about ten feet on the second day. Most of the time was
spent going from one auxiliary burrow to another. Occasionally they
would stop to nibble some alfalfa.

By the seventh day, the squirrels' radius of activity was approxi-
mately 50 feet from the main burrow. They would leave the runway in
search of food and most of their time was now spent in searching for
food. By this time the young were almost as active as the mother, al-
though she was the first out of the burrow in the morning and the last
into the burrow in the evening. She would appear about 30 minutes be-
fore the young in the morning and stay out about one hour later in the
evening.

Two weeks later all but two of the young had left the old burrow.
The mother and seven others had moved to another burrow system located
about 200 feet away. The squirrels' home was originally located in
quadrat P9. The system that they moved into was located in quadrat AD
(Figure II). About a month later (June 19) one of the family was caught near a burrow that was located in quadrat 6c which was 800 feet from the original home.

The young reach maturity at the age of four months, although they may not reach their maximum weight until they are close to a year old.
Volting takes place once a year during the late spring and summer months. The first molt takes place when the squirrel is approximately one year old. Howell (1936) gave the following description of a fresh summer pelage:

General tone of the upper parts is pinkish buff or cinnamon buff, shaded with fuscous (caused by exposure of the sub-terminal bases of the hairs); the posterior part of the back showing distinctly "stippled" effects; nose with a large patch of cinnamon; eye ring light buff; sides of head and front of fore legs cinnamon buff or clay color; sides of body and under parts pinkish buff or cinnamon buff; hind feet pinkish buff; tail above, fuscous black, mixed with pinkish buff and broadly edged with the same; tail beneath cinnamon buff or clay color edged with pinkish buff.

The color of the fresh summer pelages found in the current study agrees with the above description given by Howell. Before the molt takes place, the coloration of the pelage on the upper body is a uniform buff or drab with the under parts much deeper buff than the fresh pelage.
All of the animals that were trapped appeared to be in a healthy condition except for one male which had a bare spot above the right shoulder. The spot measured 32 sq. cm. square. All of the hair was gone from the spot and the skin was very brittle. It is possible that the loss of hair was due to an infection caused by mites, although Brown and Roy (1943) believed the large scabs were caused by fighting. Some of the males had small scars on the head and legs which were probably caused from fighting.
**Density and Composition**

The number of ground squirrels found on the five acres of prairie grass during the summer of 1960 averaged six per acre. In June of 1961, the average had increased to eight squirrels per acre. Squirrels found on the 25 acres of alfalfa averaged 1.6 per acre in 1960, but in 1961 the population had increased to 2.9 squirrels per acre. During both years, the ratio of males to females seemed to be about 10:1 when the young were first observed. Six females were living on Area A in 1960, four of which raised young. Females of breeding age (approximately 11 months) in Area B had increased to seven in 1961. The number of breeding females in Area B was seven in 1960 and ten in 1961. The number of males decreased during the second year, while the number of females increased. During both years, the decrease in the number of males was probably due to migration and a high mortality rate. The total number of burrows showed an increase from 1960 to 1961. (Figure II). There were three new burrow systems in Area B in 1961 and 17 new systems in Area A; however, some of the old burrow systems were not occupied in 1961. Counts of the burrow systems were made in June of both years. Brown and Joy (1943) found that prairie land contained the largest number of squirrels per acre. They found eight animals per acre on prairie land and three animals per acre on cultivated land. Phillips (1936) found that ground squirrels were most abundant in mowed hayfields. He found that the number of dens per acre in mowed hayfields was 30.3 per acre while the number of dens in heavily overgrown pastures was 2.4 per acre.
Effects of Predation

Ground squirrel populations seemingly remain stable from year to year in areas where the maximum density has been reached. What role the predator plays in controlling squirrel populations cannot be determined. It would be necessary to make an extensive study of the habits of both the squirrels and the predators in order to determine effects of predation on populations.
Richardson ground squirrels destroy large quantities of forage crops and grain during their lifetime. Both grain and alfalfa fields seem to attract them. Seaton (1926) tells of finding 240 grains of wheat in the cheek-pouches of one squirrel.

Studies made by Fitch, et al. (1946 and 1949) indicate that ground squirrels do considerable damage to forage crops. By measuring the amounts of natural foods eaten by California ground squirrels, they found that in the spring ground squirrels ate about 70 grains of green food a day, or approximately 4.7 pounds per month. On the basis of an average population of 2.3 squirrels per acre, this rate of feeding indicated that squirrels consumed about 11 pounds of forage per acre per month. This amount was estimated to increase about threefold during a short period in early summer after juveniles were added to the populations.

Figure III shows the amount of alfalfa eaten by an adult male squirrel from May 1 to May 20, 1941. Only the leaves of young alfalfa plants were fed to the squirrel. The alfalfa was weighed and recorded before each feeding time. The average amount consumed by the squirrel was 134.5 grams per day or approximately ten pounds per month. An average population of 2.3 squirrels per acre would consume 28 pounds of alfalfa per acre per month.

Fitch (1948) states that, "The forage is affected by so many other variables that it is difficult to identify the effect of ground squirrels." He found that squirrel populations as great as 12 per acre do not harm-
Figure XIX. Amount of alfalfa consumed by an adult male ground squirrel
fully alter the composition of the forage crop, but the total damage done by the squirrels may be in the neighborhood of 1,000 pounds per acre even though the amount actually eaten is relatively small. Lind- 

dale (1946) stated:

In evaluating the effects of squirrels on forage crops it is not enough to determine the certain kinds of plants eaten, nor can the effects be computed correctly by determining the amount of food contained in the stomach at any one time or taken in one day. These are not suitable basis for computations, partly because they change continuously and irregularly.

The mounds of dirt piled up in a field are of considerable annoyance to the farmer, especially in alfalfa fields. Mounds 34 inches high may damage a sooner as well as making the alfalfa extremely difficult to mow.

Brown and Roy (1943) found that ground squirrels are host to several ectoparasites which have been found to transmit sylvatic plague and Rocky Mountain spotted fever. They found that the animal is important to human health in two ways: (1) directly, through the carrying and transmitting of sylvatic plague infection; and (2) indirectly, through acting as a host to the spotted fever ticks, which carry and transmit Rocky Mountain spotted fever and tularemia.
Where squirrel populations are small, the wisest policy seems to be to let the cycles run their course and not attempt means of artificial control. Snows (1943) stated that:

When dealing with rodents subject to violent reductions in numbers from disease and natural causes, such as the ground squirrel, artificial control may even help the continual abundance of the rodent rather than hinder it.

He found that it took thirty man-hours to eliminate the Franklin ground squirrel on one acre of land using a shotgun and rifle.

Where the infestation is great, poisoned bait seems to be the most effective method for control, although Hinsdale (1931) found that in poisoning the California ground squirrel at least sixty species of wildlife other than ground squirrels were known to have been killed.

Lackman (1957) found that efforts to poison squirrels in the burrows with strychnine or gas had proven fruitless in the past so he experimented with a ground spray mixture of three pounds of dieldrin to fifty gallons of water per acre. Shortly after ground squirrel activity began in the spring, a border 100 feet wide was sprayed around a 30 acre area. The field was bordered with permanent blue grass sod. The insecticide was applied to the blue grass area with a horizontal boom sprayer. He found that the treatment was 100 per cent effective; however, the manner in which the dieldrin produced mortality was not determined.

The Predator and Rodent Control Branch of the U.S. Fish and Wildlife Service recommends the use of poisoned bait and poisoned gas to control ground squirrels. Commonly used baits are whole oats, whole barley, oat groats, and rolled oats mixed with a paste of strychnine, corn syrup,
baking soda, glycerine and starch. The baits are scattered in teaspoonful quantities at the entrance to the burrows. The bait should not be exposed where hogs or poultry are likely to pick it up. Calcium cyanide is also recommended as an effective control. A tablespoonful should be inserted in the burrow and the entrance covered with a piece of sod or other material. Another successful method is the use of carbon monoxide gas from the exhaust of an automobile; however, this method is practicable only where a few ground squirrels are found.
A life history and ecological study was made of the Richardson ground squirrel in order to obtain a greater knowledge of the behavior and habits of this rodent. The study was made in the north central part of Hyde County, South Dakota.

Observations of the activities of the squirrels were made in the field and under laboratory conditions. The observations were made from March 15, 1960 to Sept. 15, 1960 and from March 1, 1961, to June 15, 1961.

The squirrel's selection of a burrow site seemed to be controlled by the soil type and elevation of the land. Each summer burrow had an average of eight openings scattered over an area of 10 to 15 feet in diameter. The amount of soil raised during the construction may vary considerably. Burrows are of three types: (1) home burrows of adults; (2) auxiliary burrows at feeding places; and (3) home burrows of young.

Hibernation nests are constructed during June and July and they are composed of grasses, feathers, oat straw, and weeds.

Home ranges of ground squirrels may vary from two to four hundred feet while territories cover an area approximately one hundred feet on all sides of the home burrow.

The domestic cat was found to be the most important predator of the Richardson ground squirrel.

Temperature seems to be the major influence on daily activities of the squirrel, while climate and fat content were the major factors controlling seasonal activities. Squirrels first emerged from hibernation, approximately 75 per cent of their daily activities was
spent in exploration.

Cooperation in the form of warning whistles exists among the squirrels when danger threatens. There was also some evidence of cooperation during nest building and burrow construction.

Forms of dominance were rare among the squirrels except during breeding time.

Vocal communication was the most important form of communication among the squirrels but visual, olfactory, and tactile stimuli were also used for aid in identification.

Trapping the squirrels became increasingly difficult as food became available. Trapping success was highest during March and April.

The Richardson squirrels are cannibalistic and will attack and devour smaller species of ground squirrels.

Alfalfa proved to be the favorite food of both the wild and the caged animals. A captive male ground squirrel consumed an average of 154.5 grams of alfalfa per day.

Eating takes place within two weeks after hibernation ceases. The squirrels have only one molt a year which occurs in late spring and summer.

The number of squirrels on Areas A and B increased from 1960 to 1961 with Area A showing the greatest increase.

The Richardson ground squirrel is a potential threat to all cultivated crops. They are also hosts of ectoparasites causing disease in man.

The population of the Richardson ground squirrel seems to be increasing in central South Dakota from year to year, and proper controls should be maintained to prevent further spread of this rodent.


