The TREE SQUIRRELS of Kansas

Robert L. Packard

State Biological Survey and the
Museum of Natural History
University of Kansas

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By ROBERT L. PACKARD

Museum of Natural History and State Biological Survey
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UNIVERSITY OF KANSAS

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Introduction

Tree squirrels have been important small game in eastern Kansas since pioneer days, probably ranking second only to the cottontail rabbit. Two species, the fox squirrel (*Sciurus niger rufiventer* Geoffroy), and the gray squirrel (*Sciurus carolinensis carolinensis* Gmelin), occur in Kansas. Both live in most forested parts of the eastern United States (see Figs. 1 and 2).

Although much detailed information has been published concerning the life history and management of these two squirrels, environments differ so much from one area to the next that results of studies in Missouri, Indiana, Iowa, Illinois, Michigan, and Ohio can not safely be applied in Kansas. As Brown and Yeager (1945: 449) pointed out, hunting seasons, for squirrels, which would be biologically sound for Ohio or Michigan would not necessarily be correct for Illinois. Corresponding studies had not been made in Kansas, and because many Kansas sportsmen hunt squirrels, the State Biological Survey sponsored my study to obtain information useful in managing tree squirrels. Relationships of an animal to its habitat often are more clearly shown near the boundary of the animal's range than near the center (see Odum, 1954:31-32). Because the western boundary of the range of each species crosses Kansas, investigation in Kansas might be expected to demonstrate more clearly than has been done before some of the environmental factors determining the presence and absence of these animals.

The objectives of my study were to determine: (1) former and present geographic distribution; (2) effect of environment on squirrel production, and the essential elements of the microclimates affecting activities of the two species; (3) interrelations between these two species where they co-exist in the same area; (4) importance of tree squirrels as a wildlife resource to Kansans; and, to suggest (5) practical management plans to provide maximum hunting of these species without endangering their populations.

Acknowledgments

I am especially grateful to Dr. Rollin H. Baker who generously aided me and guided my study. Dr. Henry S. Fitch advised on methods of field study, and Dr. E. Raymond Hall gave critical assistance with my manuscript.

More than 300 Kansas sportsmen responded enthusiastically to my queries concerning squirrel hunting. Thanks are extended also to the many sportsman's organizations in Kansas, especially the Kansas Association for Wildlife, Inc., and its president, Mr. Bob Bailey, and the editor of its magazine (*The*

Kansas Sportsman), Mr. Howard Kittell. The Kansas Forestry, Fish and Game Commission granted me permits necessary for certain phases of the study. Mr. Jim Coats and Mr. Marvin D. Schwilling, Game Biologists, were helpful in many ways. Mr. E. S. Dillon kindly granted me permission to study squirrels on his farm in Douglas County.

At the University of Kansas, Mr. Earl Cross identified fleas; Mr. Earl Fowler, bacteriologist, examined tissues of dead squirrels for any infection, and Dr. R. C. McGregor identified certain plant remains found in squirrel stomachs. Also, I thank other members of the faculty and graduate students of the Department of Zoology for help. I am especially indebted to my wife, Patricia J. Packard, for typing the manuscript and encouraging me, and to the State Biological Survey of Kansas for funds and certain equipment.

HISTORY AND GEOGRAPHIC DISTRIBUTION

The first published account of tree squirrels in Kansas, known to me, was by Ruxton (1849:308) who reported, ". . . squirrels [in 1846] jumping from branch to branch . . ." in what is now Morris County. In 1875, Knox (1895:22) frequently found the fox squirrel in all stands of timber, but the gray squirrel less often. D. E. Lantz (1905:173) stated that fox squirrels with melanistic variations were common in the wooded parts of the State and that the gray squirrel was found only in eastern and southeastern Kansas.

Both species were reported in Riley County by Dice (1923:111) and along the Missouri River in northeastern Kansas by Linsdale (1928:143). Hibbard (1933:239) and Black (1937:179) indicate that the gray squirrel was found east of the Flint Hills in dense and heavily-timbered areas and probably ranged as far west as Osborne County. Hibbard (*loc. cit.*) thought the fox squirrel was mainly in eastern Kansas, and Black (*loc. cit.*) indicated that the fox squirrel was east of a line joining Phillips, Harvey, Elk, and Montgomery counties, according to museum records. The distribution of both species of squirrels was recently discussed by Cockrum (1952:112-115).

Since 1952, the fox squirrel has been taken in several localities (see map Figure 2) indicating that this species probably now occurs along all streams even in western Kansas except along the Cimarron River in the extreme southwestern part of the State.

The fox squirrel has increased its range in other states as well as in Kansas, according to Bakken (1952:Ap. B.). Terrill (1941: 24) noted a decrease of gray squirrels and an increase of fox squirrels in Missouri, owing possibly to environmental changes such as cutting timber and disturbances in general of the climactic

climax by the settlers. D. L. Allen (1943:33-35) reported the spread of the fox squirrel and the decrease of the gray squirrel in Michigan since the advent of the pioneers. The same thing has

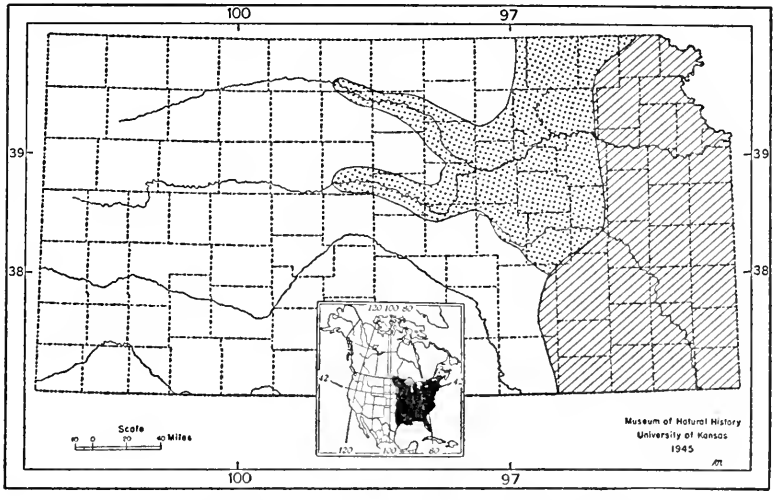

FIG. 1. Former distribution of the gray squirrel is indicated by stippled and lined areas. Present distribution is indicated by lined area.

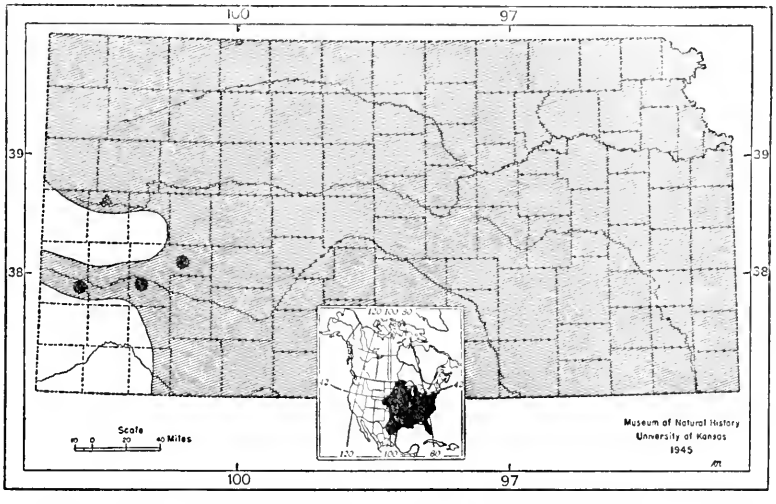

FIG. 2. Distribution of the fox squirrel in Kansas. Three localities from which marginal records were obtained by me are indicated by solid circles. The solid triangle indicates a specimen taken but not examined. For list of records of fox squirrel in other parts of the State, see Cockrum (1952:114).

been noted in Indiana by J. M. Allen (1952:9-10), and in Ohio, by Baumgartner (1940a:28,32). Hoover and Yeager (1953:359-361) indicate that the fox squirrel in Colorado has recently invaded new areas.

Residents west of the 99th Meridian, along the Arkansas River Valley, indicate that the fox squirrel, although never abundant, may have ranged as far west as Dodge City, in Ford County, as much as 50 years ago. One elderly resident of Lakin, in Kearny County, believed that fox squirrels were relatively recent invaders, within the last two decades, along the Arkansas River bottoms in that area. Several other residents of this general area also were of the same opinion. Before pioneers arrived in western Kansas, the fox squirrel probably occupied limited areas west of the 100th Meridian along such rivers as the Arkansas, Smoky Hill, Solomon, and South Fork of the Republican. The habitat, at least along the Arkansas River in western Kansas, seems to have remained essentially the same since Pike visited this area in 1806, for he mentioned (see Cutler, 1883:49-61) thin groups of cottonwoods along the Arkansas River. Adjacent to these river bottoms, wheat, corn, barley, and oats are now grown and are eaten by the fox squirrel and permitted the squirrel to invade new areas to the west. Scarcity of trees and suitable food along the Cimarron River probably accounts for the absence of tree squirrels there. Game Protector Warren Moore never observed fox squirrels when his district included the Cimarron River in Morton County.

The gray squirrel, according to incomplete previous records, probably was rare west of the 98th Meridian and east of it only locally abundant, being confined to more densely wooded river bottoms in a dendritic pattern. Today, the gray squirrel is not definitely known to occur west of the 97th Meridian (see Fig. 1) and probably is no longer found so far west as Osborne County, although one hunter reported shooting a gray squirrel in Jewell County. Although today more timber occurs within the range of the gray squirrel, most of the trees are of a species unsuitable for it. The mature oak-hickory association, which is the principal habitat of the gray squirrel, has been reduced chiefly by clearing lands for farming and by selective cutting.

Whereas the fox squirrel has extended its range to the western limits of the State, the western limit of range of the gray squirrel has retreated eastward as shown in Figure 1.

METHODS

Two areas were studied intensively. One area was the University of Kansas Natural History Reservation (see Plate 1, Fig. *b*), five miles north and one and one-half miles east of Lawrence, Kansas, providing natural environment free from the usual effects of agriculture and hunting (see Fitch, 1952:3). The second area was on the E. S. Dillon Farm (see Plate 1, Fig. *a*), six and one-half miles south of Lawrence, Douglas County, Kansas. Comparison of squirrel populations of the protected area (the Reservation) with those where the land was farmed and squirrels were hunted (the Dillon Farm) yielded useful results. Gray squirrels and fox squirrels occurred on both areas.

The most efficient live-trap, of four types used, was that made by the National Live Trap Company of Tomahawk, Wisconsin. This trap is 6 in. x 6 in. x 19 in., collapsible, constructed of heavy gauge open wire mesh, and has a rapidly acting trigger mechanism but is open and exposes the trapped animal to the weather.

Trapped squirrels were transferred to a cone of one-half inch mesh No. 24 gauge wire with a board base and were held immobile by a wooden plunger. Most squirrels entered the cone, but some had to be encouraged. Fingerling tags (Style No. 1003, Size No. 3, National Band and Tag Company, Newport, Kentucky) were attached to the ears of squirrels. Because some tags are torn out of the ears, each squrrel was toe-clipped in the fashion described by Fitch (1952:32).

Vari-colored plastic bands attached to wire collars were placed on twelve squirrels to determine if their movements could be observed in the field. This kind of marking was of some value for observing animals at close range. After the squirrel was properly tagged, aged, and checked for breeding condition, it was transferred to a cotton sack and weighed, using a 2000 gram Stansi spring scale, and released at the place of capture.

Data concerning daily activity were gathered by the method described by Hicks (1942:299-305), using a one-half hour linear count period. While the activity of squirrels was observed, climatological data also were secured. Climatological data were collected also when trap lines were checked. Temperatures and wind velocities were taken at a height of five feet from the ground three times while the linear count was being conducted. Light readings were taken at a height of six inches above the ground. At the termination of the one-half hour count, average light, temperature, and wind velocity readings were obtained for that period.

At the suggestion of Jim Coats, Game Biologist of the Kansas Forestry, Fish and Game Commission, Game Protectors were sent a questionnaire, asking them for the names of active squirrel hunters in their areas. At the same time, a second letter went to sportsmen clubs in Kansas requesting names of squirrel hunters. Names were obtained of nearly 100 squirrel hunters. In 1953, a questionnaire went to each of these persons with an enclosed sheet asking for a list of other squirrel hunters. The hunters from the original list provided an additional 100 names of sportsmen to whom a copy of the first questionnaire was then sent. The writer added names to this list by interviewing people in the course of field work. In the summer of 1954, a second

questionnaire was sent to 90 selected hunters concerning the ratio of young squirrels to old squirrels in their kills. Those who (1) reported bagging large numbers of squirrels in the 1953 season and (2) expressed considerable interest in the study were sent these summer forms. Data from these questionnaires were checked against the information obtained in the areas intensively studied. At the termination of the 1954 season, a third questionnaire was sent to all squirrel hunters on the list.

In order to ascertain present and former distribution of squirrels, the following counties in the State were visited: Anderson, Atchison, Barber, Barton, Brown, Cherokee, Coffey, Crawford, Doniphan, Finney, Hamilton, Jackson, Jefferson, Kearny, Labette, Leavenworth, Lincoln, Marshall, Miami, Nemaha, Neosho, Pottawatomie, and Stafford counties.

Squirrels collected throughout the year provided specimens for autopsy, especially to determine the condition of the reproductive tracts in relation to the breeding seasons. Many of the animals used for these examinations were kills along highways in Douglas County.

HABITAT

Kansas, east of the 97th Meridian, is a broad ecotone between the true prairie association lying to the west, and the oak-hickory association of the eastern decidious forest climax formation to the east. Brumwell (1951:190-192) divided the eastern one-third of the State into four biotic districts: Osage Savannah, Kaw Valley, Cherokee Prairie, and Ozark districts. The best representative of the oak-hickory association is in the Kaw Valley and Ozark biotic districts (a part of the Illinoian Biotic Province of Dice, 1943:21). All areas of intensive study were within the Kaw Valley biotic district. It is composed of the cottonwood-willow communities bordering the Kansas (Kaw) River and the larger streams draining into the Kansas River. The flood basins, at one time consisting of a broader belt of timber (see Cutler, 1889:61), including the various oaks and hickories and perhaps pecan (Hunt and Lorence, 1937:23), are now greatly reduced and are devoted to intensive farming. The remaining part of the oak-hickory community now is mostly on the slopes and hillsides of this biotic district. Fitch (1952:4) thinks that these communities have developed, in part, as a result of the cessation of the uncontrolled prairie fires that were formerly important in the destruction of the hardwood seedlings and the maintenance of the prairie grasses and forbs. It seems that soil-water relationships and the competition between flora were important in maintaining river-bottom woodlands and the hillside prairies.

Kansas, west of the 98th Meridian where cottonwood, willow, and tamarisk grow, has habitat favorable to the fox squirrel along river bottoms and in shelter belts recently planted. The most extensive shelter belts in Barton, Stafford, Reno, Harvey, and adjacent counties provide food as well as cover for sizeable populations of fox squirrels and are composed mostly of red cedar (*Juniperus virginiana*), honey locust (*Gleditsia triacanthos*), catalpa (*Catalpa speciosa*), ash (*Fraxinus americanus*), cottonwood (*Populus deltoides*), and Osage orange (*Maclura pomifera*).

Study areas at the Natural History Reservation

The flora of the University of Kansas Natural History Reservation (hereafter called the Reservation) has been described in detail by Fitch (1952:10-22), Fitch and Sandidge (1953:311-312), and Leonard and Goble (1952:1016-1026), and only the specific localities which were intensively studied will be described here. Four parts of the woodland on the Reservation (see Plate 1, Fig. *b*) were selected in which to observe sizes of populations, movements, and activities of tree squirrels.

FENCE WOODS-HOLE WOODS AREA—Fence Woods and parts of Hole Woods, Willow Woods, Upper Woods, and Pond Woods (see Fitch, *op. cit.*:10), make up a northwest-facing slope of 27.1 acres, bordered on the northwest by a small intermittent creek and on the south by a small belt of grassland. To the east lies a small farm pond, and the western border is a mixture of timber and grasslands. Generally speaking, the oldest trees are adjacent to the creek bed, and younger timber is on the hillside. The present aspect of the woodland has been determined largely by the time and extent of former tree cutting.

The upper story along the creek bed is primarily black walnut (*Juglans nigra*), American elm (*Ulmus americana*), and honey locust. Also present in the upper-story are hackberry (*Celtis occidentalis*), red elm (*Ulmus fulva*), a few black oak (*Quercus velutina*), and red oak (*Quercus rubra*). The second story is a mixture of vines such as greenbrier (*Smilax hispida*), Virginia creeper (*Parthenocissus quinquefolia*), wild grape (*Vitis vulpina*). Shrubs present include coralberry (*Symphoricarpos orbiculatus*), gooseberry (*Ribes missouriense*), elderberry (*Sambucus canadensis*), false Solomon's seal (*Polygonatum canaliculatum*), and species of wild cherry (*Prunus*). The herbaceous layer is varied; more prominent species are Kentucky blue grass (*Poa pratensis*), rice cut grass (*Leersia oryzoides*), Muhly grass (*Muhlenbergia* sp.), bellflower (*Campanula americana*), stinging nettle (*Urtica gracilis*), and mosses, lichens, and shelf-fungi. A dense canopy over the creek bed excludes most light from the ground during late spring, summer, and early autumn.

Black oak, red oak, and hickories which occur more abundantly, from an elevation of approximately 940 to 980 feet, on the lower part of the hill are second growth trees. Here the upper-layer is composed mostly of American elm, black oak, and red oak; also there are shagbark hickory (*Carya ovata*) and Kentucky coffee tree (*Gymnocladus dioica*). Dogwood (*Cornus Drummondi*), gooseberry and coralberry, with the previously-mentioned vines, form the mid-layer dominants. The lower layer is primarily mosses, lichens, popballs, carrion flower (*Smilax herbacea*), and some fox-tail grass (*Setaria* sp.). On the lower part of the hillside, the ground is shaded, and mulch is irregularly distributed instead of uniformly distributed.

The terrace, formerly a logging road, is dominanted by yellow oak (*Quercus Muhlenbergii*), white ash (*Fraxinus americanus*), and the various hickories with shagbark predominating. The second story consists of the vines, Osage orange, and some red haw (*Cratagus* sp.). The lower level consists mostly of poison ivy (*Rhus radicans*) and snake root (*Eupatorium rugosum*). A

considerable amount of light reaches the forest floor at all seasons of the year in this part of the woods.

From the terace (990 feet) to the ecotone between grassland and timber (1050 feet), the hill is steeper and supports yellow oaks, elms, hackberries, locusts, and walnuts as an upper-story, while the mid-layer is dogwood and gooseberry, and to a lesser extent, vines. The under-story is composed of bittersweet (*Celastrus scandens*), mosses, lichens, and grasses that are invaders from the hilltop. Outcrops of Oread limestone and steepness of slope make under-story vegetation sparse.

Close to the small pond at the northeast end of the area, peach-leaved willow (*Salix amygdaloides*), black willow (*S. nigra*), sand-bar willow (*S. eriocephala*), and cottonwood grow in close association and gradually intergrade with the oaks at the base of the north-facing slope.

SKINK WOODS-BULGE WOODS AREA—This area, comprising 15.8 acres, was selected because exposures facing both north and west were present. The eastern border is an old road used by wood choppers; grasslands lie to the north and south; a fence line is on the west. The area is bisected by an intermittent stream that drains to the north. The area includes all of Skink Woods and parts of Hole Woods and Bulge Woods (see Fitch, 1952:10). The north-facing slope resembles the previously-discussed Fence Woods-Hole Woods locality. Fitch (1954:40) has adequately described the upper slope of the Skink Woods Area.

FUNNEL WOODS AREA—The slope of 21.9 acres faces southeast and descends rapidly from an elevation of 1060 to 940 feet. Three communities are discernible; they are the elm-hackberry-coffee tree from 1060 feet to 1020 feet; Osage orange-honey locust from 1010 feet to 960 feet; a continuation of Osage orange with addition of elm and walnut primarily at an elevation at 940 feet. These communities intermingle. An ecotone between grass and forbs occurs at 940 feet.

Dominants of the upper-layer of the most elevated community are hackberry, American elm, coffee tree, Osage orange, and honey locust, while the mid-layer is formed primarily of dogwood, greenbrier, and seedlings of the afore-mentioned trees. The under-story is primarily coral berry throughout this slope, but grasses, including Kentucky bluegrass and some brome (*Bromus inermis*), are present at some places. At an elevation of 1020 feet, an outcrop of the Oread limestone bisects the area horizontally, east to west.

Upper-story dominants of the second community are almost entirely Osage orange and honey locust, the latter being more common lower on the slope. There is little mid-layering effect, greenbrier being the only true member of this group. The under-story, however, is well developed; coralberry and seedlings of Osage orange, honey locust, and elm make dense thickets. The last community, scarcely distinguishable from the Osage orange-honey locust community, has, in addition, walnut trees. The entire canopy over the south slope is much less dense than that of the north-facing slope. Mulch is not heavy, and patches of ground are bare.

WALNUT WOODS—The third area on the Reservation (18.9 acres) has a small intermittent stream, Wall Creek, coursing between hills to the north and south. This area has been designated Wall Woods and Hickory Woods by Fitch (1952:10). The aspect is somewhat like that of the Fence Woods-Hole

Woods Area. However, here black walnut, blackjack oak (*Quercus marilandica*), and some Osage orange are more common along the stream-bed area. Small fingerlike projections of grass enter the forest on the northern part of the creek where, until 1948, there was over-grazing by cattle and horses. Here the black walnut trees are the largest of any found on the Reservation; the same is true of the elms. There is a dense canopy of leaves throughout late spring, summer, and early autumn. Little mid-layering effect can be found; some dogwood and red haw do occur, however. Mulch is thick, and the forest floor is covered with lichens, mosses, fungi, and some Muhly grass and sedges (*Carex* sp.).

The Dillon Study Area

This area (see Plate 1, Fig. *a*), unlike those on the Reservation, is grazed extensively by cattle throughout the year. The woodland comprises a total of 123 acres on this 205 acre farm, and the woodlots were separated into two units for purposes of the study. Six small separated areas comprising 82 acres are devoted by the landowner to cultivation primarily of corn and wheat.

Throughout the entire area, the canopy in the woodlots is less dense than on the Reservation, and owing to moderate to heavy grazing in the woodland, the "layering effect" is less evident than on the Reservation.

NORTH WOODS AREA—This area of 28 acres has both north- and south-facing slopes, and is composed of two communities. The lower part of the north and east area is an elm-yellow oak community, and the upper slope to the top of the hill is an Osage orange-honey locust community. The elm-yellow oak community is almost identical with that of the upper hill in Fence Woods-Hole Woods of the Reservation, with the exception that here there are some shagbark hickory trees. The canopy, however, is not so dense here as on the Reservation. Mid-layering is more noticeable with abundant growth of Virginia creeper, greenbrier, and fox grape. The under-story has been greatly reduced, owing to moderate to heavy grazing. Species of poverty grasses (*Aristida* sp.) are present. The Osage orange-honey locust community almost entirely dominates the upper story vegetation of the hilltop, with Osage orange being common along dirt roads (see Plate 1, Fig. *a*) used by the landowner in transporting farm equipment to and from the several cultivated areas. Much rock outcropping occurs at the top of this hill, and the locality is severely over-grazed and eroded with little mid- or under-story vegetation present.

SOUTH WOODS AREA—The second locality, which includes a south- and north-facing slope, covers an area from the road (Pl. 1, Fig. *a*) to the top of the southwest hill (29.5 acres), bordered to the south by an old stone fence. The south-facing slope is grown to Osage orange, honey locust, and some elm, with scarcely any other vegetation. A small farm pond is in the center of this area, and a few old American elms are present. The area around the pond is extensively trampled and grazed and much of the soil is bare, but there is some Kentucky blue grass under the elm trees. Typical over-grazed pasture invaders are present, especially buffalo bur (*Solanum rostratum*), bull thistle (*Cirsium lanceolatum*), and knotweed (*Polygonum* sp.).

The north-facing slope supports a yellow oak-elm community, and the slope itself rises rapidly from the pond to the stone fence on the hilltop. This locality is not so heavily grazed because of the steepness of the slope, and mulch is present. The upper-story is dominated by American elm, yellow oak, and

some shagbark hickory. The mid-layer is predominately seedlings of these trees with some vines. Coralberry is the chief plant in the under-story vegetation.

Lakeview Study Area

This area was studied periodically in the summer, autumn, and winter of 1954, to observe squirrel activity only because vegetation became so dense at the Reservation that squirrels were difficult to see.

The Lakeview locality (20 acres) lies one-half mile south of the Kansas River and two miles west of Lakeview. At this point, bluffs are intermittently bisected by gullies at right angles to the Union Pacific Railroad. Stands of burr oak (*Quercus macrocarpa*) dominate the tops of the hills and intermingle on the slopes with those species of plants occurring in the gullies. Mature elms, black walnut, cottonwood, and some hackberries are in the gullies. The mid-layer is formed primarily by vines (wild grape, greenbrier, and Virginia creeper), but also to some extent of hophornbean (*Ostrya virginiana*) and various species of *Prunus*.

The canopy over this area is dense, and the bottoms of the gullies are in deep shade. The hillsides are so steep that an observer on one of these slopes can look into tops of trees and observe squirrels and still have a reasonably good view of the forest floor directly below.

LIVE-TRAPPING AND MOVEMENTS

Live-trapping was begun in November, 1953, at the Dillon Farm and Reservation and continued regularly until the end of February, 1955, for a total of 6229 "trap days." The Reservation was live-trapped half again as much as the Dillon Farm; heavy rains and a deep snow sometimes made the Dillon Farm inaccessible, and it was advisable to suspend live-trapping operations also at some times when dairy cattle were grazing the study areas. Live-trapping was least successful in June and July. The Reservation maintained a higher population than did the Dillon Farm throughout this study.

Complete counts of squirrels were obtained for only two areas, the Fence Woods-Hole Woods Area at the Reservation and the North Woods Area on the Dillon Farm. Table 1 summarizes live-trapping data from the several study areas, and Table 2 presents seasonal population figures for Fence Woods-Hole Woods Area and North Woods Area.

In the winter of 1954-55, a high percentage of the squirrels on the Fence Woods-Hole Woods Area at the Reservation and the North Woods Area of the Dillon Farm was captured, tagged, and released. Linear counts on these areas indicated that most of the squirrels seen were marked. After January, 1955, no new animals were trapped. Of the 27 different fox squirrels handled at Fence Woods-Hole Woods Area in the winter of 1954-55, 12 were trapped but once and may not have been resident on that area; normal mor-

TABLE 1. SUMMARY OF TRAPPING AND RETRAPPING OF SQUIRRELS ON THE TWO STUDY AREAS.

	Number of trap-days	Number of trap-days per one squirrel	Number of Fox Squirrels trapped (first time)	Number of Fox Squirrels retrapped	Number of Gray Squirrels trapped (first time)	Number of Gray Squirrels retrapped	Number of trap-days per one Fox Squirrel	Number of trap-days per one Gray Squirrel
Reservation								
January....	268	9.57	4	19	0	5	11.65	53.60
February...	554	55.40	4	5	0	1	61.55	554
March.....	159	11.35	5	7	1	1	13.25	79.50
April.....	557	32.76	5	3	7	2	69.62	61.89
May.....	190	21.11	4	2	2	1	31.66	63.33
June.....	183	45.75	1	2	1	0	61.00	183
July.....	.....	.....	.....	.....	.....	.....	.....	.....
August.....	124	62.00	1	0	1	0	124	124
September..	465	33.21	2	4	6	2	77.50	58.12
October....	297	11.88	8	3	7	7	27.00	21.21
November..	94	94	1	0	0	0	94	.00
December..	828	16.23	20	20	1	10	20.70	75.27
Total...	3,709	21.19	55	65	26	29	30.90	67.43
Dillon Farm								
January....	265	44.16	3	2	0	1	53.00	265.0
February...	220	36.66	2	3	0	1	44.00	220.0
March.....	160	32.00	1	4	0	0	32.00	.....
April.....	340	42.50	4	2	2	0	56.66	170.0
May.....	120	24.00	2	3	0	0	24.00	.....
June.....	140	70.00	0	2	0	0	70.00	.....
July.....	100	100	1	0	0	0	100	.....
August.....	160	53.33	1	2	0	0	53.33	.....
September..	200	20.00	5	4	0	1	22.22	200
October....	200	20.00	4	5	0	1	22.22	200
November..	250	41.66	3	3	0	0	41.66	.....
December..	365	24.33	6	8	0	1	26.07	365
Total...	2,520	32.72	32	38	2	5	36.00	360

TABLE 2. SEASONAL CHART OF SQUIRRELS TRAPPED AND RETRAPPED.

		Number Squirrels Trapped (1st time)	Number Retrapped	Known Mortality	Number not Retrapped	Number Different Individuals Present
Fence Woods-Hole Woods Area, 27.1 acres, Reservation						
Spring	Fox Squirrel	9	3	0	7	10
	Gray Squirrel	6	1	0	3	7
Summer	Fox Squirrel	1	0	0	0	1
	Gray Squirrel	1	0	0	0	1
Autumn	Fox Squirrel	8	4	2	4	11
	Gray Squirrel	13	8	5	1	15
Winter	Fox Squirrel	20	42	4	12	27
	Gray Squirrel	1	19	1	0	10
North Woods Area, 28 acres, Dillon Farm						
Spring	Fox Squirrel	4	2	1	1	5
	Gray Squirrel	2	0	0	0	2
Summer	Fox Squirrel	2	1	0	0	3
	Gray Squirrel	0	0	0	0	*2
Autumn	Fox Squirrel	7	4	1	3	9
	Gray Squirrel	0	2	0	0	2
Winter	Fox Squirrel	9	10	3	5	14
	Gray Squirrel	0	3	0	0	2

* Sight records.

tality may have eliminated them or they may have been transients the home ranges of which reached only to the edge of the study areas. J. M. Allen (1952:15) suggests that continuous "repeats" or retraps of marked individuals may indicate the resident population of an area. Of the nine gray squirrels marked, all were thought to be residents since they were retrapped more than once. Therefore, this area in winter carried a maximum squirrel density at any one time of 32 animals of both species and a minimum density of 20 squirrels. This maximum density yields a figure of 1.18 squirrels per acre and probably represents close to the maximum winter carrying capacity of the best Kansas squirrel habitat under favorable conditions. Brown and Yeager (1945:455) consider that a population of 1.66 squirrels per acre live in good habitat in Illinois. In comparison to the Reservation, the Dillon Farm, in the North Woods Area, maintained a known resident population of six fox squirrels and two gray squirrels. An additional five fox squirrels may have been resident, and the assumed maximum density in winter, therefore, is 13 animals, or .46 squirrels per acre. This number approximates that reported by Brown and Yeager (*op. cit.*: 456) where an average of .52 squirrels per acre was found in black oak sand plains in Illinois. They considered this to be, "fox squirrel habitat of good quality." It should be pointed out that only two gray squirrels were present in the North Woods Area on the Dillon Farm (both tagged) in the course of my study. They were tagged in the spring of 1954, and both were observed frequently into the winter of 1955.

Both live-trapping and sight records indicated that gray squirrels were to be found in the study areas where there were preferred species of mature nut-bearing trees (see Plate 2, Figs. *a* and *b*). Gray squirrels were not present at the Dillon Farm where the timber was not dense and few mature trees of any type occurred. However, the fox squirrel occurred in this habitat. Terrill (1941:25) pointed out that in Missouri, gray squirrels displaced fox squirrels where land was not pastured and where woodlots were allowed to grow dense. Size of timber seems to be of equal importance, according to Shipley (1941:12-14). Although the under-story vegetation is less dense in older stands of timber, the dense canopy reduces light there in comparison with the condition found in younger stands of timber.

Species Ratios

Data in Table 1 show that there are approximately two fox squirrels to one gray squirrel on the Reservation and sixteen fox squirrels to one gray squirrel on the Dillon Farm. Within the small areas of intensive study, however, this ratio varied depending on the time of year (see Table 3). Probably, the most accurate ratio was obtained for the winter because larger numbers of squirrels were tagged in that season. For the Lakeview area, a ratio of six fox squirrel to one gray squirrel (at least throughout the summer) was obtained.

TABLE 3. RATIO OF FOX SQUIRRELS TO GRAY SQUIRRELS ON THE STUDY AREAS.

SEASON	Reservation Fence Woods-Hole Woods		Dillon Farm North Woods	
	Average number of squirrels	Maximum number of squirrels	Average number of squirrels	Maximum number of squirrels
	Fox to Gray	Fox to Gray	Fox to Gray	Fox to Gray
Winter.....	1 : 1	3 : 1	3 : 1	8.5 : 1
Spring.....	1.5 : 1	2 : 1	2 : 1	3 : 1
Summer.....	2 : 1	2 : 1	3 : 1	3.5 : 1
Autumn.....	1 : 1	1 : 1	2.5 : 1	4 : 1

Data obtained from reports of hunters, in 1953, showed that for the entire state, 1,807 fox squirrels and 146 gray squirrels were bagged; the ratio was 20.8 (94.5 per cent) fox squirrels to 1 (5.5 per cent) gray squirrel. In 1954, a total of 1710 fox squirrels and 141 gray squirrels were bagged; the ratio was 20.1 (92 per cent) fox squirrels to 1 (8 per cent) gray squirrel.

In 1953, in those counties where both species occur, hunters bagged 11.4 (89.6 per cent) fox squirrels to 1 (10.4 per cent) gray squirrel. Squirrels bagged in 1954, where both species occur, were 11.8 (90.4 per cent) fox squirrels to 1 (9.6 per cent) gray squirrel.

Sex Ratios

Hunters took a preponderance of males of both fox squirrels and gray squirrels (see Table 4). In 1953, hunters bagged 6.63 male and only 4.08 female fox squirrels per season, and shot an average of 1.57 males to 1.01 females per trip. In a one-mile walk, hunters bagged .71 male fox squirrel to .45 females. Sex ratios of gray squirrels were similar in 1953 in the hunter's bag. Hunters bagged .54 males to .29 females; shot .13 males to .07 females per trip; bagged .06 males and .03 females per mile. In 1954, 7.78 male fox squirrels and only 5.57 females were taken by the average hunter in the season. Hunters shot 1.97 male and 1.41 female fox squirrels per trip, and averaged 1.23 males and .88 females per mile. The average hunter took .70 male to .40 female gray squirrels. A total of .17 male to .10 female grays were shot per trip, and males were bagged at the rate of .11 per mile, while females were taken at the rate of .06 per mile.

TABLE 4. SQUIRRELS SHOT AND REPORTED BY KANSAS HUNTERS.

YEAR	Male Fox Squirrels	Female Fox Squirrels	Sex Ratio Males to Females	Male Gray Squirrels	Female Gray Squirrels	Sex Ratio Males to Females
1953....	1,101	706	1.1 to 1	95	51	1.9 to 1
1954....	996	714	1.4 to 1	90	51	1.8 to 1

Data from live-trapping indicate that males of both species move greater distances than females (see Table 7), thus making males more vulnerable to the hunter. Brown and Yeager (1945:458) found that, in Illinois, more males than females are bagged and remarked that hunters, ". . . invariably shoot at squirrels in the order of their appearance until the limit is reached or the hunt is over." Actually, there may be more males than females in the population. D. L. Allen (1943:135) found that the sex-ratios of litters which he examined varied from year to year and pointed out that when squirrel populations were increasing there were more young females than young males. Litters of both species of squirrels examined in the last two years in Kansas (see Table 16) had

more males than females. Sanderson (1954:45), working in Iowa, found that populations of squirrels declined in the period 1950-1953. Therefore, if Sanderson (*loc. cit.*) is correct, and if this trend is the same for Kansas, more males than females might be expected in the populations. In Kansas, however, there was no evidence that squirrels were decreasing until after the close of the hunting season in 1954. Of hunters asked about squirrel populations in 1953, 11 per cent replied that the population was greater than in previous years; 34 per cent stated the numbers present were the same as in previous years, and 55 per cent reported that the population had decreased. In 1954, 29.5 per cent of the hunters stated that squirrels had increased; 32.9 per cent reported them remaining the same, and 37.6 per cent stated that they had decreased.

The sex ratio in 166 fox squirrels, live-trapped or collected by the writer in 1954, in Douglas County, is presented in Figure 3. This figure shows that more males than females were taken in most months. In January, male fox squirrels are more active than females; males pursue those females that are in oestrous. In February and early March, females are with their litters and not so active as males. From late March through early May, some mating and bearing of litters continues, limiting the activity of females. Rutting increases again in late May through early June, and young are born beginning in early July. From August through November, squirrels gather mast and seem to be more active than in any other period. In October and November, nearly as many males as females were taken. By December, the rut is resumed, and males again are more active than females.

Of the 108 fox squirrels taken by me in the legal open season, there were 8.5 males to every 10 females. Although this is a small sample, it may show that actually more females are present than supposed; yet the hunters bag more males.

Too few gray squirrels were examined to determine whether or not one sex was more abundant than the other. The sex ratios of gray squirrels handled, according to season, are: winter, one male to one female; spring, three males to one female; summer, three males to one female; autumn, 46.1 males to 53.9 females. Here again, more males than females may be present, although, in live-

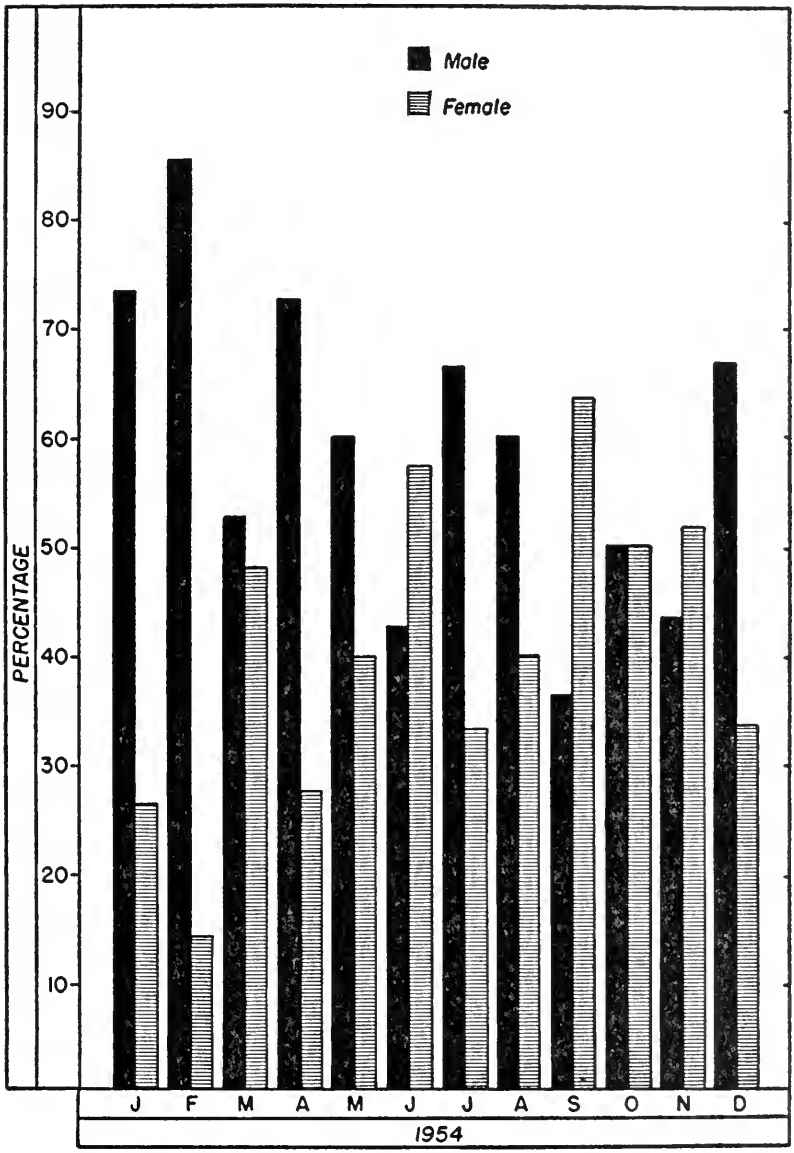

FIG. 3. Sex ratios of fox squirrels live-trapped and collected by writer in 1954.

trapping of gray squirrels on both areas, more females were taken than males.

Throughout the study, more male fox squirrels than females were live-trapped and retrapped on both study areas except in the autumn (see Table 5). D. L. Allen (1943:132, 134), Brown and Yeager (1945:458), and J. M. Allen (1952:81) in their studies all found females to be more easily and more often trapped. If males are more mobile than females, as indicated by my data, males might be more susceptible to mortality. And, if so, they would be less numerous than the females if there were an equal ratio of newly born young.

TABLE 5. SQUIRRELS HANDLED ON TWO STUDY AREAS.

	Reservation				Dillon Farm			
	Fox Squirrel		Gray Squirrel		Fox Squirrel		Gray Squirrel	
	Males	Females	Males	Females	Males	Females	Males	Females
Number....	70	50	25	30	45	25	3	4
Per cent....	58.3	41.7	45.5	54.5	64.3	35.7	42.9	57.1
Ratio.....	1.4	1	.83	1	1.8	1	.75	1

Age Ratios

Age ratios in the populations of both species were obtained by using Brown and Yeager's criteria for aging squirrels. Since my records include only one year's study, the conclusions are only tentative.

Figures 4 and 5 show the age-classes based on squirrels examined throughout the year by both live-trapping and collecting in Douglas County, Kansas.

The ratios obtained show that first litters of fox squirrels born in February were old enough to be partly self-sufficient by late April, but this group formed less than 20 per cent of the total number of animals examined at that time. By July, early-season young formed 40 per cent while second litters made up 20 per cent of the total population. Fluctuations in percentages from August to November could easily be within the range of statistical error

since the sample was small. In November, however, young of the spring and young of the summer made up 53 per cent of the population, and by December, young of both age-classes formed 59 per cent of the population. A ratio such as this, according to D. L. Allen (1943:127), is indicative of an unchanging population level. It is supposed that a higher number of young, in relation to adults, in Douglas County, might have been obtained if a better mast crop had been produced in the autumn of 1953. Baumgartner (1940a:164) judged that food produced from July to September, in Ohio, affected the overwintering population. This relationship also seems to apply in Kansas. D. L. Allen (*op. cit.*:128) and J. M. Allen (1952:81) have shown that the mast crop produced in autumn directly affects the number of potential breeding animals and, therefore, indirectly affects the next year's productivity. Persistent drought in Douglas County had greatest effect upon mast production in the summer and autumn of 1954. The effect of drought, along with other unknown factors, may have been the reason for a decrease in numbers of litters and numbers of young born per female in the summer of 1954. In the autumn of 1954, mast production was poor in comparison to that in 1953 in the areas checked by the writer, and may have been responsible for the decrease in sizes of litters born in February and March of 1955.

The small sample of young gray squirrels seemed equally successful in the spring and in the summer of 1954. However, the over-all productivity was less than in the fox squirrel. If the sample of gray squirrels is representative, drought and its effect on mast production may inhibit reproduction more in gray squirrels than in fox squirrels. On the contrary, gray squirrels may actually be less productive in Kansas than fox squirrels.

A questionnaire sent to hunters requesting ratios of adults to young in 1954 was only moderately successful. Data obtained from twelve hunters have been summarized in Table 6. No differentiation was made between young born in the spring and those born in the summer, but the figures indicate a gradual increase in the relative number of young fox squirrels bagged until a peak is reached in September. Then, the percentage of young gradually decreases. This seems to corroborate the data in Figure 4 obtained from populations of fox squirrels by live-trapping and from collecting in a smaller area. Data for the gray squirrel were too meager to be of value, but a lower percentage of young is, perhaps, suggestive of less productivity in this species.

Movements

One of the purposes of live-trapping was to establish the extent of movements of both fox squirrels and gray squirrels in relation to sex- and age-classes. Baumgartner (1943:198-199) recognized three types of movements in fox squirrels: daily, seasonal, and dispersal. Daily movements, he thought, were varied but notably limited in comparison to the other two types of movements. Goodrum (1940: 14) noted similar kinds of movements of gray squirrels in Texas.

I used two methods of trapping to determine more about these types of movements. In the North Woods Area on the Dillon Farm, and in the Fence Woods-Hole Woods Area on the Reservation, traps were placed in a pattern approximating a grid but with somewhat irregular intervals because initial field observations of the habits of the squirrels indicated that more would be caught if traps were not set in a perfect grid-pattern. Traps were sometimes moved 10 to 20 feet out of the grid-pattern to obtain better trap success. Although a home range cannot be determined with pre-

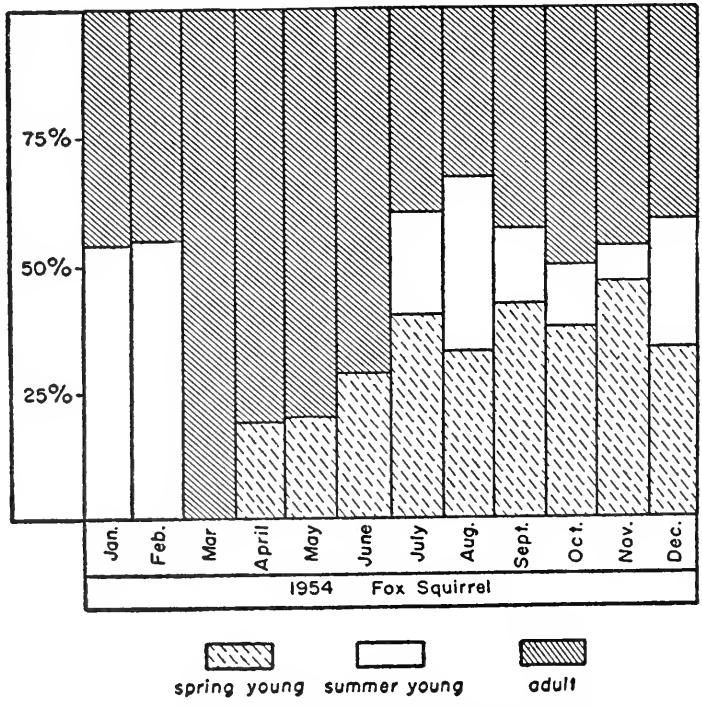

FIG. 4. Age ratios of 156 fox squirrels examined from Douglas County in 1954.

cision in this manner, an index to relative movements regardless of types of movements of tagged individuals can be established, in the writer's opinion. The second method of trapping was setting traps in places that squirrels were known to frequent. This method was used in all woods other than the Fence Woods-Hole Woods and North Woods areas.

TABLE 6. AGE RATIOS OF SQUIRRELS REPORTED BY HUNTERS IN 1954.

	Fox Squirrel		Gray Squirrel	
	Adults	Young	Adults	Young
June.....	2 (40%)	3 (60%)	0	0
July.....	23 (56.1%)	18 (43.8%)	0	0
August.....	41 (43.1%)	54 (56.8%)	1 (50%)	1 (50%)
September....	70 (40.2%)	104 (59.8%)	5 (50%)	5 (50%)
October.....	66 (47.9%)	72 (52.1%)	10 (58.8%)	7 (41.2%)
November....	16 (51.6%)	15 (48.4%)	5 (71.4%)	2 (28.5%)
Total.....	218 (45.04%)	266 (54.95%)	21 (58.33%)	15 (41.66%)

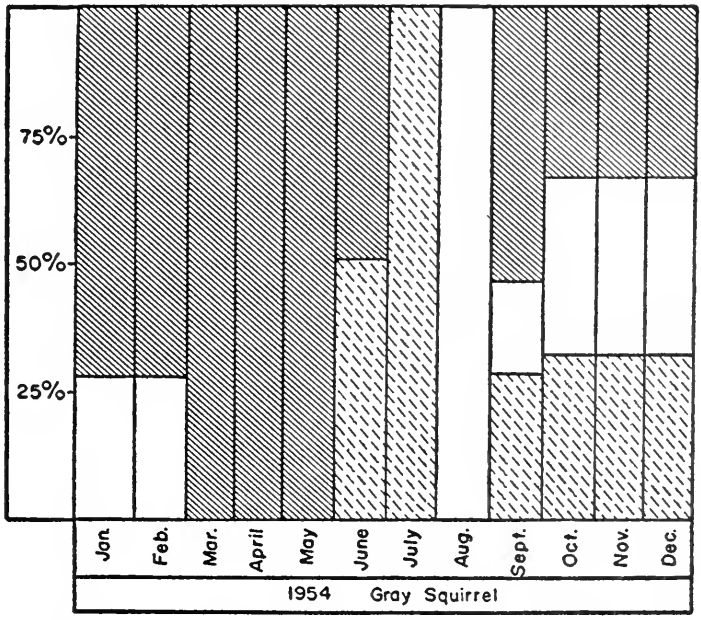

FIG. 5. Age ratios of 56 gray squirrels examined from Douglas County in 1954. For guide to shading see figure 4.

Table 7, a summarization of the results, shows that adult male fox squirrels move farther than do adult females. Young males (less than one year old) move farther than do adults of either sex or young females, although young females also move farther than do adult females. Yearling males (animals between 12 and 17 months old) move even farther than young males and therefore farther than any other age-classes of either sex. Yearling females traveled less than either yearling males or younger females, but farther than adult females. Male fox squirrels, in general, traveled farther than females of the same species. D. L. Allen (1943:142) and Baumgartner (1943:198-199) suggest that males move more and farther than females. My data indicate the same thing.

The same generalizations can be made concerning movements of gray squirrels except that no data were obtained by me on movements of their young.

Both species covered greater distances on the Dillon Farm than at the Reservation, probably to obtain sufficient food; it was less plentiful on the Dillon Farm. Difference in food supply may affect the mortality rate because squirrels moving greater distances might more often fall prey to predators. D. L. Allen (*loc. cit.*) thinks that the fox squirrel travels in 10 acres in one season and 40 acres throughout a year. Home ranges of individual squirrels might be larger in less favorable habitat than in favorable habitat. A squirrel in poorer habitat, moving long distances, might be the more vulnerable to the hunter. This would be true of all sexes and ages.

Limited movement of females in the breeding season, as pointed out by Brown and Yeager (1945:466), would reduce measurably the total activity of females observed. The pattern of movement obtained in this study seems indicative of the over-all trend in movements in a population of squirrels.

This pattern of movement may be important in providing one of the reasons for the "fall shuffle" or dispersal in populations mentioned by D. L. Allen (*op. cit.*:151), Baumgartner (*loc. cit.*) and J. M. Allen (1952:29). Baumgartner (*loc. cit.*) stated that the autumn shuffle results from "population pressure or food competition which may or may not be synonymous with intra-species intolerance." Brown and Yeager (*op. cit.*:467) suggest that juveniles are involved in this dispersal-movement. Competition for food seems to initiate the shuffle, but to me, this competition is synonymous with intra-specific intolerance. J. M. Allen (*op. cit.*:26)

stated that, "Juveniles may not be as firmly established in their home territories as adults." If so, juveniles may move farther or shift ranges more often to obtain the necessary requirements of life. Also, in autumn, when squirrel populations are highest, intra-specific strife may be greatest, and my observations indicate that adults then are the more successful and that the young and yearlings are forced out of the immediate community. One example of intra-specific strife may be provided by my records of a yearling male fox squirrel. Born in the spring of 1953, he was live-trapped in Funnel Woods Area on January 29, 1954, in good condition, weighing 670 grams. On March 10, 1954, he was retrapped in Fence Woods Area 2850 feet from the first point of capture and weighed 590 grams. On April 6, 1954, he was retrapped in Skink Woods Area, 2050 feet from the last trap station and weighed only 520 grams. At this time, his ears were lacerated; his facial region was badly scarred, and there were other fresh wounds that could have been made by incisor teeth of another squirrel. He was never captured again. Loss of weight in the winter is usual, but his loss was greater than in other animals handled in 1953 or 1954. His difficulties occurred in the breeding season; adult males then may be less tolerant of young males than at other times. Grinnell (1943: 11) suggested that animals, especially young males, moved each year out of a center of distribution into marginal habitat to escape intra-specific competition. Females seem to be more readily accepted in the established adult population than are males.

Seven fights were noted among fox squirrels; three were at the Reservation and four at the Dillon Farm. The seven fights were in August and September, 1954. Two of the fights on the Reservation involved known young and adult males, identified by plastic collars previously placed on them. In each instance, the younger animal departed from the immediate area owing to the aggressiveness of the adult. These instances of intra-specific strife seemed not to be related to food supply because, at that time, food was plentiful at the place where fighting occurred as well as in surrounding areas.

Patterns of movement (see Table 7) of gray squirrels suggest intra-specific intolerance, as young squirrels move greater distances than adults. At both the Reservation and the Dillon Farm, no indications of inter-specific strife were observed. In the autumn of 1954 one of the two gray squirrels tagged on the Dillon Farm used a den occupied by a fox squirrel in the Spring of 1954. In December, 1954, a fox squirrel again was occupying the den, but

the gray squirrel repeatedly was observed in the same area and used the den, it was believed, for escape when the area was entered by dogs and the investigator. Gray squirrels and fox squirrels fed together in walnut groves adjacent to the Skink Woods Area in the winter of 1953-54, with no indication of strife. However, the gray squirrel and fox squirrel do compete for food as pointed out in the section on food habits.

Other investigators, including Jeffrey (1937:12), Terrill (1941: 21), Brown and Yeager (1945:464), J. M. Allen (1952:23), and Bakken (1952:179) suggest differences in habitat preference rather than in actual inter-specific competition as a factor segregating the two species. Bakken (*loc. cit.*) stated that there was "no evidence that interspecies competition would result in segregation even in the less stable ecotone areas." In my study, squirrels that moved out of optimum habitats probably were young and yearlings of both species. The fox squirrel, tolerant of a broader range of ecological conditions, would be the most successful. Brown and

TABLE 7. * AVERAGE MOVEMENTS IN LINEAR FEET AMONG SQUIRRELS (OF ALL CLASSES).

Reservation
Fence Woods-Hole Woods

	Adult		Young		Yearling	
	♂	♀	♂	♀	♂	♀
Fox Squirrel	557.2 (22)	352.8 (14)	610.7 (5)	402.5 (6)	718.7 (4)	383.0 (4)
Gray Squirrel	562.5 (6)	94.1 (6)	....	525 (1)	577 (5)	624.4 (9)

Dillon Farm
North Woods

	Adult		Young		Yearling	
	♂	♀	♂	♀	♂	♀
Fox Squirrel	601.4 (5)	481.2 (3)	780.7 (4)	514.5 (2)	812.2 (2)	495 (1)
Gray Squirrel	555.7 (3)	150.4 (4)	....	....	....	....

* Numerals in parenthesis represent number of movements of squirrels in sample.

Yeager (*op. cit.*:26) believe that the "best evidence of interspecific competition at hand is that usually only one species occurs in a given urban community." Bakken (*op. cit.*:26) stated that in Kansas only fox squirrels are found in towns and villages. Actually both gray and fox squirrels occur together in towns and villages in eastern Kansas. Fox squirrels are usually the more abundant where the two species occur together. There are so many ecological variables in an urban community that it is a poor place to obtain evidence on inter-specific competition.

The mass migrations reported by Terrill (*op. cit.*:51-55) in Missouri in the 1930's were not observed in Kansas within the period of my study. No older resident hunters interviewed in southeastern Kansas remembered mass migrations of squirrels there.

The routes of escape taken by squirrels upon release from live-traps was recorded. Ninety-one per cent of the squirrels of both species left the trap station by way of the ground rather than by climbing a tree. Differences in wooded habitats did not appreciably affect escape behavior. Like Shipley (1941:124), Baumgartner (1940a:73-79), and Hungerford and Wilder (1943), I found that squirrels released from live-traps usually travel in a direction away from the presumed den or nest site. Such animals return to their homes by means of circular routes. On January 26, 1955, a male summer yearling fox squirrel was live-trapped and taken to the Laboratory at the Reservation where he was tagged, toe-clipped, and released. Because two toes had been removed, he was easily tracked in light snow. Upon release, he traveled approximately 356 feet directly south into Fence Woods Area, then east approximately 145 feet and turned north and moved 300 feet to a hollow in a dead sycamore tree.

On February 17, 1955, a female gray squirrel (previously tagged) was retrapped at the base of an American elm in the Fence Woods Area 200 feet south of the Laboratory Building. Upon release, she moved west approximately 50 feet and slowly ascended a tree. I remained motionless watching. She traveled westward through two more trees, slowly descended the second one, moved quickly over the ground, and returned to a point less than five feet from me. She looked about, then climbed and disappeared into a cavity in the same American elm at the base of which she had been retrapped. When no nearby hiding place is available, an escape route in a direction opposite from the home den or nest site seems to be followed in order to mislead a potential enemy.

Loss of Tail

Several squirrels had lost their tails. An adult male fox squirrel, handled six times at the Reservation (Tag No. 100), was bob-tailed, but seemed not to be handicapped.

ACTIVITY

The most extensive account published of activity of the fox squirrel is that of Hicks' (1949:301). Brown and Yeager (1945:464-465) observed both fox and gray squirrel activity while hunting and collecting specimens for their study. Bakken (1952:Fig. 25) presented data on both the seasonal and the daily activity of fox squirrels and gray squirrels in Wisconsin.

Information concerning activity was gathered on the Reservation, Dillon Farm, and at the Lakeview Area from the autumn of 1953 to the winter of 1954. The counting technique used and developed by Hicks (1942:229) involves, ". . . use of a definite route of known width and length with a tabulation of all individuals seen." Plots, each ten acres, were measured at the Fence Woods-Hole Woods Area at the Reservation, in the North Woods Area at the Dillon Farm, and at Lakeview. When traps were inspected, linear counts also were made. My study was made primarily to obtain data concerning activity of both species and to determine effect of climate on activities of squirrels.

Because the species-ratio differed on the three areas, three systems were devised to eliminate this variable. In the monthly activity table, squirrels seen were tabulated by number per count and by number per acre. The second system involved the patterns of daily activity; data for each species were analyzed separately to obtain actual number, average number, and percentage of squirrels seen per 30 minute count. The percentage of the total squirrels seen per count gives an index of the relative abundance of each species. The number of squirrels observed in a count was compared with average climatic conditions. The percentage of the total number of squirrels of each species observed in 20 counts selected at random where climatic conditions were approximately the same was calculated (see Figs, 6, 7, 8, 9).

Activity of the fox squirrel (see Table 8) increases in December and January, when breeding begins. This activity declines noticeably in February and March (a time which corresponds to the limited activity of females with young). Thereafter, activity increases in April and May (when breeding is resumed) and is again

followed by a decline in summer. Observations were limited in summer owing to the heavy foliage and the fact that squirrels generally tend to stay in the trees at this time. The fox squirrel and the gray squirrel were most active in October, during the time the animals are foraging for acorns and other mast and storing this food for use in winter. It should be remembered, however, that in October, squirrels are more easily observed since they spend more time on the ground than they do in other months.

The gray squirrel reached peaks in activity in January, March, and May. Probably there is some breeding in January; the most breeding is in March and May. Females bear young in April and July, which are times of relative inactivity. Two peaks in activity, in May and August, correspond to the times when young first become active (see Table 8).

Counts to determine daily activity were made also in conjunction with live-trapping on both the Reservation and the Dillon Farm,

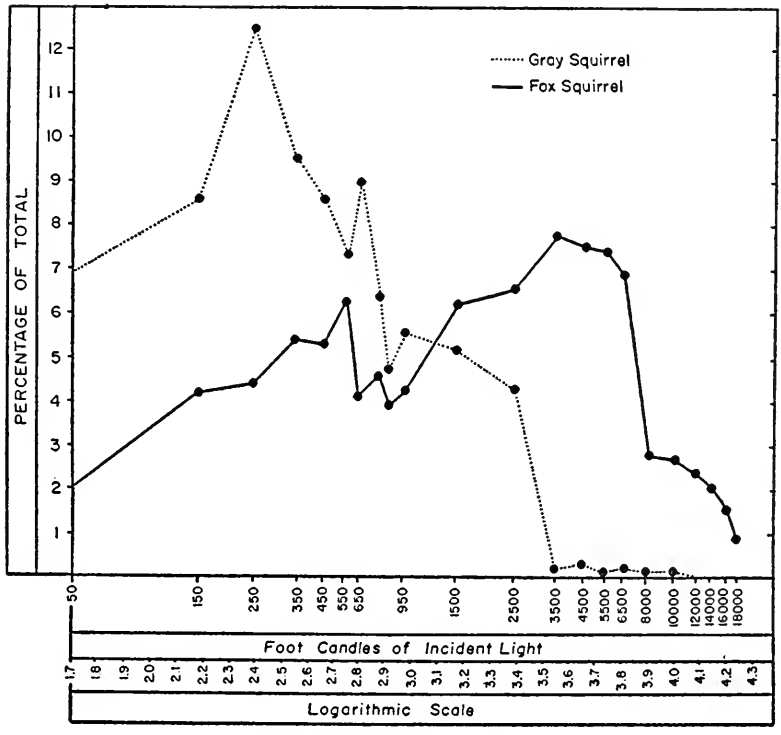

FIG. 6. Squirrel activity compared with light.

and the results are presented in Table 9. It was discovered that the greatest percentage of both species of squirrels were active between 7:00 and 8:00 A. M. in winter.

Both species of squirrels responded similarly to changes in temperature, wind, and relative humidity. The fox squirrel was the more tolerant to higher intensities of incident light than was the gray squirrel.

Light

Gray squirrels were most active when incident light, measured six inches above the ground, was between 150 and 650 foot candles (see Fig. 6). Such intensities of incident light, depending upon the forest canopy, occur early in the morning and late in the afternoon on clear days, and on cloudy days, throughout the daylight hours. Shipley (1941:20) found the gray squirrel in Virginia to be active throughout the day when the sky was overcast. Fox squirrels were most active when incident light, measured six inches above the ground, was between 1500 and 6500 foot candles (see Fig. 6) and were more tolerant of over-all light conditions than gray squirrels. Thus, fox squirrels were active longer periods per day and could occupy more open habitat than could gray squirrels.

TABLE 8. SQUIRRELS OBSERVED BY LINEAR COUNT ON THE STUDY AREAS FROM SEPTEMBER, 1953 TO NOVEMBER, 1954.

MONTH	Number 30 Minute Periods	Number Fox Squirrel	Number Fox Squirrel Per Count	Number Gray Squirrel	Number Gray Squirrel Per Count	Acres Observed	Fox Squirrel Per Acre	Gray Squirrel Per Acre
January	45	89	1.97	18	.40	450	.197	.040
February	45	63	1.40	12	.26	450	.140	.026
March	46	59	1.28	20	.43	460	.128	.043
April	47	77	1.63	10	.21	470	.163	.021
May	45	51	1.13	17	.37	450	.113	.034
June	52	35	.67	7	.13	520	.067	.013
July	60	29	.48	6	.10	600	.048	.010
August	52	51	.98	8	.15	520	.117	.015
September	67	107	1.59	34	.50	670	.159	.050
October	65	115	1.76	44	.67	650	.176	.067
November	66	101	1.53	38	.57	660	.153	.057
December	58	90	1.55	27	.46	580	.155	.029

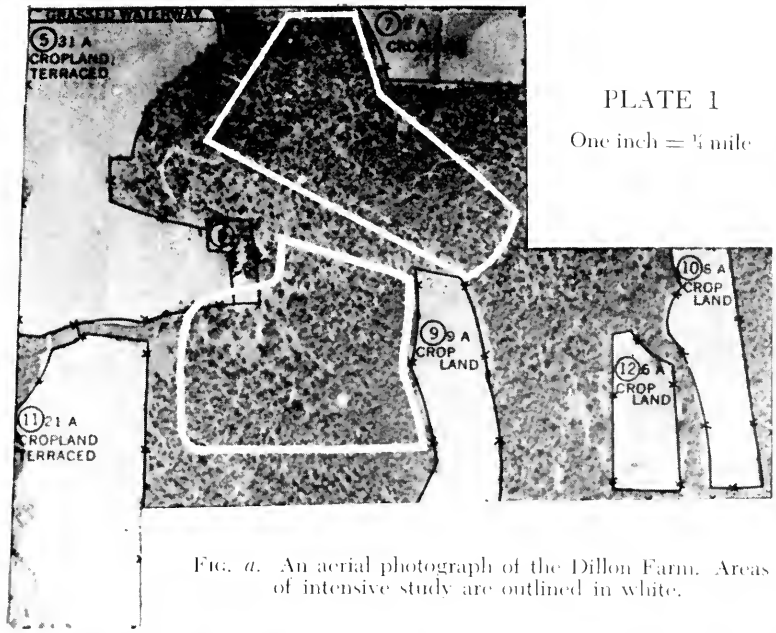

PLATE 1

One inch = ¼ mile

FIG. *a*. An aerial photograph of the Dillon Farm. Areas of intensive study are outlined in white.

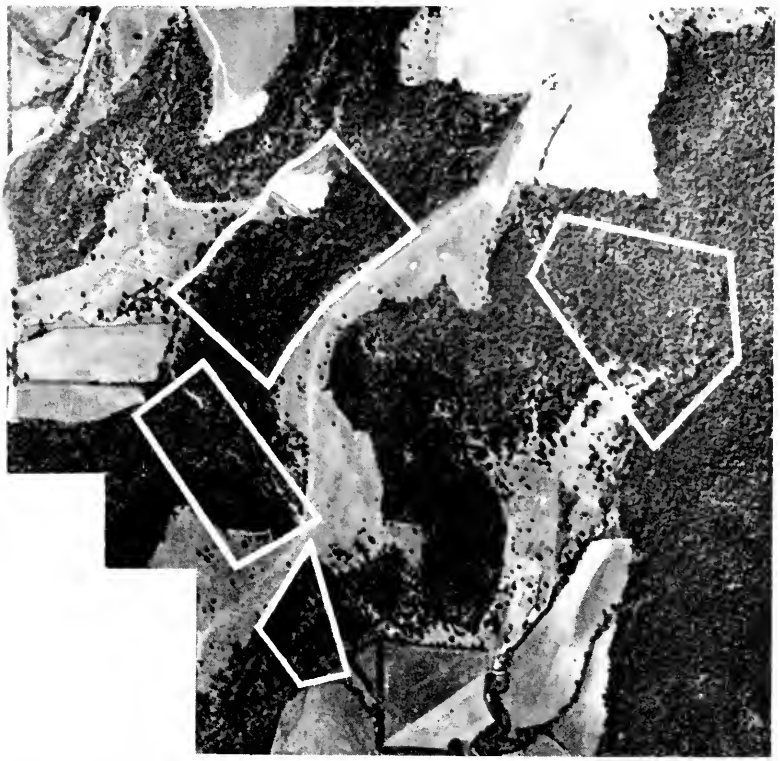

FIG. *b*. An aerial photograph of the University of Kansas Natural History Reservation. Areas of intensive study are outlined in white.

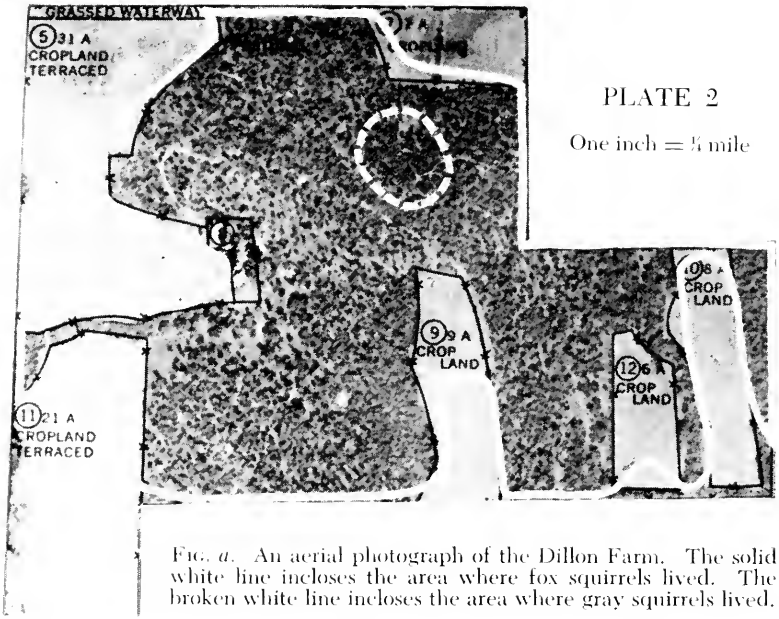

PLATE 2

One inch = ¼ mile

FIG. *a*. An aerial photograph of the Dillon Farm. The solid white line incloses the area where fox squirrels lived. The broken white line incloses the area where gray squirrels lived.

FIG. *b*. Aerial photograph of Reservation; fox squirrels occur throughout. Broken white line incloses areas where gray squirrels lived.

According to Flora (1948:233-234), the average number of hours of sunshine in winter in Kansas, east of the 97th Meridian, is five to six hours; in summer it is ten to eleven hours. West of that Meridian, there is more sunshine daily. The distribution of the gray squirrel lies east of the 97th Meridian and seems to correspond to the lesser amount of sunshine occurring in that area.

Temperature

The activity of the two species of squirrels when compared with temperatures was nearly the same. They were most active between temperatures of 43° and 72° Fahrenheit (see Fig. 7).

TABLE 9. OBSERVATIONS OF SQUIRREL ACTIVITY CORRELATED WITH TIME OF DAY.

TIME	30 Min. Periods	Number of Squirrels Observed		Number of Squirrels Per Count		Percentage of Total Observed	
		Fox	Gray	Fox	Gray	Fox	Gray
		Reservation—Winter 1953–54					
6– 7....	2	5	5	2.50	2.50	10.20	33.28
7– 8....	6	28	10	4.66	1.66	19.02	22.10
8– 9....	10	44	4	4.40	.40	17.96	5.32
9–10....	10	26	0	2.60	.00	10.61	0.00
10–11....	10	17	2	1.70	1.00	6.94	13.31
11–12....	7	10	2	1.42	.28	5.79	3.72
12– 1....	10	14	1	1.40	.10	5.71	1.33
1– 2....	7	12	1	1.71	.14	6.98	1.86
2– 3....	10	10	1	1.00	.10	4.08	1.33
3– 4....	10	13	1	1.30	.10	5.30	1.33
4– 5....	10	7	4	.70	.40	2.85	5.32
5– 6....	10	6	5	.60	.50	2.44	6.65
6– 7....	6	3	2	.50	.33	1.34	4.39
		Dillon Farm—Winter 1953–54					
6– 7....	8	7	2	.87	.25	5.59	12.25
7– 8....	5	16	4	3.20	.80	20.56	39.21
8– 9....	3	9	1	3.00	.33	19.28	16.17
9–10....	2	6	0	3.00	.00	19.28	.00
10–11....	2	4	0	2.00	.00	12.85	.00
11–12....	4	7	1	1.75	.25	11.24	12.25
12– 1....	0	0	0	.00	.00	.00	.00
1– 2....	0	0	0	.00	.00	.00	.00
2– 3....	0	0	0	.00	.00	.00	.00
3– 4....	0	0	0	.00	.00	.00	.00
4– 5....	6	4	1	.66	.16	4.24	7.84
5– 6....	4	3	1	.75	.25	4.82	12.25
6– 7....	6	2	0	.33	.00	2.12	.00

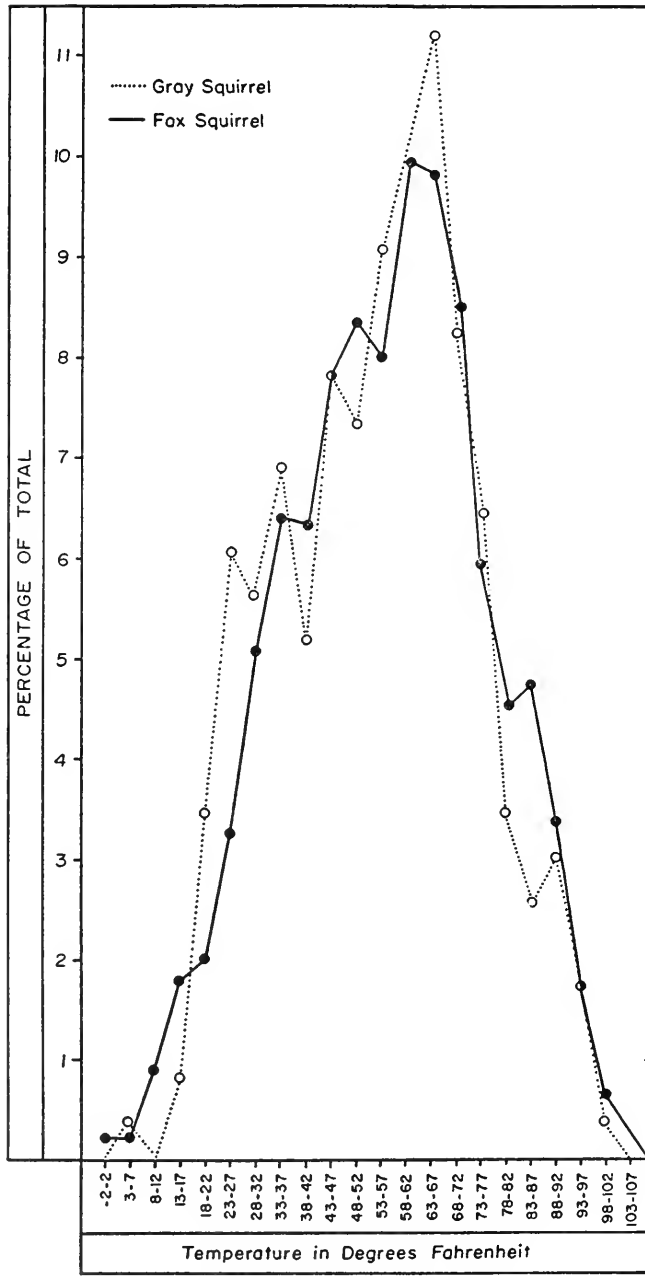

FIG. 7. Squirrel activity compared with temperature.

Wind

Both species were most active when wind velocities were less than five miles per hour (see Fig. 8). Gray squirrels seem able to climb and move from tree to tree better than fox squirrels. This, perhaps, explains the gray squirrel's ability to better withstand winds of nine to ten miles per hour than can the fox squirrel.

Relative Humidity

Both species of squirrels were most active when relative humidities were from 70 to 99 per cent (see Fig. 9). My data on relative humidity were divided into ten degree intervals like those data of Hicks' (1949:294). In Iowa, he found fox squirrels to be active when relative humidities were from 50 to 59 per cent and 80 to 99 per cent.

In my 13-months' study, in Kansas, gray squirrels were most active when there was a combination of low incident light, high relative humidities, moderate temperatures, and low wind velocities. Fox squirrels responded to like conditions but tolerated higher incident light.

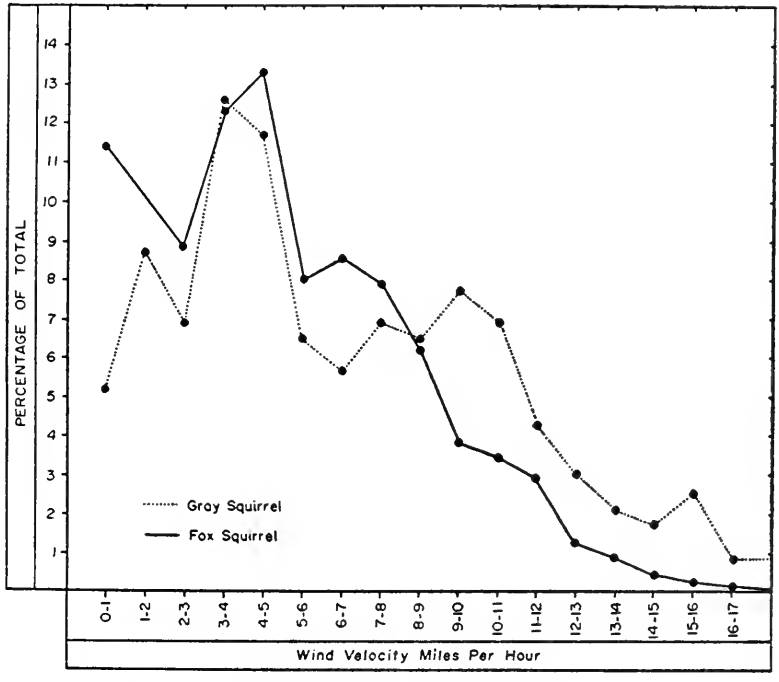

FIG. 8. Squirrel activity compared with velocity of wind.

FOOD

Foods were studied at both study areas and species eaten were collected for identification (see Tables 10 and 11).

Stomachs of 54 fox squirrels and 22 gray squirrels were collected, and the contents were analyzed (see Tables 12 and 13). Some materials found in stomachs were identified using the methods described by Baumgartner and Martin (1939). For 54 fox squirrels, the average volume of stomach contents was 10.1 cc.; one stomach contained 41 cc. of food. For 22 gray squirrels, the average stomach content was 6.5 cc.; one stomach contained 32 cc. of material.

Autumn

In the autumn of 1953, walnut, black oak, yellow oak, and red oak produced most nuts on the Reservation and, excepting those of the red oak, were consumed by both species of squirrels. Yellow oak and walnut are the most common of the above species. On the Dillon Farm, acorns of yellow oak were most abundant and seemingly were preferred by fox squirrels, while acorns of the less

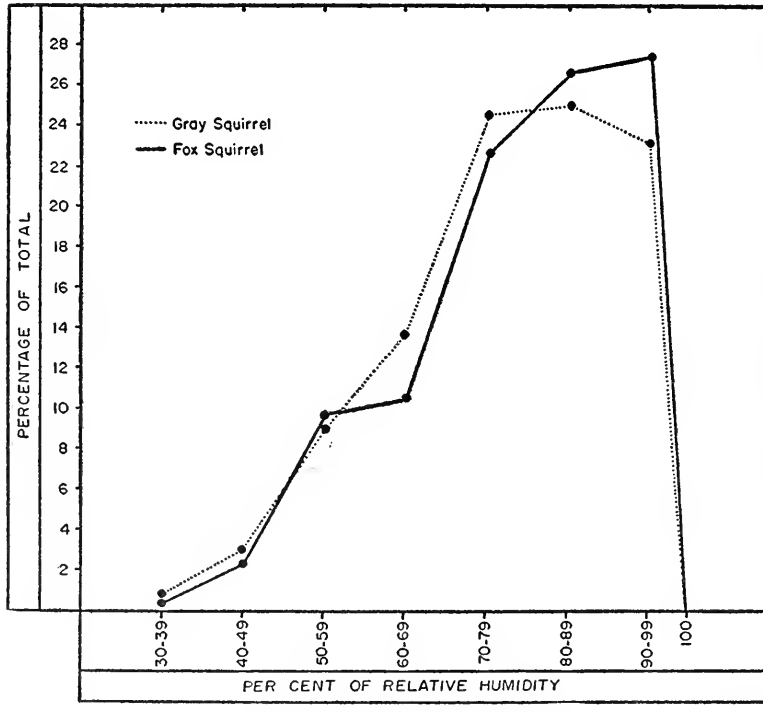

FIG. 9. Squirrel activity compared with relative humidity.

common burr oak were preferred by gray squirrels. Hickory nuts on both the Reservation and the Dillon Farm, although not abundant, were also eaten, especially by gray squirrels. Mast production was not optimum for the autumn of 1953 but was much better than in the autumn of 1954. Walnut and black oak bore fewer nuts on the Reservation in 1954 than in 1953, and yellow oak on the Dillon Farm bore fewer acorns in 1954 than in 1953. The small crop of nuts available in the winter of 1954-55 was reflected in the poor physical condition of many animals taken in live-traps.

Winter

So long as the cached mast supply remained, acorns and walnuts seemed to be preferred to other foods on both areas. Osage orange, or hedge apple, also was a highly important winter food on both areas and elsewhere, especially for the fox squirrel (see Whitaker, 1939), although, in Ohio, Baumgartner (1939:580) considered Osage orange an auxillary or emergency food for fox squirrels. In Kansas, this tree provides a staple food for fox squirrels. To determine the importance of Osage orange as food, in February, 1954, 20 walnuts and 20 Osage orange fruits were placed in the center of each of two ten-foot square plots used chiefly by fox squirrels. Each day, tracks of animals which crossed the border of loose earth, which surrounded each plot, were tabulated and were identified when possible. Tracks of tree squirrels (species could not be determined), cottontail rabbits (*Sylvilagus floridanus*), and wood mice (*Peromyscus leucopus*) were identified. At the end of February, less than one-fifth of the Osage orange fruits remained in the plots. Since gray squirrels seem not to use Osage orange to any great extent, it is supposed that fox squirrels, because of their preference for this food, may withstand shortages of acorns and walnuts better than gray squirrels. Certainly, inter-specific competition for walnuts and acorns exists where both squirrels occur together, and it would seem that the fox squirrel, with a more euryphagic habit, would be less affected by such competition than the gray squirrel.

In the winter of 1954-55, the cached nut supply was almost exhausted by January, and squirrels fed on bark and seeds of elm, dogwood, ash, and sumac. Seeds of Kentucky coffee tree and honey locust, thought to be emergency foods, were eaten extensively by fox squirrels.

One of the more important foods of the fox squirrel in the winters of 1953-54 and 1954-55 was cultivated grain, especially corn. Gray

TABLE 10. FOODS OF THE FOX SQUIRREL, ARRANGED IN ORDER OF PREFERENCE AS TO FAMILY AND THEN AS TO SPECIES WITHIN EACH FAMILY.

Reservation

Vegetal parts	Autumn	Winter	Spring	Summer
1. Juglandaceae				
Juglans nigra	nuts	nuts		nuts
Carya ovata	nuts	nuts	buds	
2. Fagaceae				
Quercus Muehlenbergii	nuts	nuts		nuts
Quercus macrocarpa	nuts			
Quercus prinoides	nuts			nuts
Quercus velutina	nuts			nuts
Quercus rubra	nuts			leaves
3. Moraceae				
Maclura pomifera	seeds	seeds		
Morus rubra				fruits
4. Ulmaceae				
Ulmus americana			buds	leaves
Celtis occidentalis	bark	bark	buds	
Ulmus rubra		bark	buds	
5. Rosaceae				
Prunus virginiana				fruit, leaves
Prunus nana				fruit
Fragaria virginiana				fruit
Prunus americana				fruit
Rubus argutus		bark		
6. Saxifragaceae				
Ribes missouriense				fruit, leaves
7. Vitaceae				
Vitis vulpina				fruit
Parthenocissus quinquefolia		bark		fruit, leaves
8. Cornaceae				
Cornus Drummondi		bark, buds	bark	
9. Leguminoseae				
Gymnocladus dioica		seeds	seeds	
Gleditsia triacanthos		seeds	seeds	
Cercis canadensis		bark		buds
10. Celastraceae				
Celastrus scandens	fruits			fruits
11. Aceraceae				
Acer Negundo				buds
Acer saccharinum				buds

TABLE 10.—*Continued.*

Reservation

Vegetal parts	Autumn	Winter	Spring	Summer
12. Oleaceae				
Fraxinus tomentosa		buds	buds	fruit
Fraxinus americana		buds	buds	fruit
13. Anacardiaceae				
Rhus glabra		bark	bark	
14. Caprifoliaceae				
Sambucus canadensis				fruit
Symphoricarpos orbiculatus		bark	bark	
15. Platanaceae				
Platanus occidentalis		bark	bark	leaves
16. Salicaeae				
Salix nigra		bark		
17. Juniperaceae				
Juniperus virginiana		fruit		
18. Compositae				
Eupatorium purpureum				leaves
Eupatorium rugosum				leaves
19. Agaricaceae				
Pleurotus sp.		plant	plant	
Animal food				
Insecta				
Orthoptera				leafhoppers, grasshoppers
Coleoptera				ground beetles
Hymenoptera				ants

Dillon Farm

1. Juglandaceae				
Carya ovata	nuts	nuts	buds	nuts
Carya species?	nuts			
2. Fagaceae				
Quercus Muehlenbergii	nuts	nuts		nuts
Quercus macrocarpa	nuts			
Quercus rubra	nuts			
3. Moraceae				
Maclura pomifera	seeds	seeds		
Morus rubra				fruit

TABLE 10.—*Concluded.*

Dillon Farm

Vegetal parts	Autumn	Winter	Spring	Summer
4. Gramineae				
Zea mays	seed	seed	seed	seed
Hordeum sp.	seed			seed
Triticum sp.	seed			seed
5. Ulmaceae				
Ulmus americana		bark, buds	buds	
Celtis occidentalis		bark		
6. Rosaceae				
Prunus virginiana				fruit
7. Leguminoseae				
Gymnocladus dioica		seeds	seeds	
Gleditsia triacanthos		seeds	seeds	
8. Vitaceae				
Vitis vulpina				fruit
Parthenocissus quinquefolia		bark	bark	
9. Cornaceae				
Cornus Drummondi		bark	buds	
10. Anacardiaceae				
Rhus glabra			bark	
11. Juniperaceae				
Juniperus virginiana		fruit		
12. Agaricaceae				
Pleurotus sp.		plant	plant	
Animal food				
Insecta				
Orthoptera				leafhoppers, grasshoppers
Coleoptera				ground beetles
Hymenoptera				ants

squirrels ate less corn than fox squirrels. In 1954, I kept a young female gray squirrel in captivity from August to mid-October, and, although corn was offered to her daily, she accepted it only when other foods were not available. Of approximately eight persons who wrote about food of the gray squirrel, only Shipley (1941:61) reports that the gray squirrel, in Virginia, eats corn.

In western Kansas, in December, 1953, corn, wheat, and cottonwood were primary foods of fox squirrels. In shelter belts, fox squirrels fed on cottonwood bark, Osage orange fruits, ash seeds, catalpa seeds, and red cedar berries. According to Bugbee and Riegal (1945), in Hays County, in winter, this squirrel ate elm seeds and fruits from Russian olive.

Spring

In the spring of 1954, at both study areas, squirrels fed primarily on buds of elm, maple, and oak, but ate also new sprouting leaves, and larvae of insects. These foods were eaten in order of their appearance, as was observed in Illinois by Brown and Yeager (1945:503-505). John W. Hardy reports to me that he observed fox squirrels eating robin (*Turdus migratorus*) eggs in Lawrence, Kansas, in April, 1955.

Summer

Both species of squirrels ate numerous kinds of berries and other fruits and preferred them to all other foods excepting cached acorns, walnuts, and hickory nuts; also ground beetles, grasshoppers, leafhoppers, and flies were eaten. By late August, acorns and other nuts again were available. The acorns of the dwarf oak (*Quercus prinoides*) are a favored food and become ripe before those of other oaks. Feeding on insects rapidly diminished after mid-August.

Mast Production

Hunters that were interviewed thought that approximately the same amounts of acorns and other mast were produced in 1953 as in 1954. In 1953, seven per cent of my hunter correspondents thought mast more abundant than in previous years; 31 per cent thought it the same, and 62 per cent thought there was less. In 1954, ten per cent of the squirrel hunters thought there was more mast than in 1953, 30 per cent thought it the same, and 60 per cent thought it less.

From the hunters' reports, it is evident that more squirrels were produced in 1954, and that mast production remained approximately

TABLE 11. FOODS OF THE GRAY SQUIRREL, ARRANGED IN ORDER OF PREFERENCE AS TO FAMILY AND THEN AS TO SPECIES WITHIN EACH FAMILY.

	Reservation			
Vegetal food	Autumn	Winter	Spring	Summer
1. Juglandaceae				
Juglans nigra	nuts	nuts		nuts, leaves
Carya ovata	nuts	nuts, buds	buds	
2. Fagaceae				
Quercus velutina	nuts			
Quercus prinoides	nuts			
Quercus Muehlenbergii	nuts	nuts, buds	buds	nuts, leaves
Quercus macrocarpa		bark		
3. Ulmaceae				
Ulmus americana		bark, buds	buds	leaves
Ulmus rubra		bark, buds	buds	
Celtis occidentalis		bark		
4. Moraceae				
Morus rubra				fruits
5. Rosaceae				
Prunus virginiana				fruits
Prunus americana				fruits
Prunus nana		bark		fruits
6. Saxifragaceae				
Ribes missouriense		bark		fruits
7. Caprifoliaceae				
Sambucus canadensis				fruits
8. Vitaceae				
Vitis vulpina		bark		fruits
Parthenocissus quinquefolia		bark		
9. Celastraceae				
Celastrus scandens	fruits			fruits
10. Platanaceae				
Platanus occidentalis		bark	leaves	
11. Cornaceae				
Cornus Drummondi		bark		
12. Aceraceae				
Acer Negundo		buds	buds	seeds
Acer saccharinum		buds	buds	seeds
13. Anacordiaceae				
Rhus glabra		bark, buds	bark, buds	

TABLE 11.—*Concluded.*

Reservation

Vegetal food	Autumn	Winter	Spring	Summer
14. Compositae				
Eupatorium rugosum				fruit, leaves
Animal food				
Insecta				
Diptera				flies
Orthoptera				leafhoppers
				grasshoppers
Coleoptera				ground beetles
Hymenoptera				ants

Dillon Farm

1. Juglandaceae				
Carya ovata	nuts	nuts	buds	nuts
Carya species?	nuts			nuts
2. Fagaceae				
Quercus macrocarpa	nuts			
Quercus muehlenbergii	nuts	nuts		nuts
3. Ulmaceae				
Ulmus americana		bark, buds	buds	
Ulmus rubra			buds	
Celtis occidentalis		bark		
4. Moraceae				
Morus rubra				fruits
5. Rosaceae				
Prunus virginiana				fruits
6. Vitaceae				
Vitis vulpina				fruits
7. Cornaceae				
Cornus Drummondi		bark		leaves
Animal food				
Insecta				
				leaf and
Orthoptera				grasshoppers
Coleoptera				ground beetles

TABLE 12. FOODS IN 54 FOX SQUIRREL STOMACHS.

Item	Frequency of Occurrence in Per Cent	Per Cent by Volume
Autumn—28 STOMACHS (3 Empty)		
Juglans nigra	68	38.5
Quercus sp.	60	17.1
Quercus macrocarpa	4	6.2
Maclura pomifera	4	10.4
Zea mays	12	10.2
Quercus prinoides	4	3.4
Carya sp.	4	1.0
Ulmus sp. (seeds, twigs)	4	1.2
Triticum sp.	8	2.6
Poa sp.	4	1.4
Soil	12	2.2
Insect (coleoptera)	4	.8
Unidentified material	12	5.0
Winter—8 STOMACHS		
Juglans nigra	37.5	7.4
Quercus sp.	37.5	12.1
Maclura pomifera	37.5	35.2
Acer sp.	25.0	4.8
Acer negundo (seed)	12.5	1.0
Gymnocladus dioica	12.5	6.4
Gleditsia tricanthos	12.5	6.1
Zea mays	62.5	16.0
Unidentified material	12.5	1.0
Summer—10 STOMACHS (1 Empty)		
Juglans nigra	22.2	9.7
Quercus sp.	33.3	5.6
Morus sp. (rubra?)	44.4	18.4
Ulmus sp. (bark, buds, seeds, leaves)	33.3	4.3
Platanus occidentalis	11.1	2.5
Zea mays	11.1	8.6
Grass (unidentified)	11.1	4.0
Insects (unidentified)	44.4	22.6
Coleoptera	11.1	1.3
Orthoptera	11.1	1.4
Diptera	33.3	6.1
Fox Squirrel	11.1	8.2
Soil	33.3	1.1
Unidentified material	22.2	6.2
Spring—6 STOMACHS		
Juglans nigra	50.0	12.7
Quercus sp.	50.0	8.4
Ulmus sp. (catkins, buds, leaves)	16.6	30.3
Celtis occidentalis	16.6	2.4
Zea mays	16.6	5.2
Unidentified root material	16.6	4.4
Unidentified seed material	16.6	14.8
Insects (unidentified)	16.6	10.6
Hymenoptera	16.6	6.3
Soil	16.6	5.9

TABLE 13. FOODS IN 22 GRAY SQUIRREL STOMACHS.

Item	Frequency of Occurrence in Per Cent	Per Cent by Volume
Autumn—14 Stomachs (4 Empty)		
Juglans nigra	60	46.2
Quercus sp.	70	41.1
Insects (unidentified)	10	3.7
Orthoptera	10	2.4
Coleoptera	10	1.6
Unidentified leaf portions	10	2.5
Soil	10	2.5
Winter—2 Stomachs (1 Empty)		
Quercus sp.	100	51.0
Celtis occidentalis (bark)	100	44.0
Soil	100	5.0
Summer—2 Stomachs		
Ulmus sp.	50	68.8
Juglans nigra	50	12.1
Insect (unidentifiefid)	50	18.1
Diptera	50	1.0
Spring—4 Stomachs (1 Empty)		
Juglans nigra	66.6	18.6
Quercus sp.	33.3	11.2
Carya sp.	33.3	21.1
Prunus sp.	33.3	42.4
Soil	33.3	6.7

the same. Since squirrels prefer only certain kinds of nuts (including acorns), and since hunters report all kinds of nuts, these reports may not accurately reflect production of preferred nuts.

WEIGHTS

Weights of 168 fox squirrels are presented in Figure 10. In spring and early summer, pregnant females averaged heavier than males. Weights of both adults and young increased in autumn when food was abundant and decreased in winter when food was less available. The small peak among adults (see Fig. 10) in February, 1954, may reflect the small sample of weights obtained for that month instead of the actual condition of the population. The decrease in weight of adult females in summer seems to result from caring for young. Weights of adult males decreased throughout the spring and seem to be correlated with intermittent breeding. Young born as late as March weigh almost as much as adults by September (see Fig. 10). In Illinois, Brown and

Yeager (1945:467) noted that the weights of juveniles born in spring do not approximate those of adults until October or November. In Kansas, young are born earlier in spring than in northern Illinois and attain adult weight correspondingly earlier.

Adult males averaged 549.1 grams (range, 500-685 grams), and adult females averaged 580 grams (range, 500-628 grams). Young squirrels weighed as little as 159 grams, when still suckling, and as much as 525 grams in late autumn.

Shortage of food in the winter of 1954-55 reduced the weight of the squirrel population. From December through March, adult fox squirrels lost ten grams per month on the Reservation and 18 grams on the Dillon Farm. Young of the previous year lost 20.5 grams per month from December through March on each area. On the Reservation, adult gray squirrels lost an average of six grams per month in this winter period, while young of the year decreased an average of 7.5 grams.

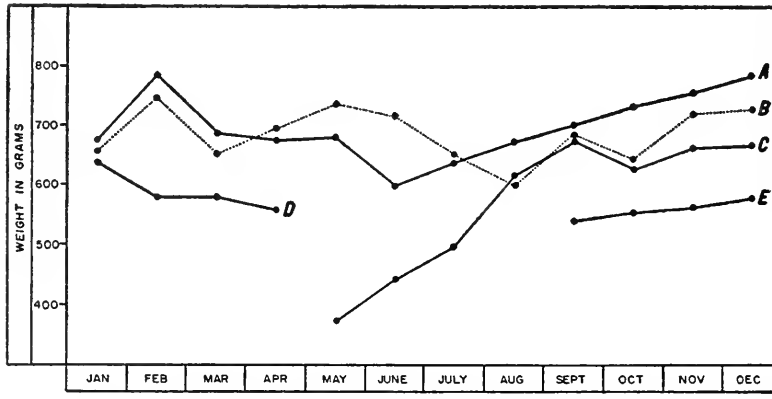

FIG. 10. Weights of the fox squirrel in 1954. A-adult males; B-adult females; C-young of spring; D-young of previous summer; E-young of summer.

NESTS AND DENS

More usable nests were present on both study areas in the winter of 1953-54 than in the winter of 1954-55 (Table 14); this was because squirrel populations declined in the winter of 1954-55 and did not keep all nests in repair. Those not repaired blew away or fell. According to J. M. Allen (1952:46), the number of nests present from year to year may indirectly indicate size of population. In Indiana, he noted that a high squirrel population in 1946 built many nests, whereas a low population in 1947 built few. Therefore, the total number of nests present in 1948 was low.

In Kansas, building of leaf nests reaches a peak in summer, and squirrels are most active immediately following showers or light rains. On three occasions in July and two in August, fox squirrels were seen building nests following light rains. Squirrels seemed not to be partial to any species of tree when building leaf and twig nests, except that the nests are always placed close to the food supply. Brown and Yeager (1945:515) also noted this habit in Illinois.

Thirty-seven leaf and twig nests were obtained from places other than the study areas and examined in detail. The bulk of the material used in constructing any nest was obtained from the tree in which the nest was situated or from another tree of the same species. Oak leaves and grasses, generally finely shredded, lined the interior. In 32 nests, the entrance faced east. The opening in the nest of the "Eichornchen" (*Sciurus vulgaris*)—a squirrel—in Switzerland faces east (Bauman, 1949:194).

Cattle grazing on the Dillon Farm, by reducing the food supply, limited the number of squirrels present; understandably, fewer leaf nests were found there than on the Reservation.

More cavities in trees were available for denning on the Reservation than on the Dillon Farm. This scarcity of tree-holes as well

TABLE 14. LEAF AND TWIG NESTS ON STUDY AREAS, 1953-55.

	Number of Nests in Use	Average Height in Feet of Nests	Average Height in Feet of Nest-Trees	Average Distance in Feet to Surface Water	Average Distance in Feet to Nearest Nut-Bearing Tree
Fence Woods-Hole Woods Area, Reservation					
Autumn, 1953.....	57	32.0	40.6	*	10.7
Winter, 1953–54...	52	30.5	42.2	60.7	12.4
Spring, 1954.....	55	31.7	40.3	42.4	11.3
Summer, 1954.....	64	29.2	37.4	112.8	8.6
Autumn, 1954.....	48	30.6	39.1	96.2	14.1
Winter, 1954–55...	39	32.2	41.4	52.1	17.2
North Woods Area, Dillon Farm					
Autumn, 1953.....	41	31.4	44.4	650.0	21.7
Winter, 1953–54...	32	34.5	39.5	88.9	38.3
Spring, 1954.....	35	30.2	42.1	45.7	36.1
Summer, 1954.....	46	29.7	41.9	310.5	18.5
Autumn, 1954.....	28	30.8	40.2	264.1	46.7
Winter, 1954–55...	18	32.6	39.8	92.6	57.6

* None on area.

as of suitable food and large nut-bearing trees probably limited the number of gray squirrels on the Dillon Farm. Of the 17 dens examined in the two winters on the Reservation, gray squirrels inhabitated 11. Only four leaf or twig nests were known to provide winter quarters for gray squirrels on the Reservation. Of the two marked gray squirrels at the Dillon Farm, one used a hollow in a tree throughout both winters. In Ohio, Chapman (1938:680) found that gray squirrels preferred tree hollows rather than leaf and twig nests as winter quarters. There are approximately two gray squirrels to each fox squirrel in the virgin stand of climax oak-hickory in the vicinity of Pigeon Lake, in Miami County, Kansas. Here, white oak (*Quercus alba*) is common and contains many cavities used by squirrels.

Fox squirrels use hollows in trees for dens, but unlike most gray squirrels, can live through the winter using leaf and twig nests alone. J. M. Allen (1952:38) points out that fox squirrels in Indiana can survive without cavities in trees for dens. In many places where fox squirrels occur in western Kansas, there are no tree-holes. Osage orange, an important and widespread tree there, rarely contains hollows; cottonwood trees, however, provide some cavities. In Finney County, Kansas, fox squirrels used nests built and abandoned by white-necked ravens (*Corvus cryptoleucus* Couch).

DISEASES AND PARASITES

Little evidence of disease in either gray or fox squirrel populations was found in 1953-55. In 1953, of 1,953 (*sic*) squirrels taken by 103 hunters, only .31 per cent were reported to be diseased. These animals had diseases classed as follows: sarcoptic mange in two fox squirrels; spotted livers in one gray squirrel and one fox squirrel; warble (probably *Cuterebra* sp.) in one gray squirrel; one fox squirrel was designated as simply being "thin due to disease." In 1954, of 1,851 squirrels taken by 88 hunters, .16 per cent of the total bag were reported to be diseased. Diseases noted were: mange in one fox squirrel; a waterlike blister between hide and flesh (probably a tape worm cyst) in one gray squirrel; and one "thin and sick" fox squirrel.

Of 39 squirrels caught in live-traps at the Reservation in September, and October, 1954, two fox squirrels and two gray squirrels were in a weakened condition. When released, none possessed enough strength to move more than a few yards. All four died and were carefully dissected. One female fox squirrel and one

male gray squirrel contained a small worm (a nematode—*Heligmodendrium hassalli*). A bacteriologist, Earl Fowler, examined portions of the liver, spleen, heart, lungs, and kidneys of two squirrels. There was a slight edema of the lungs due to a pneumococci bacteria that was isolated from one of these two fox squirrels. Mr. Fowler believed that this type of bacterium might be transmitted from one squirrel to another through close association. In the 30 to 45 minutes preceding death, all four squirrels exhibited characteristic mannerisms as follows: first, muscular spasms, especially of the trapezius; second, severe gasping for breath; third, a complete loss of muscular stability.

Parasites of gray and fox squirrels in Kansas are listed in Table 15 (see Graham and Uhrich, 1943; Heck, 1951; Loomis, 1955). One flea, identified as *Orchopeas howardii* (Baker), was abundant on both species of squirrels taken from September to November in both 1953 and 1954. No other fleas were taken, although Graham and Uhrich (1943:159-160) found *Hoplopsyllus affinis* and *Neohaematopinus sciurinus* on the fox squirrel in southeastern Kansas. Ticks of the species *Dermacentor variabilis* occurred, especially on and around the ears, on both species of squirrels in greatest abundance from April through July, 1954, and decreased noticeably in August. Studies by Fremling and Gastfriend (1955:162) have shown that densest populations of ticks (*Dermacentor parumapertus*) occur in early July. A male gray squirrel, in good condition, live-trapped at the Reservation on April 10, 1954, had 23 ticks (*D. variabilis*) on the ears, cheeks, and rostrum. This was the greatest number of ticks found on any squirrel examined by me.

Little has been published concerning chiggers that parasitize gray and fox squirrels. Brown and Yeager (1945:472) in Illinois, Allison (1953:47) in North Carolina, and Graham and Uhrich (*loc. cit.*) in Kansas mention that the genus *Trombicula* occurs on squirrels. In Kansas, Loomis (1955:manuscript) reported ten species of the genus *Trombicula* (see Table 15), three species of *Euschöngastia* and *Walchia americana* on the fox squirrel, and seven species of *Trombicula*, two species of *Euschöngastia*, *Cheladonta michéneri*, and *Walchia americana* on the gray squirrel. Chiggers infested squirrels in largest numbers in autumn, especially in November. Since squirrel populations are largest in autumn, opportunities for transmission of parasites either directly or indirectly would be good.

The only endoparasites taken from squirrels by the writer were identified as *Heligmodendrium hassali*. This nematode, according

to Heck (1951:42-43, 45), was the most common intestinal parasite of 65 squirrels of both species examined in Douglas County. Graham and Uhrich (*loc. cit.*) found *H. hassali* commonly in fox squirrels in southeastern Kansas. Heck (*loc. cit.*) found both adult gray and fox squirrels to carry more species of nematodes and cestodes than young individuals. Heck (*op. cit.*:36) examined a fox squirrel which appeared to be suffering from shock disease (see D. L. Allen, 1943:215), which he judged was caused by the presence of a large number of nematodes (*Strongyloides robustus*) that he found when the animal was autopsied.

PREDATION

Previous investigations of predation upon fox and gray squirrels have yielded an imposing list of vertebrate predators. In most cases, predation has been considered relatively unimportant to squirrel populations.

According to Seton (1929:51-52), McAtee (1935:8), Sperry (1940:20), Hicks and Henderson (1940:134), Brown and Yeager (1945:473), Korschgen (1952:35, 41, 46, 48), Llewellyn and Uhler (1952:198), animals that occur in Kansas and that are known to prey on the gray squirrel at least from somewhere within its range are: red-tailed hawk (*Buteo jamaicensis*), goshawk (*Accipiter gentilis*), Cooper's hawk (*Accipiter cooperii*), red-shouldered hawk (*Buteo lineatus*), great horned owl (*Bubo virginianus*), barred owl (*Strix varia*), weasel (*Mustela frenata*), mink (*Mustela vison*), red fox (*Vulpes fulva*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), wolf (*Canis lupus*), coyote (*Canis latrans*), domestic cat (*Felis* species?), and dog (*Canis familiaris*). The bobcat, gray fox, and goshawk, because of their rarity, along with the wolf that has been extirpated, are not so important in Kansas as are the other species. Kroschgen (*loc. cit.*), who studied the predators of game animals in Missouri, found that predation upon gray squirrels by other vertebrates was of only minor importance in affecting local squirrel populations.

In the course of my study, I found only one incident of predation upon the gray squirrel; a young male, at the Reservation, born in the spring of 1954, was found October 6, 1954, after having been partly eaten by either a dog or a coyote. Three days earlier, the squirrel had been live-trapped and tagged; the remains were 50 feet from the live-trap station.

Predators of the fox squirrel, reported by Dearborn (1932:1-52),

TABLE 15. PARASITES OF TREE SQUIRRELS IN KANSAS. SOME PARASITES WERE OBTAINED BY THE WRITER AND OTHERS WERE REPORTED IN THE LITERATURE.

Parasite		Fox Squirrel	Gray Squirrel
Group	Species		
Protozoa	*Eimeria* sp.	x	
	Amoeba (8 nucleate cyst)	x	
	Coccidia	x	
Cestoda	*Catenataenia* cf. *pusilla*		x
	Taenia pisiformes	x	
Nematoda	*Heligmodendrium hassali*	x	x
	Trichostrongylus calcaratus	x	
	Reticularia sp.	x(?)	
	Ascaris sp. (immature)	x	
	Citellinema bifurcatum	x	x
	Boehmiella wilsoni	x	x
	Enterobius sciuri		x
	Strongyloides robustus	x	x
Ticks (Ixodoidea)	*Dermacentor variabilis*	x	x
Mites (Parasitoidea)	Sarcoptidae	x	x
Fleas (Siphonaptera)	*Orchopeas howardii* (Baker)	x	x
	Hoplopsyllus affinis	x	
	Neohaematopinus sciurinus	x	
Chiggers (Acarina)	*Trombicula lipovskyi*	x	x
	Trombicula whartoni	x	x
	Trombicula sylvilagi	x	x
	Trombicula cynos	x	x
	Trombicula fitchi	x	x
	Trombigula g. gurney	x	x
	Trombicula trisetica		x
	Euschöngastia setosa	x	x
	Cheladonta micheneri		x
	Walchia americana	x	x
	Trombicula alfreddugesi	x	
	Trombicula lipovskyana	x	
	Trombicula joncsae	x	
	Trombicula kardosi	x	
	Euschöngastia diversa	x	
	Euschöngastia trigenuala	x	

McAtee (*op. cit.*:14), Bent (1938:306), Baumgartner (1940a:195-196), Errington and Hamerstrom (1940:791), D. L. Allen (1943: 217), Brown and Yeager (*loc. cit.*), Scott (1947:445, 472-474), Korschgen (*loc. cit.*), and J. M. Allen (*op. cit.*:102-103), include: raccoon (*Procyon lotor*), red fox, gray fox, bobcat, weasel, domestic cat, and dog, red-tailed hawk, red-shouldered hawk, great horned owl, and unidentified snakes.

The coyote may be an important predator of the fox squirrel in eastern Kansas. Fox squirrel remains were found in seven of 118 scats collected from the Reservation (see Fitch and Packard, 1955: 212). In three scats, fox squirrel made up the major bulk of the material. Scats containing fox squirrel were found in October, 1948 (2), November, 1948 (1), May, 1949 (1), June, 1949 (2), February, 1951 (1). Dr. Howard J. Stains (*in. litt.*) found the remains of fox squirrels in five of 705 raccoon scats from Douglas County, Kansas. The squirrel remains occurred in scats taken in April, 1953 (2), September, 1953 (1), October, 1953 (1), January, 1953 (1). He discovered fox squirrel in one of 55 raccoon stomachs that were analyzed. This raccoon was taken at Baldwin, Douglas County, Kansas, on December 10, 1952.

Snakes also have been reported as preying upon the fox squirrel in Kansas. Dr. James S. Findley recovered an almost full-grown fox squirrel (hind foot, 62 mm.) from the stomach of a 58-inch timber rattlesnake (*Crotalus horidus*) taken on August 31, 1952, one mile east of Lecompton, Douglas County. On October 20, 1954, a timber rattlesnake, caught three days earlier by Dr. Henry S. Fitch in Slope Woods at the Reservation, disgorged a male fox squirrel weighing 678 grams. Its testes were scrotal and measured 19 mm. by 14 mm., indicating that the squirrel was an adult. Most of the hair remained on the squirrel, and the state of digestion indicated that the squirrel had been eaten by the snake no earlier than mid-October.

The great horned owl has been recorded as taking fox squirrels in eastern Kansas by Packard (1955a:272). A pair of these owls nested on the Reservation in 1953 and 1954, and one individual was seen infrequently in Ridge Woods in 1953-54. Two or three pairs are residents of East Woods and Wall Woods. Pellets discovered at the base of some roosting sites of these owls yielded no fox squirrel remains. Fitch (*in. litt.*) recorded circumstantial evidence of an owl preying upon a fox squirrel when, on September 28, 1948, he found quantities of fox squirrel hair on Bulge Field, be-

neath a walnut tree. Near the squirrel hair were down feathers which he thought to be those of a large owl. One pair of great horned owls was resident on the Dillon Farm, south of the farm pond in the yellow oak-shagbark hickory community during both years of the study. Of 36 pellets examined, one, taken on December 5, 1954, showed hair of a fox squirrel.

The marsh hawk, American rough-legged hawk (*Buteo lagopus*), ferruginous rough-leg (*Buteo regalis*), raccoon, coyote, domestic cat, and dog are among the natural enemies of the fox squirrel in western Kansas. On December 21, 1953, in a shelter belt two miles south of Great Bend, Barton County, Kansas, I found the remains of a fox squirrel which presumably had been killed and fed upon by a coyote, since fresh coyote tracks led to the carcass. One mile south of the aforementioned shelter belt, I observed an American rough-legged hawk circling above another shelter planting. Below the flying hawk, two fox squirrels were seen moving under a red cedar, possibly evading this bird of prey.

Predators killed more squirrels in autumn and winter than at other seasons; squirrel populations then were most abundant and most active. The evidence points to heavier losses by the fox squirrel than by the gray squirrel.

REPRODUCTION

Both gray and fox squirrels breed twice each year in Kansas. Peak times of breeding were determined by observing times of matings, by examination of reproductive tracts of both males and females, and by observations of litters in the field.

Cowper's glands in adult male fox squirrels averaged more than 20 mm. in diameter from November of 1953 to early June, 1954, then decreased gradually from July through September, 1954, to from one to two mm. By late October of the same year, these glands increased in size, and in November, again averaged more than 20 mm. in diameter. Cowper's glands in adult male gray squirrels measured more than 20 mm. in diameter from January through early July, 1954. The glands decreased in late July and measured only from one to two mm. in diameter in August through mid-January. In February, 1955, Cowper's glands of gray squirrels again increased to more than 20 mm. in diameter. According to Brown and Yeager (1945:482), males are sexually active when the Cowper's glands measure more than 20 mm.

In Douglas County, mating-chases among fox squirrels were ob-

served: eight times in December, 1953; one time each in January, February, and March, 1954; two times in April; one each in May and June, and two in December, 1954. Mating-chases among gray squirrels were observed: two times in February, 1954; one time in May, and three times in June. According to Brown and Yeager (*op. cit.*:481), "The most obvious indication of breeding seasons in squirrels is in the mating chase."

Two gray squirrels copulated on the branch of an American elm tree at approximately 20 feet from the ground, in the Fence Woods-Hole Woods Area at the Reservation on March 5, 1954, while a third gray squirrel, presumably a male, was below them on the trunk of the same tree. This animal made several aggressive movements toward the copulating squirrels, but at each of these movements, the male involved in copulation left the female and by barking and trying to bite, caused the third squirrel to return to its original position. When the three squirrels detected the investigator, they departed through the trees.

Female fox squirrels, in oestrus, were examined in December of 1953 and 1954 and January of 1954 and 1955, and again in late April, 1954, on both study areas; female gray squirrels were found on the study areas in oestrus in February, March and June of 1954.

The number of litters seen, reproductive tracts examined, and females with embryos examined are listed in Table 16. The average litter-size for fox squirrel in 1954 was 3.1 and in 1955, was 2.2. Placental scars, counted in female fox squirrel reproductive tracts, averaged 3.04 scars in 1954, and 2.5 in 1955. Litters of gray squirrels averaged 2.25 young per litter. The reproductive tracts of female gray squirrels averaged 2.7 placental scars.

My studies, as well as others, show that litter sizes of these two species are small and that two litters are born each year. Several times, squirrels were observed to carry and defend their young in the spring of 1954 (see Packard, 1954b:471-472). On August 14, 1954, in Lawrence, Kansas, Robert J. Russell obtained a live young female gray squirrel weighing 159 grams that was being carried by an adult gray squirrel that had hold of the nape of the neck in the same manner that cats grasp their young to move them.

TABLE 16. LITTERS OF SQUIRRELS, PLACENTAL SCARS, AND EMBRYOS IN FEMALE SQUIRRELS EXAMINED PER MONTH.

	Litters Found	Average No. in Litter	Sex Ratio in Litters (♂:♀)	Reproductive Tracts with Scars	Average No. Placental Scars	No. ♀ with Embryos	Average Number of Embryos
Fox Squirrels							
1954							
January	0	0	0	0	0	0	0
February	3	3.3	3:2	0	0	0	0
March	2	3	2:1	2	3.5	1	2
April	0	0	0	0	0	0	0
May	1	4	3:1	0	0	0	0
June	3	2.7	3:1	3	3.3	1	3
July	1	3	2:1	1	2	0	0
August	0	0	0	2	3.5	0	0
September	0	0	0	1	3	0	0
October	0	0	0	1	2	0	0
November	0	0	0	12	3	0	0
December	0	0	0	0	0	0	0
1955							
January	0	0	0	0	0	0	0
February	2	2	3:1	0	0	2	2
March	2	2	1:4	2	2.5	1	2
Gray Squirrels							
1954							
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0
April	3	2	2:1	0	0	1	2
May	0	0	0	0	0	0	0
June	1	2	1:1	0	0	1	3
July	4	2.5	3:2	0	0	0	0
August	0	0	0	0	0	0	0
September	0	0	0	2	2	0	0
October	0	0	0	2	3.5	0	0
November	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0
1955							
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	0	0	0	0	0	2	2.5

Hunting

Of 225 questionnaires sent to squirrel hunters in 1953, 103 (46 per cent) usable returns came from 31 counties (25 from eastern Kansas, five from central Kansas, and one from western Kansas). Of 300 questionnaires sent in 1954, 88 (29 per cent) usable returns came from 28 counties (21 from eastern Kansas, six from central Kansas, and one from western Kansas).

In the autumns of 1953 and 1954, questionnaires were sent to squirrel hunters who were primarily residents of the eastern third of the State where there is the most squirrel hunting. A high percentage of returns for both years was received, indicating an interest by hunters in cooperating to achieve better management of these species.

A knowledge of the habits and opinions of Kansas squirrel hunters is useful in devising methods for managing squirrels in the State. How far does the average hunter walk, or does he usually "still hunt"; how many times in a season does he hunt squirrels; what per cent of Kansas squirrel hunters hunt alone and what per cent hunt with others, and what is the hunter's opinion of the present seasons? These questions were included in the questionnaires.

The average squirrel hunting party in 1953 included 1.7 hunters, and 1.6 hunters in 1954. Almost half of the hunts were by a single hunter (40.8 per cent in 1953 and 43.8 per cent in 1954). In 1953, 173 squirrel hunters went on 697 hunting trips and walked 1,561.8 miles while hunting, and in 1954, 128 hunters made 504 trips and walked 806.5 miles. Average distance walked in a single day's hunt in 1953 was 2.2 miles and 1.6 miles in 1954. A larger kill per hunter in 1954 probably was a factor shortening the distance covered in the average hunt. Information gleaned from interviews and by questionnaires indicates that the majority of Kansas squirrel hunters are both "still hunters" and stalkers; the style of hunting seems to depend on the conditions existing on the day of the hunt.

Squirrel hunters went hunting approximately the same number of times each year (4.02 times in 1953 and 3.93 times in 1954), and averaged almost three hours per hunt. Hunters, in general, bagged fewer squirrels per hunt in 1953 than in 1954 (see Table 17). The better hunting in 1954 seems to have been correlated with the favorable mast crop present in the winter of 1953-54. Although no figures on reproduction are available for the year of 1953, production was presumably less successful in that year than in the spring and summer of 1954.

Kansas squirrel hunters suggested that squirrel hunting-success in Kansas reached a low in 1953 as compared to the previous four to five years and began to rise in 1954.

No specific question was asked of sportsmen concerning the type of gun preferred, but many hunters interviewed by the writer stated that although they preferred a .22 caliber rifle for squirrel hunting, most of them used a 12 gauge shotgun, which enabled them to shoot other species of game as well.

MANAGEMENT

Opinions of Hunters and Farmers

Opinions of Kansas sportsmen and farmers should be given consideration when a management plan for tree squirrels is being devised. An analysis of interviews with these persons was made to discover their general opinions concerning summer and autumn hunting, bag limits, and other related matters. Many different ideas were expressed, and many opinions based on local conditions were obtained. Some hunters enjoy the sport of shooting squirrels in summer and early autumn when leaves are on the trees because at that time squirrels are more difficult targets than

TABLE 17. SQUIRREL HUNTING SUCCESS IN 1953 AND 1954 AS REPORTED BY HUNTERS THROUGH QUESTIONNAIRES.

	Total Squirrels Bagged	Squirrels Per Hunter Per Season	Squirrels Per Hunter Per Trip	Squirrels Shot Per Trip	Squirrels Bagged Per Mile	Squirrels Bagged Per Hour
1953—173 hunters						
Both Species	1,953	11.29	1.68	2.80	1.25	.98
Fox Squirrel	1,807	10.44	1.49	2.59	1.15	.91
Gray Squirrel	146	.84	.11	.209	.093	.073
1954—128 hunters						
Both Species	1,851	14.46	2.23	3.67	2.29	1.35
Fox Squirrel	1,710	13.35	2.06	3.39	2.12	1.24
Gray Squirrel	141	1.10	.17	.279	.174	.102

in winter and because there are many more palatable young squirrels than in late autumn and winter. Other hunters dislike summer and autumn hunting because they have killed many lactating females; so doing, they feel, may be a detriment to future squirrel populations. In addition, warm weather causes rapid spoilage of bagged game, and the numerous mosquitoes, ticks, chiggers, and other pests decrease the pleasure of summer hunting.

Farmers and landowners also have special problems involving the hunting of tree squirrels. Fox squirrels, where locally concentrated, in the eastern half of Kansas may eat excessive amounts of corn when it is in the milk stage, and in the southeastern part of the State, both species of squirrels cause some loss to pecan crops before the harvest in November. Kansans who raise these crops are interested in the reduction of squirrel populations in their areas. Many of these persons would like a season opening prior to the time when these crops become available to the animals.

It was the opinion of more than three-fourths of the hunters (85.7 per cent), who answered the questionnaires in 1954, that the present squirrel hunting season should be changed. At present, squirrels can be legally hunted in Kansas from June 15 through November 30, with a daily bag of eight and a possession limit of sixteen. This open season is the longest continuous one allowed in any of the midwestern states where squirrels are important game species. Among squirrel hunters, opinion was divided as to when the season should be, but 92.7 per cent suggested that the season should be open from as early as August to as late as December. The others suggested various seasons. Many sportsmen think the daily bag limit is too large.

Which species of tree squirrels do Kansas sportsmen prefer to hunt? The fox squirrel is larger and provides more meat for the table, whereas the gray squirrel excels the fox squirrel in sporting qualities. Most hunters interviewed expressed a hope that gray squirrels could be increased because they prefer to hunt them.

Biological Evaluation

Athough squirrel hunting in Kansas is an important sport, there is a need to increase squirrel populations in many places to improve hunting and to popularize further this sport. Whereas squirrels were hunted chiefly for food by early settlers, squirrel hunting today provides important outdoor recreation for many Kansans, as well as desirable meat for the table. The widespread interest

in squirrel hunting as a recreation in other states has been emphasized by Goodrum (1938:670), Baker (1945:8), Christisen (1950:1), Cross (1942:2), and others. With an increased knowledge of the natural history of the gray squirrel and the fox squirrel, a greater understanding of how to regulate the annual harvest can be obtained.

The study here reported on does not solve all problems relating to proper management of tree squirrels in Kansas, but does point out certain important facts. The two species are found to differ somewhat in behavior, time of reproduction, productivity, preferred living places, preferred foods, and daily activity. Time of reproduction and productivity seem to depend, in part, on food supply which varies from year to year. Therefore, any management plan for both species should take into account these differences between the two.

In the central and western parts of Kansas, squirrels are not abundant and receive little hunting pressure. Consequently, in managing squirrels, chief consideration should be given to those areas in eastern Kansas where squirrels are most abundant and hunting is popular.

Legal seasons should be based on an understanding of the reproductive cycles of the squirrels. Brown and Yeager (1945:525) state that in Illinois, "The chief objection to early season hunting is . . . the destruction of pregnant and lactating females." Data from my study show that care for young by females is almost completed by early September. Many young will not survive if lactating females are killed from June through August. Because the time of breeding is later in some years than in others, it would be well, if feasible, to determine annually, by field observations, the time of the peak of the early summer rut. When the rut was later than usual, there would be more suckling squirrels in September, and the season could be set accordingly later. The daily bag and possession limit should depend on the general condition of the squirrel population and its reproduction. In view of the current (1955) drought with its effect on food supplies of squirrels and the resulting effect on reproduction, we may, at present, be overharvesting our squirrel populations. Of the squirrel hunters interviewed, few were able to bag a day's limit, indicating that populations are not high enough to accommodate the present hunting pressure. Fortunately, when there are few squirrels, hunters hunt less than when squirrels are common.

Good gray squirrel range in Kansas must be maintained and improved if this animal is to remain abundant enough to make hunting it worthwhile. An annual census such as that made by the linear count, as outlined in this paper, might help to determine the ratio of gray squirrels to fox squirrels in selected areas in eastern Kansas. If the ratio in favor of the fox squirrel increases, it would indicate that gray squirrels were decreasing and might necessitate a reduction in the daily bag limit for gray squirrels. Preservation of large wooded areas of eastern Kansas to protect the mature nut-bearing trees for both food and den sites is especially important for the gray squirrel. Redmond (1943:387) suggests maintaining two den trees per acre in bottomlands in Arkansas. This suggestion seems appropriate for eastern Kansas. To increase suitable habitat for gray squirrels in eastern Kansas, oaks and hickories need to be planted and natural reproduction of these trees needs to be improved by reducing grazing of woodland. Ungrazed stands of at least 20 to 30 acres are necessary to maintain good local gray squirrel populations. Over-use of woodlots by livestock is more detrimental to gray squirrels than to fox squirrels.

In central Kansas, shelter belts and Osage orange hedge rows could be improved for fox squirrels by installing den boxes (for plans and proper placement see J. M. Allen, 1952:47, or Hesselschwerd, 1942:32). Winter feeding in central Kansas might be of importance in maintaining the smaller populations when winters are severe and when food is scarce. Populations of the fox squirrel can be increased in marginal areas by additional plantings of multi-purpose shelter belts. Retention of Osage orange hedge rows also increases the population of fox squirrels.

For both species, the opening of the hunting season should depend on the time of breeding in summer. Resulting young born in mid-July are partly dependent on their mothers even in late August. Chances for survival of these young, if deprived of their mothers, would certainly be greater in late August than shortly after they were born. An even larger per cent of young would survive if the opening of the hunting season were postponed until early September. At this time, there are still leaves on the trees, and young born in the spring would provide fine meat. The season should close not later than December 10; breeding among fox squirrels begins then. When they are in breeding condition, both sexes are more vulnerable to the hunter than at other times. Extreme vulnerability reduces the sport of hunting squirrels. Also, to interfere

with breeding might decrease the success of breeding and the future crop of squirrels. If based on the data obtained by my study, the open season for hunting should begin not earlier than late August or early September and should terminate not later than early December.

Taking account of existing biological information and incorporating it into a management plan will permit sportsmen, farmers, and other interested persons, working together, to continue the fine sport of squirrel hunting.

Summary and Recommendations

1. Agricultural use of the land has caused the fox squirrel to extend its range westward to include many parts of western Kansas, and has caused the gray squirrel to withdraw eastward to areas mostly east of the 97th Meridian (Manhattan eastward).

2. On two areas intensively studied, gray squirrels occurred only in dense or mature stands of oak and hickory, while fox squirrels occurred in the same habitat and in other woody situations as well.

3. On the University of Kansas Natural History Reservation, an area protected from grazing and hunting, there were more than twice as many squirrels throughout the study as there were on the Dillon Farm, a grazed and hunted area. More gray squirrels were on the Reservation than on the Dillon Farm. The winter carrying capacity in 1954-55 for the Reservation was 1.18 squirrels per acre, and for the Dillon Farm, .46 squirrels per acre.

4. In counties where both species of tree squirrels occur, hunters bag 11 to 12 fox squirrels to every gray squirrel.

5. Among adult squirrels, more males than females were found in each species. Litters still suckling, of each species, contained more males than females.

6. In late autumn of 1954, 59 per cent of the fox squirrel population was less than a year old.

7. Young and yearlings of both species move farther than adults, seemingly as a result of intra-specific intolerance.

8. Both species reacted the same way to relative humidity, wind velocities, and temperatures; gray squirrels, however, were most active in lower light intensities, whereas fox squirrels were most active in higher light intensities.

9. In a given unit of time, the observer can see more squirrels of each species in winter than in any other season. In winter, the observer can see more squirrels of both species from 7:00 to 8:00 A. M.

than at any other hour (at this season, the peak of activity is before 7:00 A. M. for the gray squirrel and after 7:30 A. M. for the fox squirrel).

10. The fox squirrel eats more kinds of foods than does the gray squirrel. No gray squirrel was seen to eat Osage orange, which is a staple food of the fox squirrel in Kansas.

11. Fewer walnuts, acorns and other nuts were produced in 1954 than in 1953.

12. Good den-trees are more important to the gray squirrel than to the fox squirrel. In Miami County, where one of the few virgin stands of climax oak-hickory is present in Kansas, many den sites are available, and gray squirrels outnumber fox squirrels approximately two to one.

13. Fox squirrels, born as late as March weigh almost as much as adults by September.

14. Diseases, parasites, and predation were not important limiting factors for squirrel populations in 1953-55.

15. Fox squirrels breed chiefly in December and January, and again in late April. Litters of this species were found in February, March, May, June, and July. Gray squirrels breed chiefly in February and again in early June. Litters of this species were found in April, June and July.

16. Hunters bagged more squirrels in the 1954 hunting season than in the 1953 season.

17. An open hunting season of August 1 to December 30 was preferred to the present season of June 15 to November 30 by 93 per cent of the sportsmen interviewed by questionnaire.

18. Most sportsmen believe the daily bag limit is too large.

19. Because time of breeding varies, an annual field investigation of the time of the summer breeding would provide a basis for setting the time for the beginning of the hunting season.

20. If gray squirrels are to increase, habitat good for them must be maintained. A 20- to 30-acre stand of mature oak and hickory with at least two den-trees per acre provides good habitat.

21. Counts to determine the species-ratio can be taken where both squirrels occur. If the number of gray squirrels decreases, the bag limit for this species should be reduced.

22. Fox squirrel habitat in central Kansas can be improved by use of den boxes, maintenance of Osage orange hedge rows, and planting of multipurpose shelter belts.

23. Data obtained from my study give basis for recommending a season of September 1 to December 10 for squirrel hunting.

BIBLIOGRAPHY

ALLEN, D. L.

1942. Populations and habits of the fox squirrel in Allegan County, Michigan. The American Mid. Nat., 27:338-379, 19 figs.

1943. Michigan fox squirrel management. Mich. Dept. Cons. Game Div. Publ. 100, 404 pp., frontispiece, 133 figs., 28 drawings in text.

ALLEN, J. M.

1952. Gray and fox squirrel management in Indiana. Ind. Dept. Cons., Div. Fish and Game. Pittman-Robinson Bull. 1, 112 pp., frontispiece, 64 figs., 7 drawings in text.

ALLISON, R.

1953. North Carolina gray squirrel investigations, 1947-1950. N. C. Wildl. Resources Comm. Pittman-Robinson (final report, 26R), 61 pp., 29 figs., Appendix XX pp.

BAKER, R. H.

1944. An ecological study of tree squirrels in eastern Texas. Jour. Mamm., 25:8-24, 5 figs.

BAKKEN, ARNOLD

1952. Interrelationships of *Sciurus carolinensis* (Gmelin) and *Sciurus niger* (Linnaeus) in mixed populations. Unpublished doctoral dissertation Univ. of Wisconsin. 1-188 pp., unnumbered appendix.

BAUMAN, F.

1949. Die freilebenden Saugetiere der Schweiz. Verlag Hans Huber Bern. xiv + 492 pp., frontispiece, 499 half-tone pictures, 66 drawings.

BAUMGARTNER, L. L.

1939. Food of the fox squirrel in Ohio. Trans. Fourth North Amer. Wildl. Conf., 579-584.

1940a. The fox squirrel: Its life history, habits and management. Unpublished doctoral dissertation Univ. Ohio State. 257 pp.

1940b. Trapping, handling, and marking fox squirrels. Jour. Wildl. Mgt., 4:444-450.

1943. Fox squirrel in Ohio. Jour. Wildl. Mgt., 7:193-202, 1 pl.

BAUMGARTNER, L. L., and MARTIN, A. C.

1939. Plant histology as an aid in squirrel food-habits studies. Jour. Wildl. Mgt., 3:266-268, 4 pls.

BENT, A. C.

1938. Life histories of North American birds of prey (part 2). Orders Falconiformes and Strigiformes. United States Nat. Mus. Bull. 170: viii + 466 pp., 92 pls.

BERTRAM, E. C., and GAULT, W. L.

1952. Kentucky squirrels, Dept. Fish and Wildl. Resources, Frankfort, Kentucky, 16 pp. mimeo., unnumbered appendix.

BLACK, J. D.

1937. Mammals of Kansas. Kansas State Board Agric., 30th biennial report, 35:116-217.

BROWN, L. G., and YEAGER, L. E.

1945. Fox squirrels and gray squirrels in Illinois. Bull. Illinois Nat. Hist. Surv., 23(5):449-536, 5 full page half-tones, 39 figs.

BRUMWELL, M. J.
1951. An ecological survey of the Fort Leavenworth Military Reservation. American Mid. Nat., 45:187-231, 6 pls.

BUGBEE, R. E., and RIEGAL, A.
1945. Seasonal food choices of the fox squirrel in western Kansas. Trans. Kansas Acad. Sci., 48:199-203, 4 figs.

CHAPMAN, F. B.
1938. Summary of the Ohio gray squirrel investigations. Trans. Third North Amer. Wildl. Conf., 677-684 pp.

CHRISTISEN, D. M.
1950. Are squirrels expendable? Missouri Cons. Comm., Missouri Conservationist, Aug., 1-3 pp., 4 half-tone pls.

COCKRUM, E. L.
1952. Mammals of Kansas. Univ. Kansas Publ., Mus. Nat. Hist., 7:1-303, 73 figs. in text, 37 tables, August 25.

CROSS, R. H., JR.
1942. Breeding habits and management of the gray squirrel in Virginia. Virginia Comm. of Fish and Game and Inland Fisheries. 1-5 pp., mimeo.

CUTLER, WILLIAM G.
1883. History of the State of Kansas. A. T. Andrea, Chicago, Ill., 1616 pp., 215 Illus., 52 views, 81 maps.

DEARBORN, N.
1932. Foods of some predatory and fur-bearing animals in Michigan. Univ. Michigan School of Forestry and Cons. Bull., 1:1-52.

DICE, L. R.
1923. Notes on some mammals of Riley County, Kansas. Jour. Mamm., 4:107-112.
1943. The biotic provinces of North America. Univ. of Michigan Press, viii + 78 pp., 1 map.

ERRINGTON, P. L., HAMERSTROM, F., and HAMERSTROM, F. N.
1940. The great horned owl and its prey in north-central United States. Agr. Exp. Sta., Iowa State Coll., Research Bull. 277:759-850 pp., 4 figs.

FITCH, H. S.
1952. The University of Kansas Natural History Reservation. Univ. Kansas Mus. Nat. Hist. Misc. Publ., 4:1-38, 4 pls., 3 figs.
1954. Life history and ecology of the five-lined skink (*Eumeces fasciatus*). Univ. Kansas Publ. Mus. Nat. Hist., 8:1-156 pp., 26 figs., 2 pls.

FITCH, H. S., and PACKARD, R. L.
1955. The coyote on a natural area in northeastern Kansas. Trans. Kansas Acad. Sci., 58:211-221.

FITCH, H. S., and SANDIDGE, L. L.
1953. Ecology of the opossum on a natural area in northeastern Kansas. Univ. Kansas Publ. Mus. Nat. Hist., 7:305-338, 5 figs. in text.

FLORA, S. D.
1948. Climate of Kansas. Rept. Kansas State Board Agric., 67:xii + 320, illus.

FREMLING, C., and GASTFRIEND, A.
1955. Seasonal abundance of the tick, *Dermacenter parumapertus*. Ecol., 36:162-163, 2 figs.

GOODRUM, P. D.
1938. Squirrel management in east Texas. Trans. Third North Amer. Wildl. Conf., 670-676 pp.
1940. A population study of the gray squirrel in eastern Texas. Texas Agr. Exp. Sta., A. and M. Coll. Bull. 591:1-34 pp.

GRAHAM, E., and UHRICH, J.
1943. Animal parasites of the fox squirrel, *Sciurus niger rufiventer*, in southeastern Kansas. Jour. Parasit., 29:159-160 pp.

GRINNELL, J.
1943. Joseph Grinnell's philosophy of nature. Univ. California Press Berkeley and Los Angeles. xv + 237 pp., 2 color pls., 2 half-tone pls., 1 drawing in text, 1 map.

HECK, O. B.
1951. A study of the adult helminths of the digestive tract and larval cestoda in tree squirrels in Douglas County, Kansas. Unpublished Master's dissertation Univ. of Kansas. 1-55 pp.

HESSELSCHWERDT, R. E.
1942. Use of den boxes in wildlife restoration and intensively farmed areas. Jour. Wildl. Mgt., 6:31-37.

HIBBARD, C. W.
1933. A revised check list of Kansas Mammals. Trans. Kansas Acad. Sci., 36:230-249.

HICKS, E. A.
1942. Some major factors affecting the use of two inventory methods applicable to the western fox squirrel, *Sciurus niger rufiventer* (Geoffroy). Iowa St. Coll. Jour. Sci., 16:299-305 pp.
1949. Ecological factors affecting the activity of the western fox squirrel, *Sciurus niger rufiventer* (Geoffroy). Ecol. Monogr., 19:287-302, 4 figs.

HICKS, E. A., and HENDRICKSON, G. O.
1940. Fur-bearers and game mammals of Iowa. Iowa Agr. Exp. Sta., Iowa St. Coll., Bull. P3 (new series), 116-145 pp., 12 drawings.

HOOVER, R. L., and YEAGER, L. E.
1953. Status of the fox squirrel in northeastern Colorado. Jour. Mamm., 34:359-364.

HUNGERFORD, K. E., and WILDER, N. G.
1943. Observations on the homing behavior of the gray squirrel. Jour. Wildl. Mgt., 5:458-460.

HUNT, E., and LORENCE, W. E.
1937. History of Fort Leavenworth, 1827-1937, 2nd ed. The Command and General Staff School Press, Ft. Leavenworth, Kansas. 301 pp., illus., pls. (1 fold), 3 diagr. (fold).

JEFFERY, L.
1937. A preliminary study of the southern gray squirrel, *Sciurus carolinensis carolinensis* Gmelin, in Missouri. Unpublished Master's dissertation Univ. of Missouri. 1-53 pp.

KNOX, M. V. B.
1875. Kansas Mammalia. Trans. Kansas Acad. Sci., 4:19-22 pp.
KORSCHGEN, L. J.
1952. A general summary of the food of Missouri predatory and game animals. Cons. Comm. Sta. Missouri. Pittman-Robinson report. 1-61 pp.
LANTZ, D. E.
1905. A list of Kansas mammals. Trans. Kansas Acad. Sci., 19:171-178 pp.
LEONARD, A. B., and GOBLE, C. R.
1952. Mollusca of the University of Kansas Natural History Reservation. Univ. Kansas Sci. Bull., 34:1013-1055 pp.
LINSDALE, J.
1928. Mammals of a small area along the Missouri River. Jour. Mamm., 9:140-146.
LLEWELLYN, L. M., and UHLER, F. M.
1952. The foods of fur animals of the Patuxent Research Refuge, Maryland. American Mid. Nat., 48:193-203 pp.
LOOMIS, R. B.
1956. The chigger mites of Kansas. Univ. Kansas Sci. Bull. In press.
MCATEE, W. L.
1935. Food habits of the common hawks. U. S. D. A., Cir. 370:1-36, 17 figs.
ODUM, E. P.
1953. Fundamentals of ecology. W. B. Saunders Co., Phila., Pa., and London, England, 384 pp., frontispiece, 119 figs. in text.
PACKARD, R. L.
1955a. Great horned owl attacking squirrel nests. The Wilson Bull., 66:272.
1955b. Notes on the defensive behavior of gray and fox squirrels while moving their young. Trans. Kansas Acad. Sci., 57:471-472.
REDMOND, H. R.
1954. Analysis of gray squirrel breeding studies and their relation to hunting season, gunning pressure, and habitat conditions. Trans. Eighteenth North Amer. Wildl. Conf. 378-389 pp.
RUXTON, G. F.
1849. Adventures in Mexico and the Rocky Mountains. John Murray, London. viii + 332 pp.
SANDERSON, G. C.
1954. Sex and age ratio of the squirrels in the bag and hunter success as reported by hunters, 1953. Quarterly Biology Reports, Iowa Sta. Cons. Comm., Des Moines, Iowa, 5 (no. 4):1-50 pp., mimeo.

SCOTT, T. G.
1947. Comparative analysis of red fox feeding trends on two central Iowa areas. Agr. Exp., Sta., Iowa St. Coll., Research Bull., 353:427-487 pp., 15 figs.

SETON, E. S.
1929. Lives of game animals. Garden City, New York. Vol. 4 pt. 1, xxii + 440 pp., frontispiece, pls. I-LI, maps I-XII, 29 synoptic drawings.

SHIPLEY, D. D.
1941. A study of the habits and management of the gray squirrel in southwest Virginia. Unpublished Master's dissertation The Virginia Polytechnic Inst. 1-166 pp.

SPERRY, C. C.
1941. Food habits of the coyote. U. S. D. I., Wildl. Research Bull. 4:iv + 1-70 pp., frontispiece, 2 full page half-tones, 3 figs.

TERRILL, H. V.
1941. A preliminary study of the western fox squirrel (*Sciurus niger rufiventer*) in Missouri. Unpublished Master's dissertation Univ. of Missouri. 1-164 pp.

WHITAKER, H. L.
1939. Fox squirrel utilization of Osage orange in Kansas. Jour. Wildl. Mgt., 3:117, 1 pl.

Transmitted January 30, 1956.