ECOLOGY AND ECONOMICS OF THE WESTERN FOX SQUIRREL, *SCIURUS NIGER RUFIVENTER* (GEOFFROY), IN PAYNE COUNTY, OKLAHOMA

By

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INTRODUCTION

This study on the ecology and economics of the western fox squirrel is for the purpose of augmenting the present information concerning this species, especially to help in its future management. The main objectives include: classification and evaluation of squirrel habitats, study of habits, determination of the breeding seasons, evaluation of census methods and study of populations, study of food conditions, appraisal of the effects of land-use practices, estimation of crop damage, and management.

Extensive field work was carried on within a ten mile radius of Stillwater, Oklahoma. Populations were sampled on four areas and studied intensively on two of the areas. The period of study extended from September, 1950, to January, 1952.

Review of Literature

The most comprehensive work concerning the fox squirrel would probably include that done by Allen (1943), who worked out the complicated breeding season; Baumgartner (1938, 1939, 1940, and 1943), who studied individual ranges and movements; and Brown and Yeager (1945), who emphasized the physiological aspects of breeding and management. All three employed live trapping as an inventory method. Goodrum (1940) developed techniques for gray squirrel inventories in eastern Texas which may be applicable in some situations to fox squirrels. Dice (1931 and 1941) discussed methods for estimating the populations of mammals. Baker (1944) used time-area counts for censusing squirrels in Texas. Duck and Fletcher (1944) in Oklahoma concluded that the only successful census

required the use of a squirrel dog. Hunt (1950) evaluated census methods applicable to fox squirrels with emphasis on the time involved for each method.

Katz (1939) compiled references concerning parasites of squirrels. Baumgartner (1940) and Allen (1943) reported that mange was a serious mortality factor among fox squirrels. Grahm and Uhrish (1943) determined the animal parasites of the western fox squirrel in Kansas. Brown and Yeager (1945) discussed parasites of Illinois squirrels. Goodrum (1940) believes that the chigger is the most serious external parasite of the gray squirrel in Texas, with 75 percent of the squirrels shot during the summer being infested.

Life history and ecological studies were conducted by Seton (1928), Baumgartner (1940), Terrill (1941), and Allen (1943). Both Allen and Terrill mention damage to field corn in the "milk stage." Taylor and Davis (1947) referred to "nuisance squirrels" in Texas corn fields and state that, "In the Hill Country, because they destroy much of the pecan crops, they are regarded as pests to be kept under control." According to Yeager (1936), fox squirrels sometimes seriously damage elm shade trees by stripping off the bark.

Acknowledgements

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MATERIALS AND METHODS

To compare crown composition as affected by grazing and site location, transects one-hundred yards long and twenty yards wide were run at three points along grazed and ungrazed streambed areas and an oak ravine. Topography, soil, density of ground cover, and other ecological conditions were also noted. All trees which had a DBH of 6 inches or more (measured by a diameter tape) were classed as dominant types. Trees from 6 inches to 1 inch were classed as subdominant types. The smaller seedlings were not counted.

Observation posts were set up at all hours of the day to determine squirrel activity in relation to weather factors, time of day and food conditions.

Trees were climbed to investigate "likely-looking" nests and dens. A flashlight equipped with a mirror attachment, made it possible to see into dens to note occupancy or recency of usage.

Live traps, illustrated on page 26, were used in the 1950 winter census. Trapped squirrels were ear-tagged for identification. Traps were baited with a variety of materials, ear corn being the most successful. Census methods are described in detail under "Populations." Snow track counts were conducted at mid-morning following a 6-inch snow. Practically all of the tracks in the snow were accompanied by diggings. A complete den count was made in all cases. Summer leaf nests were sampled by transects, as previously described. Time-area counts, "clean-up" census, and nest densities were used to estimate squirrel numbers during the summer of 1951. Den counts were compared with those of other areas.

Breeding data were gathered by the examination of nests for litters and by examination of adult female squirrels for signs of pregnancy. This information was supplemented with field observations on breeding activities. Squirrels handled during the hunt were inspected for parasites. Stomach contents of these animals were also noted. Feeding habits were observed directly by watching squirrels eat, and indirectly by noting cuttings or marks of gnawing.

Damage to crops were noted in the field from June 1, 1951, to January 1, 1952. Depredations to the pecan crop were studied intensively by sampling the utilization of pecans from a native pecan orchard. Single plots, 16 yards square, were placed under 5 trees. Pecans utilized by squirrels from these plots were counted as representative samples of the total crown areas of the trees. A detailed discussion of this procedure appears under the heading of "Damage to the Pecan Crop."

ECOLOGY

Physiography and Climate

Physiographically, the state of Oklahoma is principally a plain sloping from the high mesas in the panhandle of northwestern Oklahoma to the heavily timbered, southeastern corner of the state.

This area of 70,470 square miles represents botanically, a transition zone between the typical lower Mississippi Valley and South Rocky Mountain regions. The Cross Timbers, a forest of post oak and blackjack, divide the state generally down the center. Vegetative growth is influenced by

the hardwoods of the Missouri Valley in the eastern part of the state, flora of the gulf plain in the south, and the more northern floras (Anonymous, 1917). A timbered band approximately ninety miles wide, running along the eastern boundary of the state, comprises the major forested area in Oklahoma. There is a gradual thinning of eastern species of plants toward the western part of the state as many reach the western limits of their range. The western portion of the state is mostly void of timber growth except along stream courses and on the sandhills. The level uplands are mostly grass covered.

Payne County is located in the north-central part of the state, extending from R. 6 E., to R. 1 W., and from T. 17 N., T. 20 N. The county is composed of approximately 716 square miles, the southern half of which is generally forested while the northern half is a tall grass prairie. Elevation varies from 1,140 feet in the western edge to 800 feet in the valley of the Cimmarron River in the eastern portion of the county. The Cimmarron River flows through the county at its southern boundary with Stillwater Creek being the main tributary. There are no other major water courses or large streams within the county. Payne County lies mostly within the sandstone hills region (Koschmann, 1930). The extreme western part is in the red beds plains.

The average annual precipitation for Payne County is 33 inches (Yearbook of Agriculture, 1941). Rainfall is low during the months of December, January, and February, with an average of slightly more than one inch per month. During April, May, and June, a rainfall of about four inches monthly is normal. Rainfall is erratic, sometimes being almost torrential in the spring and summer. Snowfall is quite variable from year to year and seldom covers the ground for more than two weeks at a time.

Temperatures of 100 degrees or higher may be expected from June through September. The summers are long with occasional periods of very high daytime temperatures. The average length of the growing season in Payne County is 213 days. High summer temperatures almost invariably accompany clear skies and are attended by dry, moderate winds from the south and southwest. Generally, winters are mild and of short duration. Wide temperature fluctuations occur and a sudden drop in temperature of 40 or 50 degrees in one day is not uncommon in fall and winter months.

A southerly wind prevails, except during winter months when northerly winds predominate.

Fox Squirrel Habitats

Classification of Habitat Types.

The squirrel habitats considered in this study belong to the post oak-blackjack forest. Actually, two distinct game types were studied: (1) the streambed or bottomland and (2) the oak woods. Bottomland game type comprises 5.3 percent, and post oak-blackjack forest 42.7 percent, respectively of the total area in square miles in Payne County, Oklahoma (Table I). The remaining area is composed of tall grass prairie. The fox squirrel habitat in Payne County is found primarily along the main water courses, and secondarily along the oak woods bordering them. Fox squirrels occur occasionally over extensive oak woods areas not associated with the bottomland type. In other instances, they are entirely absent from such woodland.

Description of Study Areas.

1. Area I - Grazed Streambed. This 55-acre timbered area on the southwestern outskirts of Stillwater, Oklahoma was located along Stillwater Creek on property owned by Mr. Herman Hinrichs (Figures 1 and 2). The site was typical bottomland for central Oklahoma. Along this section of stream bottom, the fertile, alluvial soil normally supported 15 or more different species of trees of which pecan, black walnut, elm, and hackberry constituted 83.5 percent of the dominant types. There were few subdominant species and practically no seedlings due apparently to prolonged heavy grazing, as shown in Table II. The growth of understory and vines has been greatly suppressed by browsing livestock. Ground vegetation, even in the summer, is sparse. Livestock, at a rate of more than one cow to two acres, was stocked on this timbered streambed area the year around. The creek is bordered by corn and alfalfa fields, a pasture, and a variety of truck crops.

The important food-producing species included: pecan, elm, black walnut, bur oak, Kentucky coffeetree, and mulberry trees. Elm, pecan, cottonwood, and bur oak trees supply nearly all of the available dens.

2. Area II - Ungrazed Streambed. A 16-acre section of Stillwater Creek on the Lake Carl Blackwell Land Use Project area was chosen for both crown composition and population studies. This area is representative of the timbered creek bottom, but had been closed to hunting and grazing for the past ten years. The greatest width of the timbered section is about 200 yards, but averages about 150 yards. Hackberry, elm, and soapberry trees comprise 74.8 percent of the dominant species types, 83.9 percent of the subdominant species types, and 77.7 percent of all species types, as illustrated in Table III. The understory and ground cover are relatively dense. A rank stand of seedlings and weeds grow along the outer edge of

the timber (Figure 3). Crop associations included: corn and alfalfa fields, blackberries, and an apple orchard.

The important food-producing species include: bur oak, elm, mulberry, Kentucky coffeetree, and black walnut. These trees comprise 40 percent of the dominant species types. Elm, cottonwood, and bur oak trees are the only important den trees.

Defoliation as a result of a heavy infestation by lepidopterous larvae severely damaged black walnut and box elder trees during the summer of 1951.

3. Area III. This study plot comprises a portion of an oak-elm-hackberry ravine and is bordered by a post oak-blackjack oak forest. It is influenced somewhat by bottomland type, which is desirable for squirrel habitat; yet it is also typical of the more habitable oak woods range. This area was studied primarily for comparison with the bottomland type. The ravine was lightly grazed and had no crop associations. The topography is characteristically a rolling plains with the tallgrass prairie-oak woods savanna traversed by intermittent, oak-bordered streams. The soil is sandy, porous and subject to washing. This ravine is located on Hardy's farm, three miles west and one mile south of Stillwater, Oklahoma.

The three species, oak, hackberry, and elm compose 98 percent of the dominant crown cover. Post oak trees dominate the timber types in which 60 percent are dominant species and 38 percent are subdominant species. The oak trees are scrubby, growing to an average height of about 30 feet and having an average DBH ranging from six to ten inches in the dominant species class. Eight to ten different species of trees commonly occur in the oak woods. The understory and ground vegetation is dense in the wide, flat oak ravine bottom section, but becomes progressively less dense as the ravine narrows and deepens toward the upland oak section.

The important food-producing trees which occur along the oak ravine include: post oak, blackjack oak, chinquapin oak, and elm. These trees comprise 80 percent of the dominant species of crown cover.

4. Oak "Islands." Ecologically, a vegetative island is any pattern of plant life completely surrounded by dissimilar plants and dissociated from similar plant areas. The oak forest - prairie ecotone of central Oklahoma is characterized by such associations (Figure 4). Oak "islands" in this part of the state contain two or three species of oak: Quercus marilandica, Q. stellata, and Q. velutina. Buckthorn, hickory, and redbud trees sometimes comprise an important part of the crown composition of such isolated timbered areas. These "islands" serve as summer and winter ranges for fox squirrels. Because of their association with range pasture, the oak islands are generally grazed, and a browse line on the trees is noticeable. No crops are directly associated with these savannas. The "islands" are always located near the crest of a hill and on sandy, porous soils, but with well drained slopes. The trees are scrubby, dense, and grow to an average height of 25 feet. They have an average DBH of about six inches. Grazing and trampling by livestock greatly suppresses ground vegetation and understory. Fox squirrels rely solely on leaf nests for protective cover as well as for the rearing of young. Because of the scrubby nature of the trees, no dens are available for the squirrels. A summer nest density of 2.2 nests per acre was ascertained for one oak woods "island."

Oak trees supply the primary source of food. Hickory, redbud, and buckthorn trees are added food sources in some localities.

Figure 1. January 31, 1951. Dense growth of mature pecan trees in Area I along Stillwater Creek producing a crowding effect.

Figure 2. January 21, 1951. Large pecan and bur oak trees in the woodlot on Hinrichs' farm provided a stable mast crop during the 1950-51 winter seasons.

Figure 3. August 16, 1951. A fence row with dense vegetative growth provided an excellent travel lane connecting Stillwater Creek (Area II) with another ravine system.

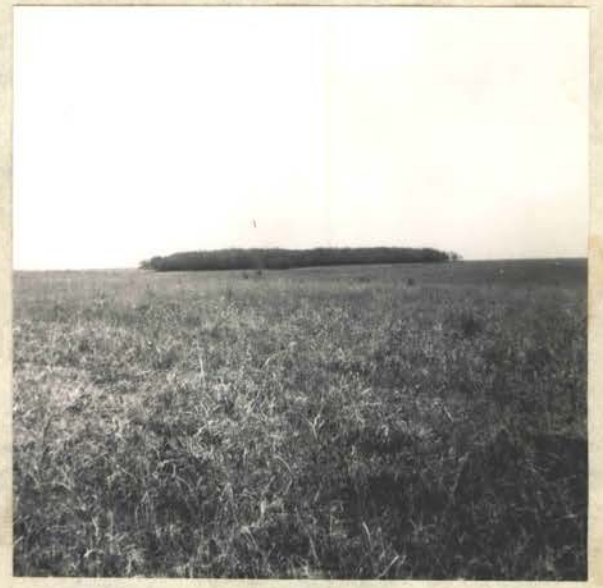

Figure 4. April 26, 1951. A 1.3 acre oak "island," 27 miles east of Stillwater, Oklahoma, surrounded by tall grass prairie. A litter of three young squirrels was taken from a leaf nest in this wooded patch.

Comparison of Habitat Types.

Due to continued heavy grazing, there are fewer trees per acre in the grazed streambed than the ungrazed streambed (Table IV).

TABLE IV

Tabulation of Species, Types and Totals for Species Classes per Acre with Crown Cover Relationship

	Area I Grazed	Area II Ungrazed	Area III Light Grazing
No. dominant species types	12	12	6
No. subdominant species types	8	10	7
Total No. dominant trees per acre	226	373	202
Total No. subdominant trees per acre	31	639	818
Total No. trees per acre	257	1012	1021
Crown cover in percent	85	85	65

Important mast-producing species are more numerous along the grazed streambed. (Sycamore, hickory, pecan, and black walnut trees are at the western limits of their range on Stillwater Creek in central Oklahoma and diminish progressively in numbers from east to west along this stream.) Bur oak and mulberry trees are three and 26 times more numerous, respectively, in the ungrazed section. A greater abundance of these two important food-producing trees was undoubtedly influenced by the restriction of grazing. Subdominant species are 20 times more numerous in the ungrazed area. Practically no seedlings are present in the heavily grazed area. Wahoo and rough-leafed

dogwood trees occur along ungrazed portions of Stillwater Creek, but are rare in grazed sections.

The summer leaf nest counts for the grazed and ungrazed sections were the same, suggesting that the squirrel population density was comparable. There are .9 dens per acre in the grazed section and .8 dens per acre in the ungrazed section.

The significant contrasts between the bottomland type and the oak woods type considered the following factors: differences in the timber stand, soil, slope, surface water sources, and crop associations. A qualitative comparison of habitat types is presented in Table V.

Fertile soil of the streambeds and bottomlands support a greater variety, and as far as the squirrels are concerned, a better quality of timber. Elm trees, which furnish more than half of the available dens, are from two to six times more numerous along the bottomland than along the oak ravines. Bur oak, black walnut, pecan, ash, mulberry, cottonwood, soapberry, Kentucky coffeetree, willow and boxelder trees are restricted primarily to the bottomland types because of higher soil and moisture requirements. A list of the tree species mentioned in this study is presented in Table VI. The average DBH of the dominant trees growing along the streambed was found to be from 11.4 in the ungrazed section to 13.4 inches in the grazed section, as compared to an average DBH of 8.6 inches for dominant species in the oak woods. The average percent crown cover for the streambed was 85 percent, whereas along the oak ravine it was 66 percent (Table IV). Soils of the streambeds or bottomlands are less subject to washing and leaching due to both decreased porosity and decreased slope. Stillwater Creek offers a stable surface water source. Intermittent streams in the oak woods become dry in the summer. Corn, which served as the only important crop associated with the fox squirrel habitats, was restricted to the bottomland type.

The timbered bottomland of Stillwater Creek provides a stable habitat for many squirrels, while the oak woods has a lower population of which many individuals are transient. The oak woods serves as an area to produce and rear young, a habitat for a few resident squirrels, an area for expansion when populations reach high levels, and a travel lane through which squirrels move from one major stream system to another.

Life History

Description.

All of the fox squirrels handled were of the characteristic rufous color on the back. A brown color phase was reported by hunters near Stillwater. The belly varied from an orange-buff to creamy white. Twelve adult squirrels were measured and weighed during the summer of 1951. The average body length of males was 10.12 inches. Males average 1.47 pounds while females weighed 1.56 pounds. Both lengths and weights indicate that fox squirrels in Oklahoma are smaller than those in Michigan (Allen, 1943; and Hunt, 1950) and in Illinois (Brown and Yeager, 1945).

Activity.

General activity of the squirrels is definitely seasonal. The daytime winter activities range mostly between the hours of 8:00 a. m. and 5:00 p. m. Fox squirrels are greatly affected by temperature fluctuations, and their activities often vary directly with the prevailing temperatures. During cold winter mornings when the sky is cloudy, squirrels stay in their dens. The warmth of the afternoon sun usually brings them out to forage

on the ground for food, or to loaf. The squirrels are usually active for two hours or more during fair winter mornings.

There seems to be a distinct period of increased activity between 8:00 a. m. and 10:00 a. m., and a lesser afternoon peak between 2:00 p. m. to 3:00 p. m. (Figure 5).

During the warmer periods of the year, squirrels are active for a longer length of time during the day. Squirrels are seen principally between dawn and 9:30 a. m., and after 4:30 p. m. to dusk in the evening. Very little activity is noticed before dawn, but squirrels are quite frequently seen after dusk, especially during the mast season.

The effect of temperature on squirrels is rather consistent and is probably the most reliable weather factor in predicting activity. Although no direct observations of squirrel activity were made at temperatures below 35 degrees Fahrenheit, many signs were seen. Tracks were seen in the snow while temperatures ranged near 0° F. The maximum temperature when squirrels were seen was about 90°. During late winter and early spring, the temperature range at which most of the squirrels are seen was between 45 and 55 degrees F. (Figure 6).

There seems to be little relationship between wind and activity. However, wind, when accompanied by low temperatures, may have been an important factor inhibiting squirrel activity. Wind seems to hamper the squirrels' movements through the trees by throwing them off balance. Sudden gusts move the branches so that jumping from branch to branch becomes more difficult.

Cloudiness alone has little effect on relative activity of squirrels. Whenever accompanied by cold winds, a cloudy sky seems to reduce sunning as well as general movements. Squirrels are much more difficult to see under conditions of complete cloudiness.

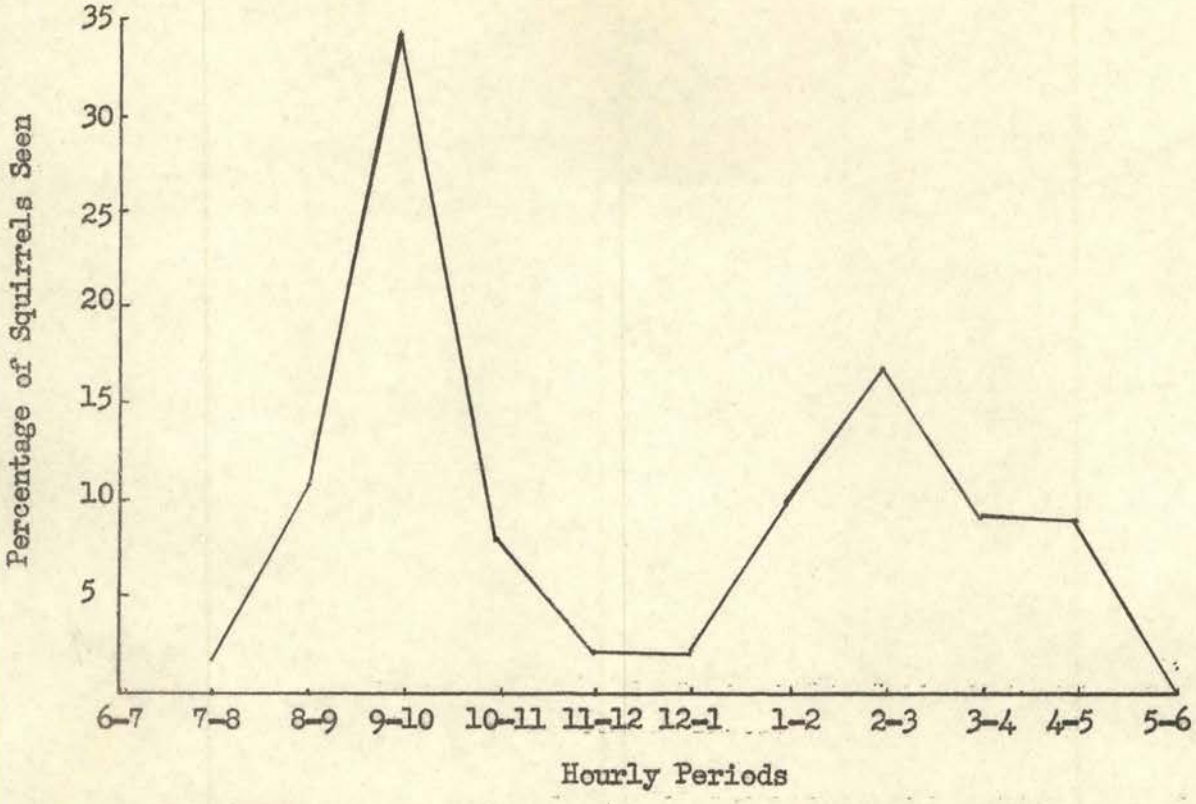

Figure 5. Daily acitivity of 40 fox squirrels from February 16, to April 6, 1951.

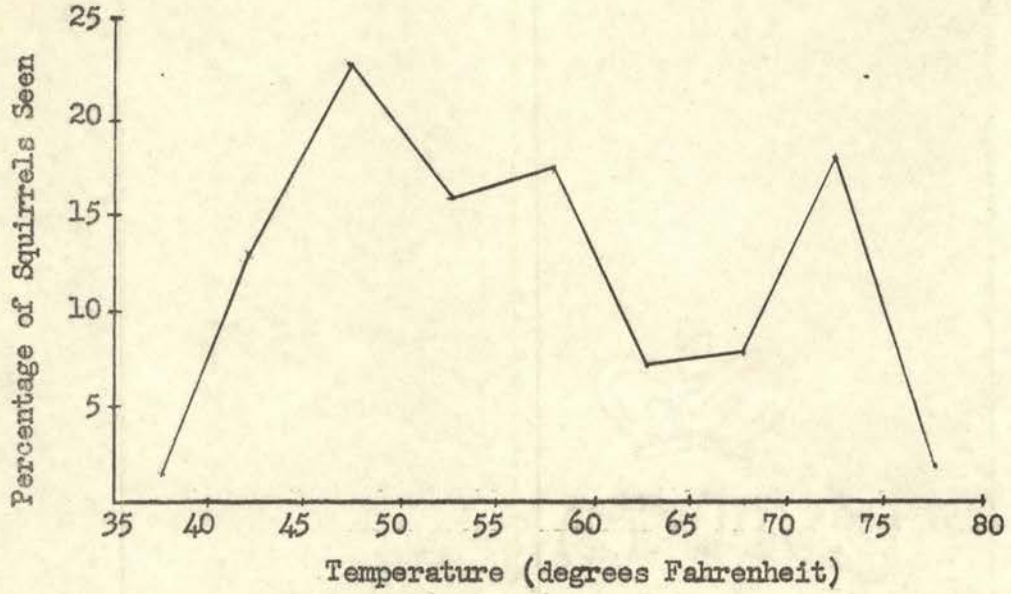

Figure 6. Activity of 40 fox squirrels based on temperatures from February 12, to April 6, 1951.

One observation was made under conditions of dense fog on February 31, 1951. The fog remained from early morning until 10:00 a. m. Visibility was approximately 50 to 85 feet. One squirrel was seen alone on the ground. Six squirrels were seen along the creek engaged in breeding chases. Other conditions of haze and slight mist had no apparent retarding effect on squirrels' actions.

The role of humidity as it affects squirrels' activities is little known. In these studies, a high humidity seemed to have a stimulating effect. This may possibly be explained by the fact that a high humidity would improve the sense of smell. During periods of drouth, squirrels might be aided in the recovering of stored food.

Activity in relation to snow can be more clearly determined than with some of the other weather factors. Snow tracking to indicate relative activity, and as a census method provides another tool useful in management of squirrels. The snow of the week of February 15, 1951 provided excellent tracking conditions. Tracks were traced to determine their range of activities, and individual counts of activities were recorded for inventory purposes. The snow depth varied from six inches to several feet in some drifts. The amount of activity varied with each squirrel. Many of them traveled just a few yards and made from one to four diggings. The minimum distance traveled from the den tree was two yards, the maximum was 30 yards. The average radius of activities from the den tree was about 15 yards. This coincides with the work by Baumgartner (1943) in Ohio. Often several trees were climbed, but sometimes only the den tree was climbed after securing the food. Most of the food dug up had been cached at the base of trees and often near the den tree so that a minimum of movement was required to secure the food.

There was a limited amount of activity by nearly all of the squirrels. They usually traveled only short distances and obtained a minimum of sustenance. The period of activity was very short.

The squirrels evidently found the buried mast by their sense of smell. They dug through the six to eight inches of snow, and if the nuts were buried in the ground they continued to dig. The snow acted as insulation so that the soil was not frozen.

No squirrels were seen during the period while the snow covered the ground. The temperatures ranged from 5 to 20 degrees, wind velocity from 0 M.P.H. to 25 M.P.H., cloudy to clear skies, and intermittent light to heavy snow alternating with periods of no precipitation.

The role of rain as a weather factor was essentially important during dry periods. There seemed to be a marked increase in activity after rains. At such times diggings were much more numerous. Squirrels had been seen in the presence of a light drizzle, but no observations were made during downpours. Precipitation was especially important in softening the soil to permit digging by squirrels, and moist soil aided the squirrels' sense of smell (Cahalane, 1942).

The physical character of the soil, whether dry, moist, or frozen, directly affected the ability of squirrels to procure food. One of the most difficult periods for squirrels was winter drouth. No measurements of weights during the dry periods were made, but these animals probably loose some weight during this period. Allen (1943) reported a decrease in Michigan fox squirrel weights during winter. An ice-covered ground prohibited digging for stored mast. Furthermore, ice-bound limbs make perilous traveling conditions through the trees.

One of the best methods of indirect observations which was used as an index to populations was the recency and frequency of diggings. This method was applicable during winter months when the squirrels relied heavily on stored mast crops.

Tracks in mud, snow, and dust indicated relative activity, and were important in census work, and in food studies when associated with diggings. Cuttings of bark, twigs, buds, mast, and other similar activities were often important in food studies and nesting habits. Evidence of gnawed shells, twigs, and other debris along paths marked squirrel runways. Although there was some use of runways by squirrels, they used them much less than some of the smaller rodents.

Migrations and Movements.

Accounts of mass movements by gray squirrels and lesser movements by fox squirrels are scattered throughout the literature. To the best of my knowledge there are no stories of thousands of fox squirrels migrating up and down Stillwater Creek.

Local, small-scale movements of a limited number of individuals are rather common in the spring and fall months. On one occasion seven fox squirrels were observed traveling in a group on a slope along Stillwater Creek. This action may have been associated with a shortage of food or possibly with breeding activities. At this time the soil was extremely dry and hard, making it difficult to dig up cached food. Shallow diggings by squirrels were observed from time to time, but apparently they were unable to procure many of their cached nuts. Young squirrels are commonly seen along roadsides in the spring of the year. During May, 1951 numerous squirrels were seen crossing alfalfa fields and moving through travel lanes to other timbered ravines and to oak woods sections.

Courtship.

Goodrum (1940), reported that gray squirrels in Texas were polygamous and at times congregated in great numbers while breeding.

In Oklahoma, from three to six fox squirrels were involved in the mating chases. Often a female was chased by one or more males. The males exhibited keen rivalry, with one of them being the aggressor, fighting off all other males. When one male tired another took up the chase. The chase was accompanied by much chattering and indescrible sounds made by the animals. The procedure consisted of short chases, alternating with periods of resting. During the chases, a male would make rapid bursts of speed but seldom succeeded in overtaking the female easily. When the female was finally overtaken, she promptly turned and drove the pursuing male away. The whole affair was noisy with much scrambling around the trunks and dashes across the ground. Sometimes they would start at the bottom of the tree trunk and spiral upward, with the male following only a few inches behind. The concentration of squirrels, the noise and their apparent unawareness during breeding activities may make them more vulnerable to predation at this time. Duration of the mating chase was prolonged and in one chase lasted more than one hour and fifteen minutes. Copulation was not actually observed.

Breeding Season.

Authorities concerning the fox squirrel agree that there are two major breeding seasons. Baumgartner (1940), Allen (1941) and Brown and Yeager (1945) report winter and summer breeding peaks.

Due to only meager information, the breeding periods in Oklahoma have not been definitely defined. Only six litters were handled during the 1951 season. One young squirrel was found March 1, 1951. Its age, estimated at

three weeks (based on age characters described by Allen, 1943), indicated an early breeding period, probably about December 25. Three more litters were found in April and two in August. This evidence suggests a breeding period from about December 25 through July. A preponderance of juvenile squirrels were seen during April and May, 1951. Young squirrels seen in May appeared to be about the same age. The size and weights of young squirrels shot during May was quite uniform. Thus a heavy, early breeding season presumably exists in Oklahoma and possibly corresponds closely with the breeding season in Michigan as determined by Allen (1943).

Births of young squirrels were recorded from the second week in February through August. Of the litters obtained, two were secured from pregnant females which had been shot and four were taken from nests.

Chronological Development of Young.

The development of young fox squirrels has been adequately described by Allen (1943, p. 117-120). The following is an attempt to describe the sequence of events in the chronological development of the young squirrels in Central Oklahoma. The period from February 8, to March 1, represents the birth period for most of the spring litters. By March 7, the majority of young squirrels had their eyes open. At this time their ages ranged from four to seven weeks. By April 18, many young squirrels were from 10 to 13 weeks old and were actively scurrying about. They were mostly independent by the middle of May, but remained close to the home den. They moved about quite a bit, often traveling in groups of two's or three's, the younger ones occasionally tagging after their mothers. The young exhibited gregariousness and enjoyed feeding and playing together. At this time many were seen

crossing roads and moving through travel lanes. By the last week in May, most of the young squirrels born in early spring were weaned and completely independent. The development of young squirrels in Oklahoma is possibly three weeks in advance of Michigan fox squirrels. The earliest births recorded by Allen (1943) were in mid-February and most of the young were born in March. Births of summer litters in Oklahoma occurred from late June through August. Summer young may be expected to be seen from mid-August through September.

Nesting.

Nests used for wintering are bulky leaf nests, or smaller, compact twig nests. The leaf nests are rather loosely arranged and a variety of lining materials are found in them. Twig nests, used only for wintering, are found only in post oak or blackjact oak trees. These are tightly woven and round in shape. The exterior is composed of stout oak twigs with the leaves stripped from them. The twigs are woven compactly as a base with either a grass or leaf lining forming the interior as well as the top surface of the nest. Twig nests were fewer in number than leaf nests. Recently occupied leaf nests appeared from ground level to be oval in shape indicating that they were intact. Flat-topped nests characteristically had the top blown off by wind and were not utilized.

Leaf nest-building activities were mostly restricted to the second and third weeks in May. Lesser, late-summer nest-building activities were observed in August and September. The number of summer nests in the bottomland type reached a density of 7.3 nests per acre, while in the oak woods it varied from 2.2 to 3.3 nests per acre.

Small twigs are fashioned so that their trimmed ends face outward at an angle producing a hollow cavity within. The inner lining is pressed flatly from the inside so that a relatively smooth surface is formed. Repair and use of crow nests by squirrels is common. Leaf nests are repaired in early fall in preparation for winter.

Material used for nest construction varies with the habitat. Along creeks associated with oak woods, leaf nests are built of oak twigs containing their leaves. Along streambeds not associated with oak woods, nests are constructed of various materials including bur oak, elm, hackberry, willow, and pecan twigs. The types and sizes of trees used for nesting are variable. Elm trees are favored building sites along streambeds, while oak trees are most commonly used in oak ravine bottoms. Post oak, blackjack oak, elm, bur oak, hackberry, willow, and cottonwood trees all are commonly used.

Lining material includes roots, grass, shredded bark, leaves, rags, and horsehair. The lining substances are generally chewed into fine pieces. Oak leaves and bluestem grass (Andropogon furcatus) are the most frequent lining material in the oak woods. Leaves of bur oak, elm, pecan, and hackberry trees are mostly frequently used in nest construction along streambeds.

The entrances to the nests are characteristically located on one side and often near the top. The diameter of the entrances is not more than two and one-half inches.

The majority of nests are located in the crotch of a tree, but occasionally one is placed on the side of the trunk, attached to branches.

Nests are built from heights ranging from 20 to 60 feet, averaging about 25 feet from the ground. Due to the additional supporting effect, nests are preferably built in grape vine and green briar tangles.

Twig and leaf nests are used for wintering, for rest and refuge in summer, and for rearing young. During the winter, nests along ravines associated with oak woods are commonly used. There is very little utilization of nests along the streambeds from October to May. Nests used for winter litters are found primarily along oak ravine systems. One nest, containing a litter of three young squirrels, was found in an oak "island" April 26, 1951, 27 miles east of Stillwater on highway 51. This 1.3 acre area is completely surrounded by prairie and was isolated from any other timbered association (Figure 4).

Investigations to determine the utilization of winter nests by fox squirrels were conducted by examining leaf nests along oak ravines and streambeds (Table VII). Only 26 usable nests were found in approximately eight linear miles of streambed and oak ravine. Of 39 "likely-looking" nests examined, seven were occupied and 12 had definitely been used recently. All of these were associated with oak woods areas. Many remnants and nest fragments were seen, but few of them were examined. For every three "nests" seen only one appeared to be intact. Actually two-thirds of the "likely-looking" nests were intact. Four of 39 nests contained litters of young squirrels.

Squirrel nests were found to be occupied by opossum, deer mice, and birds. A great-horned owl was seen perched on top of an old squirrel nest. When nests were inhabited by other animals, they were in poor condition and apparently abandoned by the squirrels. An aerial wood rat nest, 25 feet above the ground, was found in a post oak tree August 16, 1951 at a Lake Carl Balckwell picnic area. Although the nest by all outward appearances, had been built by a fox squirrel, it contained an adult female wood rat with two young rats. The nest cavity was smaller than that of a typical fox squirrel nest, being four inches wide and five inches high.

Dens.

The average entrance diameter to 11 dens was 2.5 inches wide and 3.2 inches high. The average depth of many of the dens examined could not be measured because they led into either hollow trunks or into hollow, crooked limbs.

The height of the dens ranged from 60 feet to ground level. Twenty-five dens had an average height of 25.8 feet from the ground.

Occupied dens usually had gnawed marks around their entrances. Those dens whose entrances faced downward were more favorable than those dens whose entrances faced upward. Den entrances facing upward were subject to exposure to moisture and sometimes were uninhabitable for this reason.

Dens are used for protection from inclement weather, sleeping, refuge, and for the rearing of litters of young squirrels. No dens in old snags or hollow trees were found to be occupied permanently. Squirrels use large hollows in trees for refuge, resting, and loafing. None of these hollows are used for wintering. Permanently occupied dens are restricted to living trees. Dens which did not have an average-sized entrance, invariably led into a smaller cavity in which the squirrels were safe from predators. Certainty of usage and occupancy of dens often cannot be determined because many dens led into hollow limbs or trunks where observations could not be made. Some use could be detected by the presence of fresh scat or freshly chewed foods, and by the presence of a characteristic odor of the urine. The majority of the dens meeting the optimum requirements are used sometime during the year.

Definite preferences are shown by the squirrels in selecting den trees. Ninety-two percent of the dens along the streambed were found in elm, cottonwood, and pecan trees (Table VIII). Elm trees supplied 65 percent of the dens. Because elm trees are abundant, make a rapid growth, and are subject

to rot, they furnish a greater number of dens at a faster rate than do all of the other species of trees combined. Based on population estimations during the winter of 1950-51, utilization of dens by fox squirrels varied from 93 percent in November to 82 percent in February. Fifty-four den trees furnished 62 dens or .8 dens per den tree. An average of 300 dominant trees per acre along the streambed provided .87 den trees per acre.

There were approximately .35 dens per acre along oak ravines, but dens in upland oak sections are rarely found and often are absent altogether. The slow growth of the oaks, their scrubby nature, and resistance to rot makes them poor den-producers. Post oaks are the most important den trees in the uplands, and elm trees supply the majority of the dens along the oak ravines.

Competition for dens is probably not too keen except in the oak woods where good dens are at a premium. Two squirrel dens were found to be occupied by hives of wild bees. Small birds have been seen to enter squirrel dens. Red-bellied woodpeckers roosted in hollow tree cavities at night. Deer mice have been found in squirrel dens. On one occasion a squirrel and an opossum were occupying the same large hollow. Raccoons and owls also occupied some of the larger hollows. The flying squirrel may compete directly with the fox squirrel for dens. Gray squirrels are reported to have inhabited portions of Stillwater Creek fifty years ago, prior to the cutting of many of the hickory trees, but are apparently absent from this water course at the present time. The gray squirrel inhabits Black Bear Creek, Noble County, about 15 miles northeast of Stillwater, Oklahoma.

Populations

Six inventory methods were evaluated during this study to determine their applicability to Oklahoma conditions. To estimate fluctuations in numbers, a winter inventory during the 1950 season was compared with a summer inventory during the 1951 season. The population study indicated indirectly, the effect of hunting pressure on fox squirrel numbers. Concentrations of squirrels were noted in certain areas.

Winter Census, 1950.

Trapping. Eleven squirrels were trapped in a 13-acre woodlot in Area I from November 9, to December 20, 1950. Five "home-made" box traps were baited with whole corn (Figure 7).

Figure 7. April 6, 1952. Box trap constructed of 1 x 2 inch mest welded wire, 1 foot square and 2 feet in length. Refrigerator tray door slides on curtain rods.

None of them were retrapped. Nine of the 11 squirrels trapped were males. On the basis of the individuals trapped, a fall population density of .84 squirrels per acre existed in the woodlot. It is felt that this figure is somewhat unsatisfactory, and that a higher population level existed. Trapping by using the same technique in January and February was unsuccessful.

Placement of the traps considered areas of greatest activity. Trap locations were chosen where digging and feeding activities were prevalent. Trapping sites included: on or beside logs, at the base of trees containing nests or dens, on tree stumps, and in runways. The trapping sites were selected to take advantage of the far-ranging activities of the squirrels. Baumgartner (1940), states that, "Random distribution of traps is very effective in pastured woodlots, but yields only moderate returns in unpastured woods."

Trapped animals were marked by ear-tagging. This method has been used by several workers with some success. Ear-tagging is simple to perform, but is effective for only a limited time since squirrels tend to scratch them off. A more lasting method devised by Chitty (1937) and improved by Linduska (1942), is the ringing or banding technique. Miscellaneous methods such as ear notching, use of dyes and leg bands have proved to be of little or no practical use (Linduska, 1942). Toe clipping has been used successfully by Allen (1943) and Baumgartner (1940), but is objectionable because this type of marking is not earily recognized by hunters.

Apples, pecans, walnuts, acorns, peanut butter and corn were tried as baits. Ear corn was by far the best bait. Apples attracted opossum, but at that, several opossum were trapped when corn was used. These animals severely damaged the traps in which they were caught. One very large boar opossum "walked through" two traps while seeking the bait, but finally was

stopped after tripping a third trap. Browsing cattle did not molest the traps.

The abundance of winter mast probably reduced the success of trapping. Cold weather apparently influenced the activities of the squirrels so that they entered the traps more readily in search of food.

Snow track counts. Adequate snow for tracking conditions did not fall until February 14, 1951. By the next morning the snow had stopped falling so that conditions for an inventory on February 15 were excellent. The inventory was conducted on a 55-acre farm (Area I). Every squirrel track on the area was traced in an attempt to determine the activities of individual animals. The movements of individuals overlapped in some cases so that it was difficult to distinguish the number of squirrels involved. Cottontail tracks added to the difficulties in ascertaining the number of squirrels represented by the tracks. Individual cottontail tracks were much more extensive and were not associated with diggings. The track pattern and foot impression of cottontails were easily distinguished from those of squirrels.

Forty-one individual snow tracks were counted in the 55-acres indicating a population density of .74 squirrels per acre (Table IX). The ungrazed portion of the streambed tallied 1.14 counts per acre, whereas the grazed section tallied only 0.4 counts per acre. The woodlot count was intermediate between the streambed counts, tallying 0.83 counts per acre. A possible explanation for the difference in numbers between grazed and ungrazed sections of the streambed can be ascribed to differences in the relative number of dens. The ungrazed section has an abundance of mature elm trees and few pecan trees. The grazed portion has many pecan trees and fewer elm trees per acre.

Den counts. Data on den counts are presented in Table X. Forty-nine dens or .9 dens per acre were counted in 55 acres in Area I. Thirteen dens

were counted in 16 acres of streambed in Area II, giving a density of .81 dens per acre. Although there were fewer elm trees per acre in Area I than Area II, the average DBH of elm trees in Area I was three inches greater than that of Area II. Den counts in oak woods areas were variable, depending on the size of the trees, the association with ravine systems, and the abundance of elm trees. Some oak woods areas were completely without dens. A density of about .35 dens per acre were counted along an oak ravine in Area III. No dens were found in the two oak "islands."

Comparison of census methods. During the 1950 season, a November population of .84 squirrels per acre was trapped along Stillwater Creek. A slight decrease in population on the same area was indicated by a February population estimate of .74 squirrels per acre by the snow track count method. Mid-winter trapping was unsuccessful. An average of .87 dens per acre was counted along the streambed. Trapping results were unsatisfactory, since none of the trapped individuals were retrapped. The results from the snow track census are believed to be reasonably accurate. Hunt (1950) considered this method promising and practical since it is not too time consuming. Obviously, this method has its limitations since it is seasonal and depends on a favorable snow fall. Still, this method is probably the fastest sampling procedure yet devised and provides an accurate means to inventory winter fox squirrel populations.

Summer Census, 1951.

Summer fox squirrel populations were studied intensively at only one site. The density obtained here was used to compare with other habitats. An estimation of population density of fox squirrels was made from May 20, 1951, to August 16, 1951 on Area II by using the "clean-up" method. Time-area counts

and leaf nest counts were made on four areas during the last week of May, 1951. The dens were also counted. This intensive study plot included 16 acres of timbered bottomland along Stillwater Creek, approximately eight miles west of Stillwater, Oklahoma. The area is located just below Lake Carl Blackwell dam, which serves as the western boundary. The timbered section is bordered on the north by an abandoned field and an apple orchard, on the south by a weed field and an alfalfa field and is continuous with the rest of the creek at its eastern end. Influx into the hunting area was reduced because of its timbered association at only one point. Any inflow, due to population pressure from the adjoining section of Stillwater Creek, was low because of a homogeneous habitat and excellent food conditions over an extended length of the stream. A general uniformity in the width and the stand as well as an abundance of many kinds of foods along the timbered section of the creek made this place favorable for population studies. The entire study area is under the jurisdiction of the Zoology Department, Oklahoma Agricultural and Mechanical College, and has been closed to hunting for ten years. No poaching was noted during the course of the censusing work.

Time-area counts. A modification of the method devised by Goodrum (1940), was investigated to inventory fox squirrels. Eleven time-area counts, at 30-minute intervals, were made before and after the hunt. The counts were made between the hours of 6:00 a. m. and 9:30 a. m. under favorable weather conditions during May, 1951. The time of day, the number of squirrels seen, and the distance at which they were observed were recorded. The space used in the computations was a half-circle (180°), with the radius being determined by averaging the distance in yards from the squirrels seen to the observation post. The estimation of squirrel populations by this method was discarded because of its greatly exaggerated results. Hunt (1950), evaluating census

methods in Michigan, concluded that this method was not applicable to Michigan habitats.

Nest counts. The principal nest-building activities in the 1951 season were noted during the second and third weeks of May. Nest counts, whereby only the freshly built, "green" nests were counted, were conducted immediately following this period of nest-building activities. Transects bisecting the creeks were conducted on three areas to sample summer leaf nest densities and in the oak "island," the total number of nests were recorded (Table XI).

TABLE XI

Nest-Squirrel Relationships on Four Study Areas

	Nests per Acre	Squirrels per Acre
Area I (Grazed)	7.3	2.14
Area II (Ungrazed)	7.3	2.14
Area III (Light grazing)	3.3	0.97
Oak "Island" (Grazed)	2.2	0.65

It is interesting to note that nest counts for Area I and Area II were comparable, indicating approximate squirrel densities in grazed and ungrazed regions of the same habitat type. Area III, an oak ravine, had less than one-half the number of nests that were counted along the streambed. The upland oak "island" had the lowest nest density of all areas censused.

"Clean-up" census. Estimation of population densities of animals by the "clean-up" method involves: the known kill, the area size, and an estimation of the residual populations, and of the influx during the censusing

period (Leopold, 1948). Results of this inventory appear in Table XII, below. Because there is no accurate method known to determine the influx of squirrels during "clean-ups," this factor was omitted in the census. A reciprocal movement into and out of the kill area during the greater part of the inventory probably eliminated much of the influence of the influx.

TABLE XII

"Clean-Up" Census Summary

Number of squirrels killed	Total population	Percent killed	Resident population	Number of acres	Squirrels per acre	Residual population
29	84		34	16	2.12	5

A time-count census (Table XIII), whereby the number of squirrels seen per hour before and after the kill, was used to estimate the residual population. This procedure was essential in determining the percent of kill in the "clean-up" method. The post-hunting, time-count census indicated that only five squirrels were left in the kill area. A population density of 2.12 squirrels per acre before the kill as compared with a density of .29 squirrels per acre after the hunt, indicated that the resident population was substantially reduced. The fact that the level of the squirrel population was decreased progressively during the hunt to a very low density at the end of the hunt, helps to substantiate the hypothesis that the estimation of population was little affected by influx.

Eighty-four percent (29 squirrels) of the population was killed from the 16-acre area. The residual population was estimated to be five squirrels by the time-count method. A resident population of 34 squirrels before the hunt was thus indicated. Calculations for the "clean-up" census appear in the following formula:

1. The number of squirrels seen per hour after the hunt divided by the number of squirrels seen per hour before the hunt, equals the percent of residual population.

Where:

A is the number of squirrels seen per hour before the hunt;

B the number of squirrels seen per hour after the hunt; and

C the percent of residual population, or $C = \frac{B}{A}$.

Then: on the basis of the data presented, $C = \frac{.36}{2.18}$ or a residual population of 16 percent.

100 - C = percent killed (100 - 16 = 84).

2. Then, the percent killed (84): the number of squirrels killed (29):: 100: X (the total number of squirrels in the area, ie., resident population).

$\frac{84}{29} \times \frac{100}{X} = 34$, the resident population of squirrels before the hunt.

3. Resident population ÷ number of acres = population density

34 ÷ 16 = 2.12 squirrels per acre.

TABLE XIII

Time-Count Census

	Number of hours	Number of squirrels seen	Number of squirrels seen per hour
Pre-hunting census	5.5	12	2.18
Post-hunting census	5.5	2	.36

Comparison of Census Methods.

Time-area counts, leaf nest counts, and "clean-up" tallies were used to estimate population densities. A time-count census was used to estimate the

residual population. Table XIV compares population densities of the various census methods.

Time-area counts were found to be inadequate, possibly because dense summer vegetation greatly obscured the vision of the observer.

A summer leaf nest count of 7.3 nests per acre was made in the intensive study site. A population density of 2.12 squirrels per acre was calculated by the "clean-up" method. The nest-squirrel ratio was determined by dividing the average number of squirrels per acre (7.3 ÷ 2.1 = 3.4 : 1). The average number of nests per acre divided by the average number of nests per squirrel (7.3 ÷ 3.4) indicated a density of 2.14 squirrels per acre by the leaf nest census. Thus, the leaf nest census and the "clean-up" census compare very favorably. Goodrum (1940), working with the gray squirrel, estimated one nest for every two squirrels. If the ratio of summer nests to squirrels remained constant over comparable timbered areas, then leaf nest counts would provide a rapid and fairly accurate method to determine fox squirrel densities. Table XV illustrates the relationship of den and summer nest counts to squirrel densities.

Concentrations.

The aggregating of squirrels in particular areas was noticeably seasonal and was associated with favorable food conditions. In late spring and early summer, they were numerous in the vicinity offruiting mulberry trees. With the development of the green corn in mid-summer, squirrels were conspicuously present in corn fields. These animals gathered in groups as the pecans ripened in late summer and fall in native pecan orchards. As many as nine squirrels were reported to have been taken by a hunter from a single pecan

tree after the nuts had matured in the fall. Concentrations were also noted around farm ponds, in picnic areas, and generally where food was abundant. On the basis of observations, squirrels appeared to be more numerous in the wider portions of the stream bottoms.

Seasonal Fluctuations.

A 1950 fall population of .84 squirrels per acre decreased to .74 per acre by late winter. By summer, the population had almost tripled, increasing to 2.12 squirrels per acre. Theoretically, the population should slightly more than triple itself by late summer. The late summer population in average years is approximately two and one-half times the breeding population under Michigan conditions (Allen, 1943). The abundant acorn yield was thought to be largely responsible for a high survival rate and a high level population of the breeding stock.

Sex and Age Ratios.

Thirty-one or 58 percent of 53 squirrels handled were males. Only two of eleven squirrels trapped were females. One-half of the 16 young squirrels taken during the 1951 season were females. Brown and Yeager (1945), found a 59 : 41 sex ratio with males predominating.

Fifty-nine percent of the 29 squirrels shot during the summer of 1951 were immature. Only three of 11 squirrels trapped in the fall of 1950 were immature. Litter sizes ranged from one to three individuals. The average litter size of six litters handled was 2.2 individuals per litter. Of these litters, five were females and six were males. Due to the small number of animals handled, there is no adequate basis upon which to establish sex and age ratios. Males were more numerous than females. The sex ratio of young

squirrels was 50 : 50. Young squirrels were less numerous in the fall population of 1950, but predominated in numbers during the summer of 1951.

Hunting Pressure.

Probably the most important single decimating factor in fox squirrel populations is the annual kill by hunters. No direct information was obtained on the number of individuals taken from a particular hunted area. "Shooting out" a population of fox squirrels from a section of streambed along Stillwater Creek would be virtually impossible. Mid-winter hunting during the breeding period would result in but meager results, as the general activities of the animals are substantially reduced by cold weather. Estimations of kill by many hunters and farmers were considered unreliable, so that the intensity of hunting could not be accurately determined. Most significant is the fact that during the 1951 season the population increased to a high summer density after rather heavy hunting pressure. If the age ratios given above are a true representation, the ratio of young to adult squirrels decreased considerably from summer to fall. Young squirrels are much less wary and are more susceptible to predation and hunting. Juveniles make up approximately 60 percent of the normal fall population in Michigan (Allen, 1943). Allen believes that about two-thirds of the squirrels die each year and of these, one-third are taken by hunters, one-third by other decimating factors, and one-third survive to form the next year's breeding stock.

Parasites and Predators.

No internal parasites were found in the examination of 28 squirrels. The dog tick, Dermacentor variabilis was common on squirrels taken in the

summer of 1951. Ticks were found chiefly on the head, especially behind the ears. Practically all of the squirrels were infested with fleas. No mange was observed in any of the squirrels handled. Allen (1943) reports that, "Sarcoptic mange (Scabies) appears to be the most serious natural mortality factor among Michigan fox squirrels." None of the animals handled in this study suffered from "shock."

Scant information is available in the literature concerning fox squirrel predation. Three accounts of owl predation were observed in this study from examination of about 300 pellets. An owl pellet found on Himrichs' farm contained parts of a fox squirrel skull and tibia. The pellet may have been of a barn owl, since a pair included the farm as part of their range. A fox squirrel skull was found in an oak woods on the Lake Carl Blackwell area in an owl pellet. Remains of a squirrel's hind leg and vertebrae were discovered on a horned owl roost. The roost was located in the rafters of an abandoned farm building, 12 miles west of Stillwater, along Stillwater Creek. Common nesting owls included: barn, barred, horned, and screech owls.

Cooper's, red-tailed, and marsh hawks regularly nest in this vicinity. These raptors are potential predators of fox squirrels. A Cooper's hawk perched in a tree watched a fox squirrel for more than five minutes with apparent interest. When approached, the hawk flew only a few feet to another tree, alighted and continued to watch the squirrel. Red-tailed hawks seem to be prominant natural enemies of fox squirrels (Errington, 1930 and English, 1934). Marsh hawks have a rather weak grasp and are more adapted for seizing and holding its victims rather than piercing into vital body parts. Marsh hawks are restricted mostly to prairies unlike the red-tailed and Cooper's hawks. It is unlikely that these prairie hawks are important predators of squirrels.

A fox squirrel was caught and killed by a farm dog shortly after it had been released from a trap. It is doubtful that farm dogs or cats make a habit of hunting squirrels, although they may occasionally catch them. Because of the coyotes' nocturnal habits, fox squirrels are not likely to fall prey to these carnivores.

Opossum and raccoon, which are quite numerous along Stillwater Creek, may occasionally prey upon squirrels. Fox squirrels were not found to occupy large hollows permanently so that predation by these animals would ordinarily not be significant.

Copperheads occur along streambeds and in oak woods in this section, but are not numerous. No observations were made on predation by snakes, but these reptiles were certainly in a position to attack a squirrel if given an opportunity. Judging from these meager accounts, one may assume that predation was not an important mortality factor during the course of this work.

Abnormalities.

An adult male fox squirrel shot August 16, 1951, had four pairs of well developed mammary glands. The characteristics are similar to those of a gynandromorph or a sexual mosaic-gynandromorph with normal sexual organs, but with patches of tissue of the opposite sex in parts of the body (Huettner, 1949). The sexual organs of the squirrel appeared to be normal, the testis measuring 42 mm.

An old male squirrel which was blind in the left eye was captured by hand in the oak woods by shaking the saplings in which he jumped. The lens of the eye was definitely opaque, resembling a cataract. The squirrel appeared to be only slightly incapacitated by the blind eye.

Food Conditions

Food Succession.

A seasonal food list is presented in Table XVI. Bark and even the woody portion of twigs are chewed by squirrels in January and February. Squirrels eat buds of elm and other trees in late winter and early spring. Samaras of elm are taken from March through May. Those of boxelder, ash and redbud do not mature until late summer, and they persist through most of the winter. Mushrooms are eaten as early as February, and are available mostly in the spring and summer at periods when there is adequate rainfall. Young, succulent leaves of elm, soapberry, and hackberry are important during April and May. Mulberries fruit from May to mid-July. Corn is in the "milk stage" in June, July, and August and is especially important then. Pokeberries mature as early as July 22. Green pods of Kentucky coffeetrees are cut and eaten by squirrels in July in large numbers. Hackberry seeds fruit in June and July and persist through the winter. They are either taken directly from the tree, or twigs bearing the seeds are cut and then stripped by the squirrels. Blackberries are taken in July and August. Acorns, pecans, walnuts, and hickory nuts are cut from the trees while still green during July, August, and September. The mature nuts are eaten through fall and winter to April. Early summer harvest and the fall plowing of corn fields eliminates the majority of this crop for use by the squirrels in winter.

Elm seeds form a spring staple from the time they are first produced until about mid-May. They are particularly important at this time because of the scarcity of other foods. Squirrels were seen in isolated elm trees several hundred feet from wooded areas. Squirrels in oak woods areas move into the

stream bottoms in the spring to feed on elm seeds. One squirrel traveled 200 hundred yards from a den in the oak woods to a streambed to feed in an elm tree. Another was seen feeding on elm samaras in April in an isolated elm tree 150 yards from any other timbered association.

The mast crop during both the 1950 and the 1951 seasons was excellent. An excellent crop of bur oak acorns was accompanied by a very meager pecan yield during the 1950 season. The reverse was true during the 1951 season, resulting in adequate winter food conditions for both seasons.

Availability of Foods.

Food availability is dependent mainly on the season of the year, weather conditions, land-use practices, and competing animals. Pecans and acorns are not available from April to July, but mushrooms, fruits of mulberries and other plants, corn, and succulent green vegetation are. Mast was utilized roughly from July through March. Drouths, floods, and ice temporarily make buried nuts unobtainable. Squirrels are capable of scenting mushrooms in the soil at a depth of three inches and are able to dig through the soil to reach them. During the winter of 1950, an extremely dry period extended from the latter part of November to January 20, seriously impairing the squirrels' ability to recover stored mast in the soil. Because of hard, dry soil all diggings by squirrels during this period were shallow, and much of the buried mast was never reached. Precipitation on January 20, 1951 made the soil soft so that numerous squirrel diggings were observed. Diggings into the moist soil were sufficiently deep to reach buried mast.

Rains in March, 1951 inundated the ground in which squirrels had buried acorns near a pond. During the latter part of March and early April the

squirrels were seen digging up buried acorns as the water line receded. The acorns not only became available after receding waters left the moist soil pliable, but the water also preserved the acorns so that they were still palatable.

A poor pecan crop in the fall of 1950 was further reduced through the effects of the pecan weevil, web worms, and tree girdlers. An abundant bur oak acorn crop became infested with acorn weevils. The veritable failure of the pecan crop forced squirrels to rely heavily on acorns in the streambed areas. An abundant crop of acorns in the oak woods during the fall of 1950 greatly increased the food supply in that area. Whether or not more squirrels survived the winter is not definitely known. The breeding condition, however, would be much better. The acorn crop from year to year varies tremendously so that the upland oaks are rather unstable squirrel habitats. Although of short duration, ice-covered, and frozen ground prevented digging in the soil. Early harvest and plowing of corn is recommended in Oklahoma to control the Southwestern corn borer (Diatraea grandiosella) and other insect pests. Plowing of corn fields generally follows harvest in August and September. Corn is not usually shocked by Oklahoma farmers. Shocking of corn in the northern states greatly benefits wildlife during winter (Allen, 1943). Allen believes that ear corn is the most important winter food of fox squirrels in Michigan.

A 40-foot strip of dense growth of giant ragweed (Ambrosia Sp.) bordering a corn field appeared to act as a barrier to squirrels. Another corn field adjoining the undamaged field margined with only a sparse growth of ragweed and sunflower about 15 feet wide was moderately damaged.

Food Preferences.

Preferred fall and winter foods include: acorns, pecans, hickory nuts,

and black walnuts. Elm samaras, mulberries, mushrooms and leaves of various trees are evidently preferable during the spring months. Green corn is a delicacy during summer. From observations on captive squirrels, pecans are more palatable than any other food. Acorns and black walnuts are also favored foods. Pecans were eaten by the captive squirrels I kept before walnuts and hickory nuts, but when these hard-shelled nuts were cracked open, they were eaten as readily as pecans.

Green pecans are eaten in large numbers by squirrels during August, except when associated with field corn. When pecan groves are bordered by corn, the pecans are of secondary importance while the corn is available.

During the winter of 1950, squirrels concentrated in the vicinity of a large, high-producing pecan tree, although bur oak acorns were particularly abundant. When the pecans from the tree were depleted, squirrels were seen in increasing numbers in an area where bur oak trees were numerous and acorns littered the ground in great numbers.

Competition.

Competition for food was not a critical factor in the depletion of the 1950 winter food supply. Cattle browsing the creek bottoms were undoubtedly the most serious competitors for acorns. Insects are particularly destructive (Moznette et al., 1940). Twig girdlers (Oncideres texanus) dispoil many immature pecans by cutting twigs containing clusters of the nuts. The pecan weevil (Curculio caryae), pecan nut casebearer (Acrobasia caryae), and the hickory shuck worm (Laspeyresia caryana) injured the nuts. The fall web worm (Hyphantria cunea) reduces the yield of both pecan and black walnut trees. Acorn weevils further reduce the mast crop. Flying squirrels and wood mice

are direct competitors for mast. Bluejays consume large quantities of acorns in the oak woods and pecans along the streambed. Bob-white, cottontails, and free-ranging poultry contend for acorns in oak forests. Crows, flickers, and woodpeckers consume large quantities of mast. Wood rats cache pecans, Kentucky coffeetree pods and corn. Late summer plowing of corn fields and the pecan harvest in November and December further diminish the food crop. All in all, there was a high degree of use of the mast by many species of animals, but due to a heavy yield, the winter food supply in all of the areas studied was sufficient to sustain a high population of squirrels.

Storage.

The greatest activity in storing food was observed during the months of October and November, immediately following the release of the mast from the trees. Nuts and acorns are cached throughout the winter months and even as late as March 6, 1951, when a squirrel was seen burying a walnut.

All of the mast is cached by burying it in the soil. The depth of the holes varies from one inch to seven inches. Squirrels are able to bury nuts in less than a minute. No mast was found cached in dens or tree hollows.

Recovery.

Squirrels are aided in recovering their buried nuts by their sense of smell (Cahalane, 1942). They are commonly seen rustling around, with their noses to the ground while searching for food. Recovery of food as affected by weather has already been discussed.

Effects of Land-Use Practices

The multiple effects of land-use practices upon the fox squirrel populations were relatively unimportant. Grazing, cutting, crop associations, and expansion by building activities, seemed to have little effect on the present squirrel population.

Grazing.

Intensive grazing on a yearly basis is a common practice among the land owners. Heavy winter ground cover was present on ungrazed streambed soils (Figure 8). Figure 9 illustrates the contrast between undergrowth on grazed and ungrazed areas. Oak "island" in cattle ranges are utilized by livestock for browsing and resting (Figure 10). Yearly grazing as practiced in this region resulted in reduction of summer ground vegetation and suppressed the growth of seedlings (Figure 11). The effects of grazing, which might be considered important as related to the squirrel population, were the reduction of the underbrush and ground vegetation, erosion as a result of depletion of ground vegetation and trampling, competition by stock for available mast, and probably most important, the eventual destruction of future habitat due to browsing of seedlings by stock. As the mature trees die off, they will not be replaced and the forested areas cannot propagate themselves when subjected to excessive grazing.

Cutting.

The cutting of mature timber along streambeds associated with croplands will eventually result in serious washing along the steep banks. The farmers

apparently eliminate these trees in an effort to reduce the shading effects on their crops and to extend forage ranges (Figure 12).

Crop Associations.

Corn is the primary crop utilized by squirrels in this vicinity. They eat ear corn in the late summer and winter except in cases where the corn fields are plowed up. Planted pecan orchards are used by squirrels to a small extent along the margins. There was no known use of vegetable crops, melons, berry patches, or fruit orchards.

Encroachment of civilization via building projects further reduced squirrel habitat.

Burning.

Fires were significant only in oak woods areas. Fires destroyed mast on the ground, killed or injured mast trees, den trees, burned leaf nests, and delayed the growth and development of trees in the spring by destroying buds and shoots. Fires were more serious in the winter when dead leaves and grass acted as fuel. Late winter burning made certain ranges uninhabitable by destroying the potential early spring food crop. Trees suffering from severe burning were several weeks late in their spring growth.

Flooding.

Fall flooding may be harmful by carrying away mast. The flooding of lowlands may temporarily make a range uninhabitable. If the mast is not washed away it may be preserved until later in the season and become

Figure 8. January 21, 1951. Heavy, winter ground cover composed mainly of giant ragweeds on an ungrazed portion of Stillwater Creek.

Figure 9. January 21, 1951. Stillwater Creek showing contrast between grazed portion (right) and ungrazed area (left).

Figure 10. April 26, 1951. An oak "island" showing browse line and reduced ground vegetation as a result of moderate grazing.

Figure 11. August 19, 1951. Excessive grazing at the rate of almost two cows per acre greatly reduced ground vegetation and prevented the growth of seedlings along the streambed.

Figure 12. April 17, 1951. Cutting of elm trees in a gully to increase pasturage area for livestock.

available to the squirrels when the water recedes. Floods probably do not often seriously deplete or make mast products unavailable for long periods of time.

Farm Ponds, Seeps, and Water Holes.

Timber growing below farm ponds attained a larger size and a more rapid development in the spring due to the influence of the additional moisture. American elm, willow, post oak, and blackjack oak were far advanced (probably as much as two weeks) as compared with trees of the same species in the same vicinity when the former were found along rivulets leading from seeps. April 26, 1951 post oaks, along a gully system below a seep, had their full complement of leaves; whereas, post oaks in other areas had not even leafed out yet. This advance in growth could be very important in the attractiveness of such a habitat in the spring and might

affect the distribution of squirrels in the vicinity. Terrill (1950) found that gray and fox squirrels alike concentrated near farm ponds.

Seepage below ponds encourages the growth of important food plants. It provides a relatively permanent source of water, and along with seeps and springs, provides a semi-permanent water supply further down stream due to seepage and overflow. This may be an important factor in the extension of the squirrel range.

Squirrels are often seen around ponds and other sources of water supply. Their tracks could usually be found in the mud around the edges of ponds.

ECONOMIC RELATIONS

Aside from sporting and aesthetic values, this work attempts to relate economic damage by the fox squirrel to agricultural crops. The extent to which fox squirrels damage crops is not well known. Whether or not their injurous habits justify control measures depends largely on the intensity of the damage. Farmers in the Stillwater region have complained of depredations to pecans and corn. Light damage is quite extensive, occurring almost everywhere these crops are grown, but heavy damage is usually quite localized. The younger, planted orchards have some marginal damage, while orchards with larger, mature trees have more extensive damage, often containing dens in which squirrels are able to pass the winter. The majority of the native pecan groves were heavily damaged during the 1951 season. Corn, when planted near Stillwater Creek or its tributaries, was invariably damaged by squirrels. Typically, nearly all of the ears of corn in the "milk stage" were eaten by squirrels from the

edge of the field to a distance of 15 or 20 feet towards the center of the field. Corn usually was eaten on the side of the field bordering the streambed for the entire length of the field.

Damage to the Pecan Crop

The objective of this study was to make a quantitative estimate of pecans utilized by fox squirrels in a native pecan orchard. The period of study extended from September 10, 1951 to the pecan harvest, December 11, 1951. Although only intensive field study was carried out in the grove, observations were made along Stillwater Creek in native and planted orchards.

Description of Area

The study area, Agronomy Grove, is located along a tributary to Stillwater Creek, one mile west of Stillwater, Oklahoma. The grove is managed by the Horticultural Department, Oklahoma A. and M. College and is composed of about one acre of timber. Native trees in the area are large and of varying ages. There were two den trees and at least two known spring litters of fox squirrels produced in the grove. There was a high density of squirrels, and at least six had been shot from the area during the 1951 hunting season. The grove was grazed by sheep until the latter part of September. Both the understory and ground cover were sparse. The trees were sprayed with 50 percent wettable DDT at four pounds per 100 gallons of water for insect control. Such spraying had no apparent effect on the squirrel population.

The mouse population was rather low except along the grove margins, where a rank growth of weeds afforded adequate cover. Woodmice and cotton rats were present in limited numbers. No wood rat nests were located in the grove, undoubtedly due to the reduction of ground vegetation by grazing and clean cultivation practices.

The winter population of birds was relatively high. Bluejays, flickers, and woodpeckers were the most important ones using pecans in the grove.

Crows inflicted considerable damage to the pecan crop along Stillwater Creek. Flocks of from 100 to 200 birds were counted in both native and planted orchards. These birds were especially fond of the thin-shelled varieties.

Procedure.

Five trees of varying ages were selected for study. A single plot, 16 yards square, was marked off by string under each tree. Dead leaves, sticks, and other debris were cleaned from the plots periodically to facilitate counting. Counts of pecans were made at two to four day intervals, depending upon weather conditions and squirrel activity. During the period, the green pecans were being consumed by the squirrels, none of the green or mature pecans were marked, but were counted as they appeared in the plots. By October 25, 1951, all of the green pecans had matured and these nuts had begun to fall to the ground. From that time on the pecans were accounted for either by noting the marked nuts or by noting middle lamellae and chipped shells. The lamella is the partition dividing the halves of the kernel.

Pecans in the plots were counted and then marked by dipping one end in white enamel paint. (Squirrels held in captivity concurrently with

these studies ate pecans marked with the white paint as readily as those pecans which were not marked). Squirrels in the grove consumed the marked nuts without hesitation. Records were kept of the number of green and unmarked pecans, the number of marked pecans, the number of unmarked pecans, and the number of middle lamellae which had been dropped into the plots from the squirrels feeding in the trees above them. These counts made from September 10, 1951, to December 11, 1951, are presented in Table XVII. These data account for pecans taken from the plots, and for those which were consumed in the trees. In order to account for the number of unmarked nuts which were taken from the plots, it was assumed that the percentage of marked nuts taken would be about equal to the percentage of unmarked nuts taken. In addition, each middle lamella would represent one pecan consumed by squirrels. Chipped pecan shells were gathered along with middle lamellae and compared with them as a check for the validity of the lamellae counts.

Bird counts were made to estimate the utilization of pecans by birds as compared with squirrels. A record also was kept of the number of pecans which had been eaten by deer mice.

The determination of the average weight of one pecan was necessary to calculate the pounds of pecans taken from each plot, because the take of pecans was recorded as a tally of individual nuts. Six hundred fifty-eight ripened pecans were weighed, and 3.44 grams was the average weight per nut. Although green pecans were much heavier (5.49 grams), the average weight of a mature nut was taken as the basis to estimate the weight of the immature nuts.

The number of pecans taken from the plots was theoretically proportional to the number taken from the remainder of the crown areas of the trees, as each plot furnished the basis for a measure of a segment of the crown area.

Thus, it was necessary to estimate the crown area of each tree. By determining the average crown radius for each tree, the approximate crown area could be estimated. Crown radii were measured in eight different directions from the tree's center. By applying the average crown radius per tree to the formula for the area of a circle, the crown area for each tree was ascertained.

Indicators of Damage.

Fox squirrels either cut twigs bearing clusters or took individual nuts while feeding. Green pecans were taken from the time they were in the "water stage" until they matured. To reach the developing kernel, the squirrels gnawed through the green, outer shucks. There was considerable waste of food when green pecans were taken. Frequently, not more than half of a green pecan was actually consumed. In chipping the shells from the kernels of mature nuts, the squirrels characteristically marked the shells with two parallel grooves by the lower incisors.

While feeding in the trees, the squirrels usually ate the pecan on the spot and dropped chips and the portion of the uneaten nut to the ground directly below the feeding area. The middle lamella was often left intact but was well cleaned of the pecan meat. The best criterion for determining the number of mature pecans taken directly from the trees was this middle lamella which was dropped to the ground by feeding squirrels.

Damage to pecans by squirrels could readily be distinguished from that by birds. Squirrels invariably left incisor marks on chipped pecan shells. Birds cracked the pecan shells with their beaks. Beak marks could sometimes be found on chipped shells and those pecans were ordinarily without the marks of gnawing. Birds were not so efficient at removing the pecan meats from the shells.

Woodmice left tiny incisor marks on the pecans, and cut small holes through the shell leaving finely serrate margins around the periphery of the hole. These mice ordinarily cut two holes into the pecan, one on either side, whereas fox squirrels cut through the pecans from one end, then chipped the shell off by using the lower incisors as a lever. Cotton rats, which were held in captivity for a period of two weeks, were unable to cut through pecan shells, but ate the germ from whole corn without difficulty. House mice and pack rats, which in some situations also feed upon pecans, were not found in the vicinity of the pecan grove under study,

Formula for Estimating Pecan Damage by Squirrels.

The total quantity of pecans taken from the five plots is theoretically proportional to the quantity taken from the crown areas of all five trees. To estimate the total damage by squirrels in the orchard we may apply the formula: $\frac{N}{A} :: \frac{X}{A^1}$, where:

N = the total pounds of pecans taken in five plots,
A = the area of these plots in square yards,
X = the undetermined pounds of pecans taken from five trees,
A^1 = the total crown area of the five trees in square yards, or

$$\frac{3.19}{80} \times \frac{x}{1838.6} = 73.3 \text{ pounds taken from the five trees measured.}$$

Then, the total pounds of pecans taken from five trees divided by the estimated yield[1] of the orchard should give the approximate percent use (damage).

Thus,

$$\frac{73.3}{495} = 14.8 \text{ percent use.}$$

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[1]Yield estimates were furnished by the Horticulture Department, Oklahoma A. and M. College. The yield estimate for the five trees was 495 pounds.

Therefore, we may estimate that the total pounds of pecan taken from five trees divided by five equals the average pounds of pecans taken per tree. So,

$\frac{73.3}{5}$ = 14.6 pounds estimated use.

Extent of Damage.

Fox squirrels in the grove took an estimated 73.3 pounds of pecans from the five trees measured, or an average of 14.25 pounds per tree. This rate of use amounted to 14.8 percent of the estimated yield. Pecan cracking companies paid .26 cents per pound for high quality nuts of this type during the 1951 season. At this price, the squirrels took $3.70 worth of pecans per tree from September to the harvest period. A record of pecans taken from the five plots by squirrels is presented in Table XVII. Table XVIII illustrates the relationship of tree size, yield, and use.

The use of pecans by the squirrels was quite uniform throughout the grove. The early maturing nuts were, of course, taken sooner than the later maturing nuts. During the 1951 season, squirrels fed on green pecans for a two-month period, from August 20, to October 23. Damage to green pecans was 35 percent of the total amount of pecans taken by squirrels until the harvest. This surprisingly high percent use of green pecans was possibly associated with their lower food value as compared with that of the mature nuts. This suggests that a greater quantity of green nuts are needed to meet daily food requirements. Also, there was considerable wastage of these immature nuts. So far as known, the squirrels in the grove relied on little else other than pecans from late August to the harvest.

The damage to mature nuts, which were taken from the tree and from the ground, was 65 percent of the total pecans taken by squirrels. There was both a greater fall and a greater utilization of pecans during November. Forty-one percent of the total use occurred during this month (Figure 13). Squirrels took the majority of the mature pecans from the ground. Approximately 32 percent of the pecans counted in the plots were taken by squirrels. Very few of these nuts were observed to be buried by the squirrels.

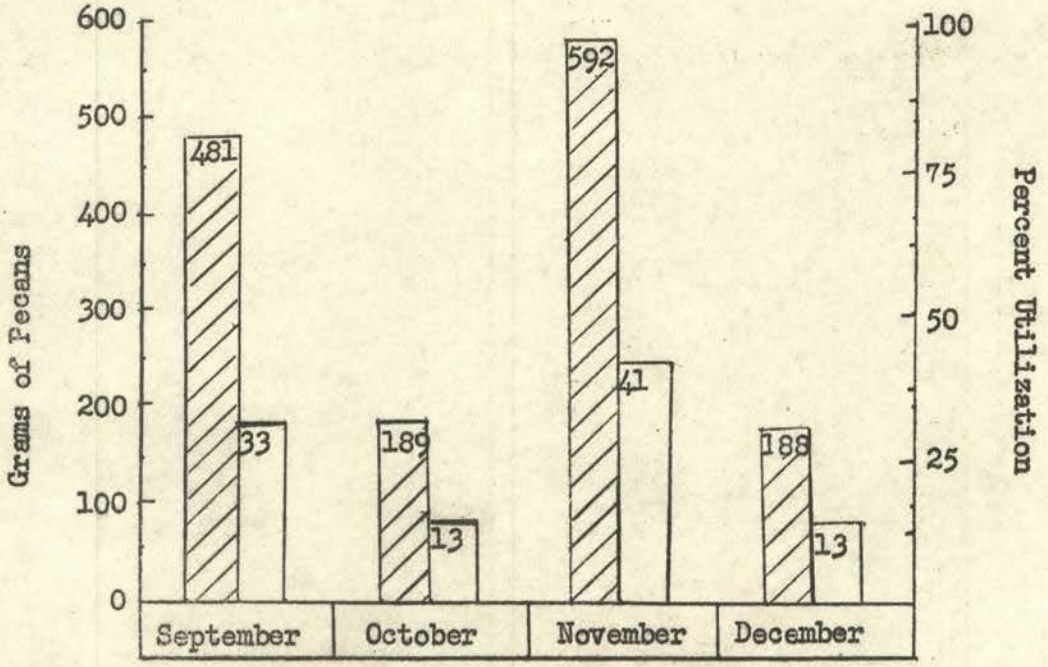

Figure 13. Monthly utilization of pecans from five plots by squirrels by weight in grams and percent.

Woodmice accounted for two percent of the pecans taken from the five plots. Only one mouse was trapped in 56 trap-nights. The mouse population apparently was low.

Birds which were important users of pecans in the grove included: bluejay, yellow-shafted flicker, and the red-bellied woodpecker. Both hairy and

downy woodpeckers occurred in the grove, but were not observed to eat pecans.

Bird counts were made at various times of the day. Bluejays were quite gregarious and fed in flocks of from four to 12 birds in the grove. An average of between six and seven birds were counted for each 30-minute interval. An average of two red-bellied woodpeckers were seen per count. Flickers were slightly less numerous.

The birds fed strictly in the trees. They would either walk to the end of a limb to take the pecan, or as bluejays, fly to the cluster, "standing still" in mid-air as they took a pecan directly from the cluster without alighting for any support. After obtaining a pecan, the bird carried it to a limb or crotch where it smashed the shell with its beak. One red-bellied woodpecker consumed three pecans in a ten-minute period. Birds began using pecans about mid-October. An average of ten birds were seen per count. No estimation of damage by birds has been made, but they probably consumed fewer pecans than did the squirrels.

Three "Spirolum whirlers" (spiral aluminum bands), two inches wide and 15 feet long, were stretched between two pecan trees in the grove by the Oklahoma A. and M. Horticultural Department as bird repellants. These whirlers, painted either red or green on one side, were quite specific against crows, the other birds being heedless of them. They were so effective against crows that not a single crow was seen in the grove during the course of the investigation. Crows flying by either flew around the grove, or flew several hundred feet above it.

Sources of Error.

Two main sources of error in this study involve: (1) inaccurate estimate

of the yield, and (2) duplication of counts of pecans, used by the squirrels. Counts of the middle lamellae which were arbitrarily assigned to pecans taken from the tree may actually have included some of the pecans which had fallen into the plots.

Yield estimates were made both by myself and by members of the Oklahoma A. and M. Horticultural Department. These estimates are thought to be reasonably accurate. An early freeze caused some of the shucks to adhere to the pecan shells so that a few of the nuts were never harvested.

Some of the middle lamellae tallied undoubtedly duplicated counts of pecans taken from the trees, and pecans taken from the plots. Middle lamellae counts represented one-tenth of the total estimate of damage.

Damage to Other Crops.

Both sweet corn and field corn were commonly eaten by fox squirrels during June and July. A small patch of sweet corn 20 by 100 feet bordering the creek was completely consumed by squirrels during the summer of 1951. Field corn was characteristically eaten to a distance of 15 or 20 feet into the fields. During the summer of 1950 an estimated 15 bushels of corn was consumed by squirrels from a 25-acre field. Hendrickson and Schlesselman (1937) report that fox squirrels accounted for .8 bushel from standing corn in a 2.2-acre field. Generally, damage was moderate, but in a few cases was quite serious.

A small apple orchard on Stillwater Creek was unmolested by squirrels. The Entomology Department orchard, containing peach, plum, and apple trees was undamaged. Blackberry patches planted within a few yards of the creek were not observed to be squirrel-molested. Vegetable gardens associated with the creek were apparently untouched by fox squirrels.

CONCLUSION

Originally, the area of Payne County was composed principally of tall grass prairie intermingled with oak savannah. The high moisture requirement of such trees as elm, bur oak, cottonwood, willow, and others limited their growth to ravine systems. These wooded growths produced favorable areas for fox squirrel habitation. At the present, the bottomland game type comprises slightly more than five percent of the total area in Payne County (Duck and Fletcher, 1944). The post oak-blackjack forest, which includes nearly 43 percent of the total area, is not so important as fox squirrel habitat. The remaining area is composed of tall grass prairie, thus a relatively small area is inhabitable by squirrels. Intensive farming with cropping, grazing, and cutting have further reduced the habitable range.

Continued grazing at the rate of nearly two cows per acre seriously reduces ground vegetation and suppresses seedling growth. Fewer trees per acre were counted along the grazed streambed than the ungrazed streambed (Table IV). Although grazing little affects present squirrel populations, these timbered areas will be unable to reproduce themselves causing a gradual elimination of such areas.

Squirrel activities were mainly influenced by food, weather, and the breeding season. The concentration of squirrels in areas of heavy mast in the fall, near mulberry trees in the spring, and in the corn fields in summer illustrates their awareness to food sources within their cruising range.

Variation in the daily activities of fox squirrels, which in the summer time was principally during the early morning hours, and in the wintertime during the mid-morning hours, exemplifies the bearing of season on the

squirrels' periods of activity. The animals were most active when the temperature ranged from about 40 to 80 degrees F. There possibly exists optimum weather conditions at which squirrels are most active. Snow influenced their activities in that it affected their ability to move about and find food. The fact that there was a very limited amount of activity during cold and snow suggests the importance of this weather factor to the amount of food consumed during inclement weather. Allen (1943) reports that there is usually a marked loss of weight during extended inclement weather. Rain was particularly important in that it made the soil soft so that the squirrels could procure nuts or acorns which had been cached in the soil.

Movements of squirrels were noted during the spring and fall months. The "fall shuffle" as described by Allen (1943) was evident in Oklahoma. Young squirrels were commonly seen during May, moving along the travel lanes, to and from oak woods, through fields, and across roads. These movements may actually have been immigrations to new areas due to population pressure. Baumgartner (1943) believes that fox squirrels exhibit some social antagonism so that the animals will tend to move from high to lower population levels.

Courtship behavior as observed was similar to that described by other authors. The males, which were strongly competitive during these mating activities, appeared to be older, stronger, and more mature individuals. In all cases, the female was shy to the advances by the male. A marked mid-winter breeding season apparently existed which perhaps was two weeks in advance of the breeding season in Michigan. A lighter breeding season was observed during May and June.

Leaf nests were used in winter in the oak woods, but rarely along the streambeds. The fact that there was nearly one den per acre suggests that the bottomland could support a rather high winter population of squirrels.

Den counts in the oak woods were extremely low; and in the upland regions, dens often were not even present. Elm trees serving as den sites were doubly important since leaf nests were not utilized for wintering along streambeds. Elm trees are excellent sources of dens since they are readily susceptible to rot, make a rapid growth, and are numerous along the streambed.

There was a definite correlation between the number of dens per acre and the winter squirrel densities. As the number of dens decreased the population level of the squirrels also decreased (Table XV). Den counts are worth little for making a summer inventory of squirrel populations.

Snow track counts are probably the most reliable winter inventory method in Oklahoma. Hunt (1950) suggests the value of this method as being a quick and valid estimate of fox squirrel numbers. Winter nest counts are useless in this portion of Oklahoma because fox squirrels along the streambed do not use these nests for wintering. Trapping, although successfully employed by Allen (1943) and Hunt (1950) in Michigan, Baumgartner (1943) in Ohio, and Brown and Yeager (1945) in Illinois, was largely unsuccessful in Oklahoma. Squirrels showed a marked preference for pecans over the slightly bitter bur oak acorns and they concentrated in areas where the pecans were abundant. Eighty-two percent of the squirrels trapped were males. None of the squirrels were retrapped. Because of the abundance of food during the trapping period, the squirrels were not highly attracted to the bait in the traps.

Nest counts during the summer compared very favorably with the "clean-up" census. The "clean-up", like the trapping method, is quite time-consuming and is of little value when time is at a premium. A transect method using leaf nests as an index to summer populations is the quickest inventory method. Goodrum (1940) and Hunt (1950) found nest counts to be adequate systems for enumerating fox squirrels.

Causes of seasonal population fluctuations would include the following: hunting kill, food conditions, breeding success, movements, predators, and parasites. Naturally pre-hunting and post-hunting season populations will differ. After normal winter losses from predation, starvation, or adverse weather conditions the early spring population - the breeding population - can be expected to be the low the annual population cycle. After a successful breeding season in early spring and summer, the late summer and fall population of squirrels should represent the peak of the year (Allen, 1943).

The variation of the squirrels' diets depends mainly on food succession, availability, and preference. Preference of foods was exhibited mainly in the fall and spring months; for instance, pecans were taken before acorns in the fall, mulberries were preferable over other foods in late spring, and green corn was favored over green mast products and succulent growth in the summer.

Competition for mast products in a year of high yield is prcbably insignificant; on the other hand, a low mast yield would intensify competition for this food. Cattle are serious competitors for bur oak acorns and in years of light yields quickly deplete the supply. The 1951 crop had been exhausted through use by cattle and other animals by mid-November. Insects, birds, and rodents are constant competitors for these mast crops.

In late winter months, squirrels must rely on their diminishing stored food, bark, buds, and other items. Emergency foods are taken in greatest quantities at this time. Prolonged winter drouth or continued low temperatures would undoubtedly be important to the welfare of these animals. Weaker individuals would likely die off first so that winter survival would be somewhat selective.

It is interesting to note that certain tree species leafed out as much as two weeks in advance of others of the same species when associated with seeps, ponds, or other sources of additional moisture in the spring. Such trees produce early spring food which comes at a critical time in the year when food is generally scarce. Such areas were more attractive to squirrels at that time.

It must be emphasized that, although nearly 15 percent of the pecan crop was utilized by squirrels in the study area, this damage would not necessarily be the same in other areas. Agronomy Grove is essentially a native pecan orchard which is bordered by a timbered streambed - a condition which is typical in this vicinity. It is possible that similar damage occurred all along Stillwater Creek. This loss to the farmer must be quite significant, and he would certainly profit by taking preventive measures to reduce the crop loss.

Annual damage to the pecan crop depends primarily on the yield. In years of light yields, squirrels, birds, and mice take practically all of the crop. In years of heavy yields, the damage is less noticeable. Squirrels are greatly attracted to, and concentrate in the native pecan groves in the fall of the year. This influx of squirrels into the orchards intensifies the depredations to the pecan crop. Even heavy hunting in such areas did not seem to materially reduce the squirrel population.

Mouse damage was negligible. Bird damage, especially by bluejays and crows was heavy all along Stillwater Creek. In Agronomy Grove, which was protected from crows, bluejays and woodpeckers consumed large quantities of pecans. The benficial value of the woodpeckers, however, may warrant their protection.

To some, pecan production is a business, and the incomes of these persons may be largely dependent on the amount of pecans harvested. Still, we cannot overlook the aesthetic value of these animals and the hunting sport they may provide. The squirrels themselves should also be harvested as a crop, and "nuisance" squirrels should be controlled. Yet, they should not be eliminated. Measures to reduce the loss of the pecan crop from wildlife should be exercised by farmers.

Moderate damage to corn during the summer occurred all along Stillwater Creek. Many farmers take these depredations for granted and are willing to sacrifice part of their crop just for the aesthetic and hunting pleasures these animals provide. Some farm owners encourage hunting in late summer and fall to protect the pecan crop. Damage to other crops was insignificant.

MANAGEMENT

Woodlot management practices carried out by famers to perpetuate fox squirrel ranges seems to be the most logical approach to current management needs. Monetary benefits to the land owner from the game on his property is low indeed, and he must be sincerely interested in wildlife to be willing to perform measures which will favor production of this game species. To make a living by farming, the agrarian must weigh and measure each problem carefully, as any businessman. He should attempt to determine the economic value of game on his farm. In some cases, squirrels are so destructive that they must be controlled. In general, this game mammal is not sufficiently destructive to warrant indiscriminate slaughter. In north-central

Oklahoma, streambeds are used primarily for grazing stock and all of the arable soil is utilized for cropping. The following practices are suggested for squirrel management:

1. Moderate grazing of streambeds. This will permit the growth of seedlings to reproduce the timber stand. Avoid fall grazing, when possible, to eliminate competition for mast by livestock.
2. Avoid cutting of den trees, bee trees, "coon" trees, trees along fence rows and indiscriminate cutting in general. Selective cutting to improve native pecan orchards would not greatly affect squirrel populations.
3. Indiscriminate burning of oak-prairie ranges is not only an unwise range practice, but may be highly destructive to the game coverts, especially of the fox squirrel.
4. Farm ponds favor the welfare of fox squirrels and other game-farm species. These ponds should be fenced against livestock to protect the pond from trampling which brings about filling and erosion.
5. The present seven and one-half month hunting season extends from May 15, to January 1. The opening date for hunting should be delayed until August 1. This would allow protection for the spring litters. When damage to corn is excessive, farmers may be expected to protect their crops from squirrel damage which is mostly in June and July. An August 1, opening date of the hunting season would allow ample time to reduce the squirrel population before pecan damage begins.
6. An annual census to show the yearly trends in squirrel populations is desirable. Such a census is valuable in evaluating fox

squirrel habitats and showing the effects of hunting pressure over a period of years.

7. Excessive damage to the pecan crop may be diminished by late summer hunting. An early harvest of the crop would probably prevent at least one-third of the crop damage by squirrels and additional damage by birds. Trapping, by using both steel traps and box traps, baited with whole corn may further reduce the squirrel population. Bird repellants to discourage highly destructive species, such as crows, would considerably aid in pecan loss.

SUMMARY

The major findings of a two year study of the ecology, life history, and economics of the fox squirrel in Payne County, Oklahoma were:

1. Fox squirrel habitats were classified into two major types - streambed and oak woods, the former being of primary importance.
2. Squirrels were found to be mostly diurnal, their activities being seasonal. There appeared to be an important mid-winter breeding period, and another lesser one during May and June.
3. Live-trapping, time-area counts, leaf nest counts, den counts, snow track counts and a "clean-up" census were used to estimate squirrel population. The nest counts and snow track counts showed promise as quick inventory methods. Population densities varied from 0.84 squirrels per acre in the winter to 2.12 squirrels per acre in the summer.

4. Variation in the squirrels' diet depended mainly on food succession, availability, and preference.
5. Land-use practices have little effect on present squirrel populations, but over a period of time the intensive farming may deplete squirrel habitats to a low carrying capacity.
6. A quantitative estimate of damage to the pecan crop revealed that fox squirrels took nearly 15 percent of the crop. There was slight to moderate damage to corn. Practices useful to reduce the pecan crop loss due to squirrels and birds include: hunting, early harvest, trapping, and spirolum whirlers.

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APPENDIX

TABLE I

Approximate Area in Square Miles Occupied by the Game Types of Payne County, Oklahoma[1]

Habitat type	Area square miles	Percent
Tall grass prairie	352	52.0
Bottomland timber	36	5.3
Post oak-Blackjack forest	290	42.7
Total	678	100.0

[1]Adapted from Duck and Fletcher (1944).

TABLE II

Crown Cover Composition by Acreage

Area I - Grazed Streambed

Species	Dominant species per acre - 6" DBH and above	Subdominant species per acre - 1" - 6" DBH
Pecan	117.0	—
Elm	29.2	2.4
Black Walnut	29.2	2.4
Hackberry	17.0	4.9
Bur Oak	9.7	2.4
Ash	4.9	12.2
Willow	4.9	—
Kentucky Coffeetree	4.9	2.4
Box Elder	2.4	—
Mulberry	2.4	—
Cottonwood	2.4	—
Red Cedar	2.4	—
Buckthorn	—	2.4
Soapberry	—	2.4
Total	226.4	31.5

Area II - Ungrazed Streambed

Hackberry	114.6	231.7
Elm	85.4	100.0
Soapberry	73.2	205.0
Bur Oak	31.7	7.3
Kentucky Coffeetree	19.5	2.4
Ash	12.2	17.0
Box Elder	9.7	24.4
Cottonwood	7.3	—
Mulberry	7.3	46.3
Black Walnut	4.9	—
Buckthorn	4.9	2.4
Honey Locust	2.4	2.4
Total	373.1	638.9

Area III - Oak Woods Ravine

Post Oak	122.2	314.8
Hackberry	29.6	37.0
Chinquapin Oak	18.5	70.4
Blackjack Oak	14.8	311.1
Elm	14.8	7.4
Honey Locust	3.7	—
Redbud	—	70.4
Buckthorn	—	7.4
Total	203.6	818.5

TABLE III

Crown Cover Composition by Species

Area I - Grazed Streambed

Species	Dominant species percent	Subdominant species percent	Dominant Species DBH[2] range inches	Dominant Species DBH ave. inches	Subdominant Species DBH range inches	Subdominant Species DBH ave. inches
Pecan	51.5	—	7-31	16.0	—	—
Black Walnut	12.4	7.6	10-17	14.1	4	4
Elm	12.4	7.6	9-25	15.7	5	5
Hackberry	7.2	15.9	7-16	11.8	5	5
Bur Oak	4.1	7.6	7-13	10.1	4	4
Ash	3.1	38.5	6-20	10.6	1-5	3
Willow	2.1	—	18-20	19.0	—	—
Box Elder	2.1	—	6-13	9.1	—	—
Kentucky Coffeetree	2.1	7.6	8-12	10.0	1	1
Red Cedar	1.0	—	8	8.0	—	—
Mulberry	1.0	—	10	10.0	—	—
Cottonwood	1.0	—	27	27.0	—	—
Buckthorn	—	7.6	—	—	3	3
Soapberry	—	7.6	—	—	1	1
Total or Average	100.0	100.0	6-31	13.4	1-5	3.2

Area II - Ungrazed Streambed

Hackberry	30.0	36.0	6-27	9.6	1-5	2.5
Elm	22.2	15.9	6-22	12.8	1-5	1.6
Soapberry	19.6	32.0	6-22	8.6	1-5	2.2
Bur Oak	9.1	1.2	6-26	14.0	1-3	2.0
Kentucky Coffeetree	5.2	0.4	6-21	12.8	5	5.0
Ash	3.2	2.5	7-17	12.6	1-4	2.5
Box Elder	2.6	4.0	6-9	7.5	2-5	3.8
Cottonwood	2.4	0.0	11-13	13.6	—	—
Mulberry	2.4	7.2	6-9	7.0	1-5	3.5
Black Walnut	1.3	0.0	15-18	16.5	—	—
Buckthorn	1.3	0.4	7-11	9.0	4	4.0
Honey Locust	0.7	0.4	13	13.0	5	5.0
Total or Average	100.0	100.0	6-27	11.4	1-5	3.2

[2]Diameter Breast High.

TABLE III (CONTINUED)

Species	Dominant species percent	Subdominant species percent	Dominant Species DBH range inches	Dominant Species DBH ave. inches	Subdominant Species DBH range inches	Subdominant Species DBH ave. inches
Area III - Oak Woods Ravine						
Post Oak	60.0	38.5	6-11	8.2	1-5	2.2
Hackberry	14.5	4.5	6-14	8.1	1-5	2.7
Chinquapin Oak	9.1	8.6	6	6.0	1-5	3.2
Blackjack Oak	7.3	38.0	6-17	10.0	1-5	2.2
Elm	7.3	0.9	6-12	9.2	2-4	3.0
Honey Locust	1.8	—	10	10.0	—	—
Redbud	—	8.6	—	—	1-5	2.6
Buckthorn	—	0.9	—	—	1-5	3.0
Total or Average	100.0	100.0	6-17	8.6	1-5	2.7

TABLE V

A Qualitative Comparison of Habitat Types

Streambed (bottomland) type	Post oak-blackjack forest type
1. Fertile, bottomland soils	Relatively infertile, usually upland soils
2. Mature stand of timber along permanent or semi-permanent water course	Age and size of trees variable, usually secondary growths - often far from water
3. Varied growth of stable mast-producing trees	Three species of erratic mast-producing trees
4. Many species of trees producing diversified foods in early spring and summer	Usually not more than eight species of trees, late maturing in spring
5. Numerous elm and other desirable den trees	Few good den trees - both size and quality
6. Typically in direct association with beneficial agricultural activities.	Either apart from or indirectly associated with beneficial agricultural activities.

TABLE VI

List of Tree Species Mentioned in This Study

Ash.
Green Ash. *Fraxinus pennsylvanica* var. *lanceolate* (Borkh.) Sarg.[3]

Blackhaw. *Viburnum rufidulum* Raf.[3]

Black Walnut. *Juglans nigra* L.[3]

Box Elder. *Acer negundo* L.[3]

Buckthorn. (Gum Bumelia) *Bumelia lanuginosa* (Michx.) Pers.[3]

Catalpa. *Catalpa speciosa* Warder[3]

Cottonwood. *Populus deltoides* Bartr.[3]

Dogwood.
Rough-Leafed Dogwood. *Cornus asperifolia*[4]

Elm.
American Elm. *Ulmus americana* L.[3]

Slippery Elm. *Ulmus fulva* Michx.[3]

Hackberry. *Celtis spp.*[3]

Kentucky Coffeetree. *Gymnocladus dioicus* (L.) K. Koch[3]

Locust.
Black Locust. *Robinia pseudoacacia* L.[3]

Honeylocust. *Gleditsia triacanthos* L.[3]

Mockernut Hickory. *Carya tomentosa* Nutt.[4]

Oak.
Blackjack Oak. *Quercus marilandica* Muenchh.[3]

Black Oak. *Quercus velutina* Lam.[3]

Bur Oak. *Quercus macrocarpa* Michx.[3]

Chinquapin Oak. *Quercus muehlenbergii* Engelm.[3]

Post Oak. *Quercus stellata* Wangenh.[3]

Osage-Orange. *Maclura pomifera* (Raf.) Schneid.[3]

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[3]On the authority of Preston (1948).
[4]On the authority of Robinson and Fernald (1908).

TABLE VI (CONTINUED)

Pecan. Carya illinoensis (Wang.) K. Koch[3]

Persimmon. Diospyros virginiana L.[3]

Redbud. Cercis canadensis L.[3]

Redcedar. Juniperus virginiana L.[3]

Red Mulberry. Morus rubra L.[3]

Sand Plum. Prunus angustifolia Marsh. var. Watsoni (Sarg.) Waugh.[4]

Smooth Sumac. Rhus glabra L.[3]

Sycamore. Platanus occidentalis L.

Wahoo. Euonymus atropurpureus Jacq.

Western Soapberry. Sapindus drummondi Hook. and Arn.[3]

Willow. Salix nigra Marsh.[3]

TABLE VII

Squirrel Utilization of Nests from
March 1 to April 10, 1951

	Post Oak	Elm	Blackjack	Hackberry	Total or Average
Number of nests examined	20	9	8	2	39
Number of nests containing squirrels	3	2	2	—	7
Number of nests recently used	7	3	2	—	12
Number of nests intact	16	4	5	1	26
Percent utilization	35	33	25	0	31

TABLE VIII

Frequency of Dens in Relation to Tree Species

Species	Number of dens	Percentage
Elm	40	64.5
Cottonwood	11	17.9
Pecan	6	9.6
Bur Oak	4	6.4
Ash	1	1.6
Total	62	100.0

TABLE IX

Individual Snow Track Counts in Area I with Six Inches of Snow on February 15, 1951

Location	Number of acres	Number of counts	Counts per acre
North border (Grazed)	25.0	10	0.40
South border (Ungrazed)	17.5	20	1.14
Woodlot (Grazed)	13.2	11	0.83
Total or average	55.7	41	0.74

TABLE X

A Comparison of Den Counts on Four Areas

Area	Number of acres	Number of dens	Number per acre
Area I (Grazed streambed)	55	49	.90
Area II (Ungrazed streambed)	16	13	.81
Area III Oak ravine	20	7	.35
Oak "island"	1.3	—	—

TABLE XIV

Summer and Winter Population Densities of Area and Area II

Census method	Area I summer	Area II winter
Nest count	2.14	—
"Clean-up"	2.12	—
Time-area count	16.6	—
Den count	0.81	0.9
Snow-track count	—	0.74
Trapping	—	0.84

TABLE XV

Relation of Nests and Dens per Acre to Summer Squirrel Densities

Area	Nests per acre	Dens per acre	Squirrels per acre
Area I (Grazed streambed)	7.3	.9	2.1
Area II (Ungrazed streambed)	7.3	.81	2.1
Area III Oak ravine	3.3	.35	.97
Oak "island"	2.2	—	.65

TABLE XVI

Seasonal Food List Based on Observations and Stomach Analysis from October 1, 1950, to October 1, 1951

Food eaten	Part of food consumed	Period of use	Extent of use
Blackberries	fruit	June, July	Supplementary
Blackjack oak	acorns	July - April	Staple
	twigs	Jan., Feb.	Emergency
	bark	Jan., Feb.	Emergency
Black walnut	nut	July - March	Staple
Bur oak	acorns	July - March	Staple
	twigs	Dec., Jan., Feb.	Emergency
	bark	Any time	Emergency
Corn	kernel	June, July, ?	Supplementary
Hackberry	bark	Dec., Jan.	Supplementary
	leaves	May	Emergency
	berries	July - early Sept.	Supplementary
Elm	seeds	March, April, May	Staple
	bark	Dec., March	Emergency
	leaves	Late April, May	Supplementary
Hickory	nut	July - March	Staple
Kentucky coffeetree	pod and seeds	July - September	Supplementary
Mulberries	fruit	Late May - mid-July	Staple
Mushrooms	crown	Whenever available	Supplementary
Pecan	nut	Late Aug. - March	Staple
	twigs	Dec., Jan., Feb.	Emergency
	bark	Dec., Jan., Feb.	Emergency
Pokeberries	fruit	July - ?	Supplementary
Post oak	acorns	July - March	Staple
	twigs	Jan., Feb.	Emergency
	bark	Jan., Feb.	Emergency
Soapberry	leaves	May	Supplementary

TABLE XVII

Pecans Utilized by Fox Squirrels in Five Plots Placed Singly
Under Trees in a Native Pecan Orchard
From September 10, 1951, to December 11, 1951

	September	October	November	December	Total or average
		Marked Pecans			
Number Counted	—	25	224	68	317
Number Taken	—	6	83	12	101
Percent Take	—	24.0	37	17.6	31.8
Amount Taken, (Grams)	—	20.6	285.5	41.2	347.3
		Unmarked Pecans			
Number Counted	—	3	224	68	295
Number Taken	—	.9	71.2	21.6	93.7
Percent Taken	—	24	37	17.6	31.8
Amount Taken, (Grams)	—	3.1	244.9	74.3	322.3
		Green and Unmarked Pecans			
Number Taken	140	35	—	—	175
Amount Taken, (Grams)	481.6	120.4	—	—	602
		Middle Lamellae			
Number Counted, (Taken)	—	13	18	21	52
Amount Taken, (Grams)	—	44.7	61.9	72.2	178.8
		Total Utilization			
Number Taken	140.0	54.9	172.2	54.6	421.7
Grams	481.6	188.8	592.3	187.7	1450.4
Pounds	1.06	0.42	1.30	0.41	3.19

TABLE XVIII

Relation of Variety, Diameter Breast High, Crown Area and the Estimated Yield of Pecan Trees to Pecans Taken by Squirrels

Tree Number	Variety	Diameter breast high inches	Average crown radius from center of tree yards	Crown area sq. yards	Estimated yield pounds	Pecans taken by squirrels under each tree pounds
1	Native	34	10.4	339.6	150	22.4
2	Native	26	11.7	429.8	160	23.8
3	Stewart	18	8.2	211.1	35	5.0
4	Native	51	13.6	580.7	110	16.0
5	Native	26	9.4	277.4	40	6.1
Total				1838.6	495	73.3

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