Hartman, George F
Life history and management of the fox squirrel with particular reference to the western race...

LIFE HISTORY AND MANAGEMENT OF THE FOX SQUIRREL WITH PARTICULAR REFERENCE TO THE WESTERN RACE SCIURUS NIGER RUFIVENTER (GEOFFROY)

by

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INTRODUCTION

The fox squirrel, indigenous to much of the forested land lying east of the prairies, is a well-known species. At the present time it is most common in the Central, Gulf, and Lake states, and it is here that it is most popular as a game species. Sportsmen of the North-central and Lake states, however, consider the fox and the gray squirrels of much less sporting value than the other small game species. In spite of this opinion, hunting returns for Ohio, Michigan, Wisconsin, and adjoining states show that a very large number of squirrels are taken annually. For instance, in Wisconsin, the reported kill of squirrels is greater than that of any other small game, except rabbits.

The regarded value of squirrels as game species increases as one goes south, reaching its height of popularity in Texas, where Goodrum (1938 p. 670) reports the desirability of squirrels as game to be only second to quail.

Possibly the major reason why these animals are frequently disregarded as game by the sportsmen is due to the fact that approximately 80 percent of the kill is made with shotguns. How many hunters would shoot a pheasant sitting or running on the ground?

Fox squirrels, as well as their gray relatives, have served American history and tradition well. Squirrel stew held an important place in the diet of the pioneers. The squirrel, the houn'-dog, and the Ozark mountain boy with his long rifle form a traditional triangle that is only equaled by the Darkey, his dog, and his 'possum.

The enormous annual fox squirrel kill indicates that these animals should be managed on a basis comparative with the other seemingly more desirable species.

Unlike the gray squirrel, fox squirrels, particularly the western race, have adapted themselves very well to the changes in their environment brought about by the settlement of the country, and have even pioneered into territory that was formerly held by the gray species. This seems to indicate that the fox squirrel is the more desirable of the two species for management.

At the present time, our knowledge of the life history and ecology of this species is quite incomplete, and while it is being intensively studied in several states, findings vary greatly, due, no doubt, to differences in the physical, climatic, biotic, and nutritional factors of each locality. Many of these differences are to be found in the more common literature while others can be shown by a more intensive study of library material supplemented with field data from various localities.

SYSTEMATIC ACCOUNT

The fox squirrels are classified in the Order Rodentia, superfamily Sciuroidae, family Sciuridae, and subfamily Sciurinae, and as with most other true tree squirrels, they are placed in the genus Sciurus "(from Gr. Skiouros or squirrel; literally 'shade-tailed,' from Gr. skia shade + oura tail, in allusion to the animal's habit of sitting as it were in the shade of its own tail)." (Hatt p. 15). The fox squirrels, together with the Apache Squirrel, Sciurus apache Allen; Arizona Gray Squirrel Sciurus arizonensis arizonensis Coues; and the Huachuca Gray Squirrel, Sciurus arizonensis huachuca Allen; are the United States representatives of the subgenus Guerlinguetus, a group restricted to North and South America. This subgenus among other ways differs from the sub-genera, Sciurus, the gray squirrels; and Tamiasciurus, the red squirrels; by the fact that it has but a total of 20 teeth whereas the other two have 22 teeth. The dental formulas are:

I., $\frac{1}{1}$; C; $\frac{0}{0}$; P., $\frac{1}{1}$; M., $\frac{2}{3}$ = 20 - fox squirrels

I., $\frac{1}{1}$; C., $\frac{0}{0}$; P., $\frac{2}{1}$; M., $\frac{3}{3}$ = red and gray squirrels

The fox squirrels are the largest of the North American

arboreal squirrels, and also the most variable in color. (Anthony 1935 p. 258). Size, therefore, together with the rusty- to blackish coloration, aids in distinguishing it from the reds and often the grays although in the case of the latter, dentition may be the easiest and most positive method.

At the present time seven subspecies of fox squirrels are recognized by Miller (1923 pp. 225-227). Map 1 shows roughly their present distribution.

Nomenclature

Like most other species of wide distribution, Sciurus niger is known by many names, among them the most common being fox squirrel, big red squirrel, red-tailed squirrel, cat squirrel, white-nosed black squirrel, and yellow bellied squirrel (Seton 1929 p. 82). The name fox squirrel, however, is the one most commonly used.

Linnaeus named the species Sciurus niger in 1758, from specimens that were probably taken in South Carolina[1] and which are now classified as Sciurus niger niger[2] and are commonly known as Catesby's Black Fox Squirrel. Owing to the many different color phases found in the group, many specific and subspecific names were given to them. Audubon and Bachman (1849) recognized twenty-four different forms.

[1] 1758 Sciurus niger Linnaeus Syst. Nat., ed. 10, V. I, p. 64.

[2] 1886 Sciurus niger niger True, Proc. U. S., Nat. Hist. Mus.; (1884) p. 595.

Extreme variations in habits and habitats of the group throghout its range probably also accounted for some of the many scientific names used in the past.

The following list, taken from Miller (1923 pp. 225 - 227) gives the more commonly used names of the past:

Sciurus niger niger Linnaeus. Catesby's Black Fox Squirrel.

Sciurus niger Linnaeus, Syst. Nat., ed. 10, Vol. I, p.64.
Sciurus niger niger True, Proc. U. S. Nat. Mus., Vol. 7, (1884) p. 595.
1885 (Part).

Sciurus niger avicennia Howell Mangrove Fox Squirrel.

Sciurus niger avicennia Howell, Jour., Mamm.; Vol. I, p. 37, Nov. 28, 1919.

Sciurus niger neglectus (Gray), Northern Fox Squirrel.

Macroxus neglectus Gray, Ann. and Mag. Nat. Hist. Ser. 3, Vol. 20, p. 425. Dec. 1867.
Sciurus niger cinereus True, Proc. U. S. Nat. Mus., Vol. 7 (1884), p. 595. 1885.
Sciurus ludovicianus vicinus Bangs, Proc. Biol. Soc. Washington, Vol. 10, p. 150. Dec. 28, 1896. (White Sulphur Springs, West Virginia, Greenbrier Co.)
Sciurus ludovicianus neglectus. Nelson. Proc. Biol. Soc. Washington, Vol. 13, p. 170. Oct. 31, 1900.
Sciurus niger neglectus. Osgood. Proc. Biol. Soc. Washington, Vol. 20, p. 45. April 18, 1907.

Sciurus niger byranti H. H. Bailey Byrant Fox Squirrel

Sciurus niger byranti Bailey-Bailey Mus. and Libr. Nat. Hist. Newport News, Va., Bull. No. 1, p. 1. Aug. 1, 1920.

Sciurus niger rufiventer (Geoffroy) Western Fox Squirrel.

1803 Sciurus rufiventer Geoffroy, Catl. Mamm. Mus. Nat. Hist. Nat., Paris, p. 170.
1806 Sciurus ludoviceanus Custis Barton's Med. and Phys. Jour. Vol. 2, pt. 2, p. 47.
1885 Sciurus niger ludovicianus True, Proc. U. S. Nat. Mus., Vol. 7 (1804) p. 595, 1885.
1907 Sciurus niger rufiventer Osgood Proc. Biol. Soc. Wash. Vol. 20, p. 44. April 18, 1907.

Sciurus niger texianus (Bachman). Bachman Fox Squirrel

1838 Sciurus texianus Bachman, Proc. Zool., Soc. London, p. 86.
1907 Sciurus niger texianus Osgood Proc., Biol. Soc. Wash. Vol. 20, p. 46. April 18, 1907.

Sciurus niger limitis (Baird), Texas Fox Squirrel.

1855 Sciurus limitis Proc. Acad. Nat. Sci. Philadelphia Vol. 7, p. 331.
1896 Sciurus ludovicianus limitis Bangs. Proc. Biol. Soc. Wash., Vol. 10, p. 147. Dec. 28, 1896.
1907 Sciurus niger limitis Osgood, Proc. Biol. Soc. Wash., Vol. 20, p. 47. Apr. 18, 1907.

Description of the Various Races

The first described fox squirrel was the black squirrel of South Carolina, one of the three color phases of the race S. n. niger. Pelage of the black phase varies from a glossy black to partly black to dark brown in color, excepting the ears and nose which are always white. Grading from the dark brown, are the two other color phases, the buff and the gray. The extreme form is pale smokey-gray above, including the tail, and white beneath. The crown is black or blackish and the nose, ears and feet are white. Some specimens of this phase have the feet and underside of tail, buff, thus approaching the next darker phase. In the buff phase, the upper parts are described as being of a general tone of pinkish-buff and the underparts, feet, and lower side of the tail a clay color or cinnamon-buff (Howelll). Measurements given by Anthony are: total length, 27 inches; tail, 12 inches; hind foot, 3.5 inches.

Mangrove Squirrel

Howell (1919 p. 31) describes this species as being, "Similar to Sciurus niger niger but decidedly smaller; coloration much darker (more tawny) both above and below; feet clearer white (less tinged with buff)." Seton (p. 84) describes it as being much darker and more tawny than the southern fox squirrel and that it also has feet of a clearer white. Average measurements given are : total length, 21.4 inches; tail, 10 inches; hind foot, 3 inches.[1]

Northern Fox Squirrel

Said by Anthony (35 p. 256) to be "similar to niger but color less rusty in hue, underparts generally whitish, ears never white; nose sometimes white. Total length, 23 inches; tail vertebrae, 11 inches; hind foot, 3 inches."[2] Seton (1929 p. 83) states that it is much like the western form, rufiventer, but of "paler colors and usually with the belly white."

Byrant Fox Squirrel

This little-known squirrel is described as being distinctly larger than the typical niger and with the above "bluish gray, thickly grizzled with black, ends tipped with white, sides similar, below white. Nose white. Tail with a pronounced black stripe on outer edges." Bailey (1920 p. 1). It has the general appearance of the gray phase

[1] Anthony 1935. Fox Squirrels in Field Book of North American Mammals. Pp. 257-259.

[2] Ibid.

of niger, but without the black patch on the head.

Bachman Fox Squirrel

Sciurus niger texianus is slightly larger than rufiventer and smaller than niger. It has about the same type of coloration as the southern fox squirrel, but is sometimes a little lighter. The ears and nose are less extensively white than in niger and the head has some black. The belly is either tawny or whitish. Measurements given are : length, 25 inches; tail vertebrae, 11 inches; hind foot, 2.7 inches.

Western Fox Squirrel

Sciurus niger rufiventer, perhaps by far the most common fox squirrel, is regarded by Anthony ('35 p. 253) to be smaller than typical niger, but Seton (1929 p. 82) reports a Michigan female in his collection to weigh 2 1/4 pounds. Other records of individuals of a comparable weight are not uncommon. This subspecies can be distinguished from its neighboring forms in that its nose and ears are never white. The general color pattern is quite variable but "usually tawny brown grizzled with gray above, and pale rufous or yellowish brown below." The tail is mixed with black, but individuals especially the young having tails with long white hairs along the edges are frequently taken.

Melanism and Albinism

Melanism is frequently found in the niger race, and as mentioned previously, it was from this dark form that

the specific name was received. Perhaps all other races also have melanistic or at least partial melanistic individuals. There is one skin of a partial melanistic phase of a rufiventer squirrel in the collection of the University Museum at the present time. The underparts, feet, chin, lower portion of the legs, the nose, and crown are black. Gibbs (1895 p. 151) reports of a partially melanistic squirrel that had the chin, throat, belly, breast, and inside of the legs black. He thought that it might have been a fox-black squirrel hybrid. Wood (1923 p. 22) reports of another similar fox squirrel that was taken near Ann Arbor, Nov. 12, 1910, that had "the whole underside jet black." Kennicott speaks of fox squirrels having black underparts which he had only seen in Southern Wisconsin and Northern Illinois.

Partial albinism among fox squirrels, in which the underparts are white are occasionally found, but total albinism seems to be very rare. Wood (1922 No. 123) reports one albino fox squirrel that was taken in Washtenaw county, and is now in the collection of the Museum.

Of the mutant color phases, albinism is by far the least common.

GENERAL ECOLOGICAL REQUISITES OF VARIOUS SUBSPECIES

It has long been recognized that various plants with wide distributions, adapt themselves to various soil types. In their centers of distribution, they may be found growing on several classes of soils, while at their extreme northerly and southerly limits of distribution, or any other distribution boundary i. e., altitude, they may be found growing on but a single soil type. Jack pine, for an example, can be found on almost any soil, including those of organic nature, at its center of distribution, the area north of Lake Superior. At its southern limits, the Central Wisconsin Sand Plain, and the Indiana Dunes, it is to be found on these sandy soils and ceases to exist where these soils intergrade into those of a limestone origin. At its northern extreme, Jack pine grows only on limestone soils. In its region of optimum growth the climate is moderately cold. At its southern limits, it of course tolerates a much warmer climate, but it can only do so on the acid sandy soils. At the species' northern limits it tolerates the colder climate by growing only on the heavier limestone soils. Extremes in climate, therefore, may be a factor in determining the soil type which a species occupies.

While reading through the literature on the American Arboreal Squirrels, the author noted that the environmental requisites of fox squirrels differ throughout the country. This was found to be true in individuals of the same species and (as environment often creates the animal), usually so among individuals of different sub-species. The cause of this selectivity may be due to either physical, biotic, nutritional, or indirect chemical factors.

By common consent of most Lake States naturalists, the Western Fox Squirrel Sciurus niger rufiventer (Goeffrey) is more or less a border species, while our gray squirrel Sciurus carolinensis leucotis is the squirrel of the forest. Kennicott (1856 p. 579), writing about the Western Fox Squirrel recognized this. He states:

> "The fox squirrel loves neither the lowlands nor the deep woods, and though found living in the heavily timbered districts of Indiana and Illinois, it is less at home in these than in the more open ground. It is properly an inhabitant of the timber of the prairie regions, and its favorite habitat is the 'Oak Openings' of Wisconsin and Michigan and the groves or edges of the belts of timber that skirt the streams watering the prairies of Illinois."

Unfortunately, the "Oak Openings" are now gone; but man, in clearing land, has created many small groves comparable to them. Thus the range of the fox squirrel was increased when the land was cleared while that of the gray squirrel was decreased. Early records show that the fox squirrel, although native to Southern Michigan, was to be found only in limited areas. The first record of a fox

squirrel taken in Michigan is given by Sager (1839 p. 412) and Baird record one specimen taken near Ann Arbor in 1859 (pp. 444-448). It appears that they were uncommon in the Ann Arbor area for some years. Wood writes that he never saw a fox squirrel near his home in Lodi Township until about 1875, and that they were rare for several years after that (1922 p. 14). An examination of a Survey Map published in 1843, shows that "woods openings" occured in Lodi Township, but that they were not extensive.

With the opening up of the country the species spread northward even entering the birch-beech-maple forest, where its distribution is localized around areas where such species as red, white, black and pin-oaks, butternut, and bitternut trees are found to constitute a fair portion of the composition of the stand.

The following map (Fig. 1) shows the spread of the fox squirrel in the State of Michigan and indicates some of the counties where it is now to be found (Wood and Dick pp. 459-46).

It is not to be inferred that the extension of the range was only to the north, as the fox squirrel was not found in Central Ohio until 1880, and as the sub-species now found there is the western type, the extension of the range also must have been in an easterly direction. Here again the extension of the range is the direct result of Man's operations. (Chapman, 1936). Chapman also found that

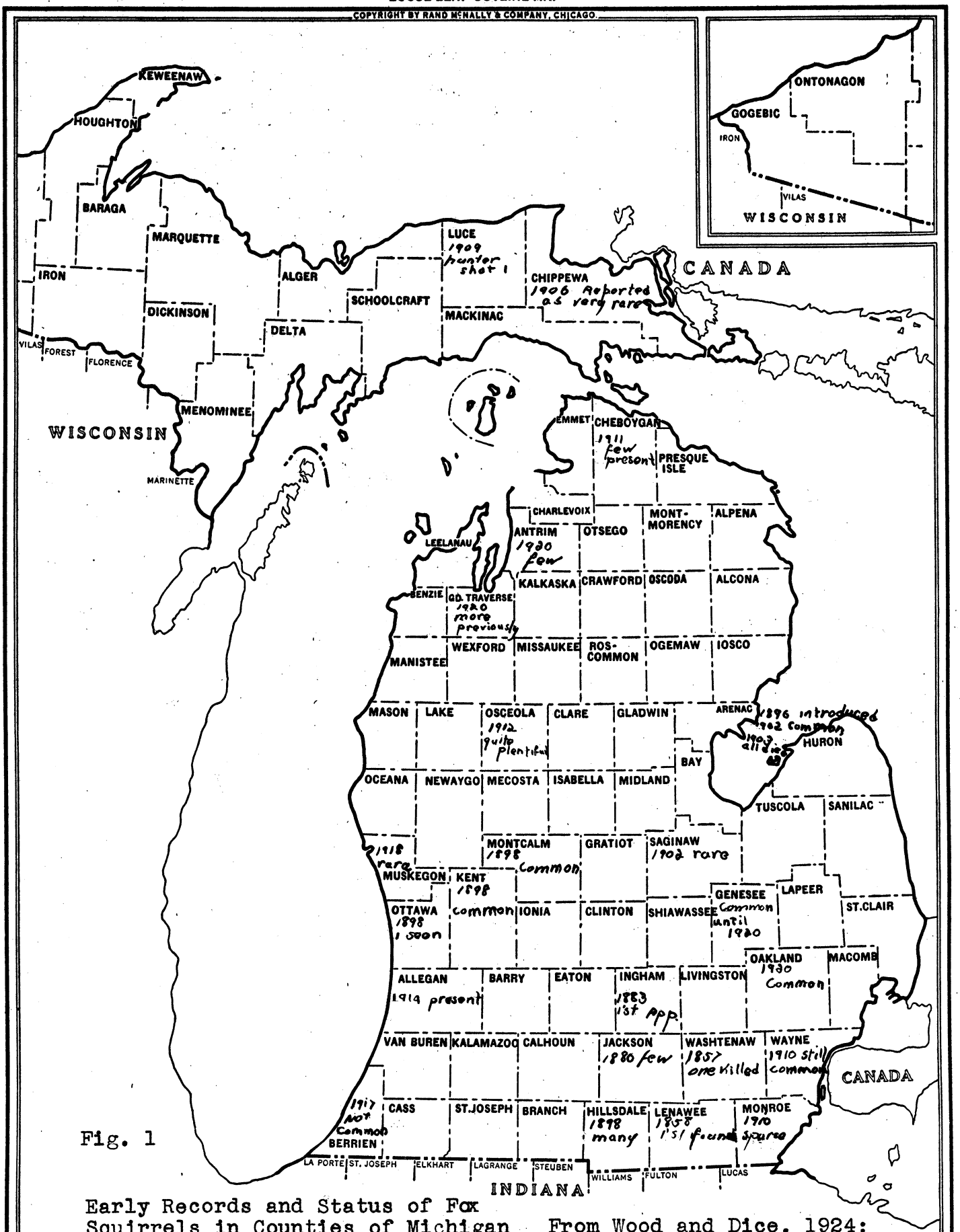


Fig. 1

Early Records and Status of Fox Squirrels in Counties of Michigan in Past Years

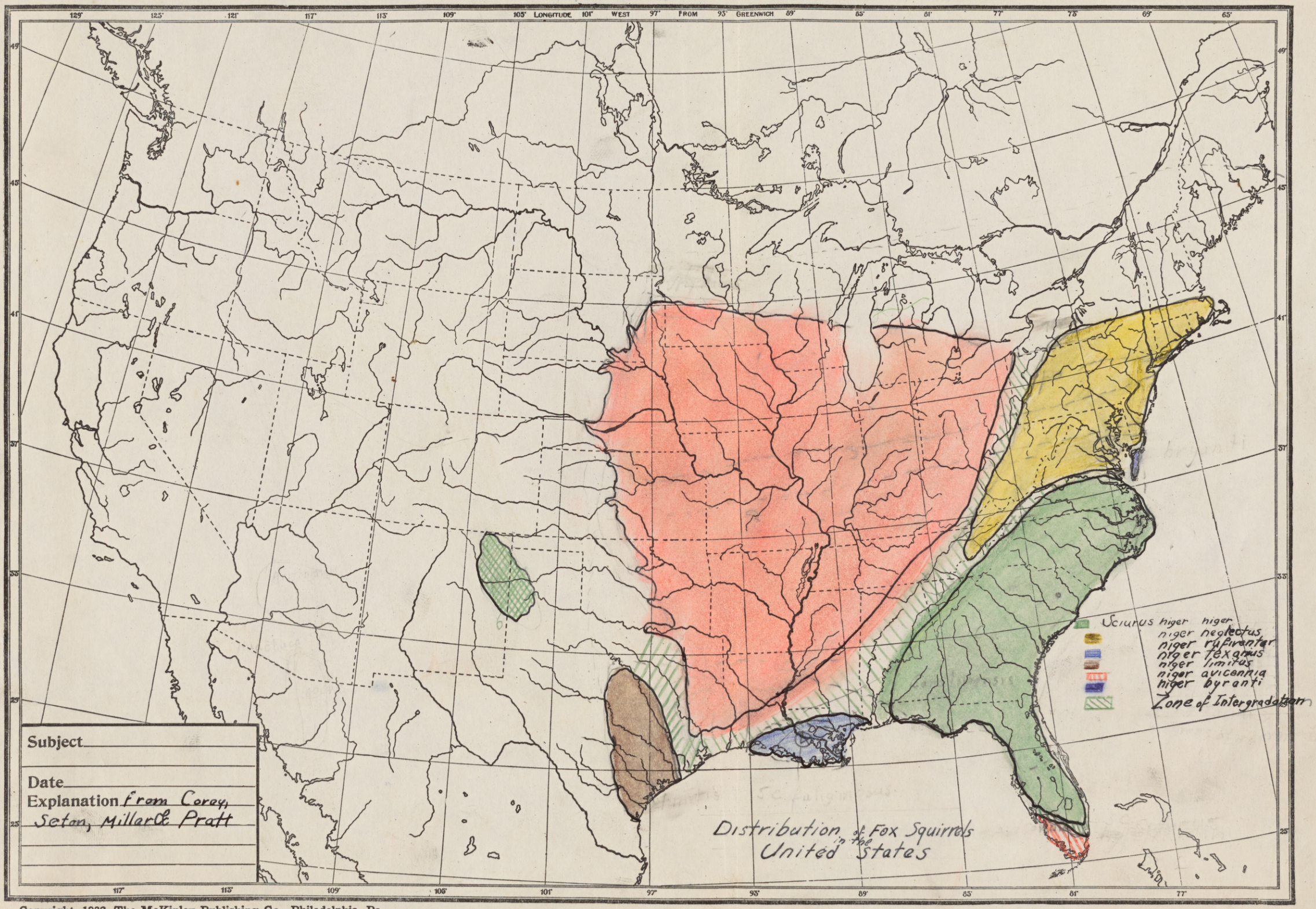
From Wood and Dice, 1924; Wood 1914, 1911, 1922; and Wenzel 1912

the fox squirrel requires eighty percent of its home range to be in woodlots and twenty percent of it in cultivated or other open lands; whereas the gray squirrel requires all of its home range to be in woods. Here again the fox squirrel took over the area formerly occupied by the gray squirrel.

Rufiventer shows its characteristic as an "edge type" species well in Ohio, Indiana, Missouri, Iowa, and Texas, but Hamilton (1930 p. 310) reporting on its status in Kentucky speaks of it as being rare except in the heavily wooded parts where it is not much molested. Welter and Sollberger (1929 p. 80) also found the fox squirrel to be "not at all common in Kentucky." In both cases, hunting may or may not have been the cause of its scarcity. Hicks (1938 pp. 418-419) reports that, though the fox squirrel is found in all of the counties of Ohio, they are outnumbered by the gray squirrel four to ten times in the unglaciated hill country of the southern part of that state. This would seem to indicate that hunting is not the chief factor limiting the abundance of the species. It is interesting to note that both of these areas lie within the chestnut, chestnut-oak, yellow poplar forest region of the United States. Here then, soil types may affect squirrel abundance indirectly through the vegetation and area supports.

In the northwest portion of Arkansas, Black (1936 pp. 29-35) regards the fox squirrel as a species of the

McKINLEY'S DESK OUTLINE MAPS. DOUBLE SIZE. No. 175a. THE UNITED STATES.



prairie edge types, but he found them to prefer the denser growths of timber. Here again some outside factor such as temperature, water, or overshooting may be the determiner of this preference. Kellogg (1937), writing on the race indigenous to Central and Southern Tennessee, classes the squirrel as a species that is always found in the big timber, but that it prefers the gum and cypress trees of the swamps.

It may, therefore, be concluded that the rufiventer race of fox squirrels is primarily an upland border type or an inhabitant of the smaller upland woodlots in the central, northern, and western parts of its range, while at its southern and southeastern limits it is primarily an inhabitant of the extensive and lowland types of forests.

Northern Fox Squirrel - Sciurus niger neglectus

Distribution - see Figure 2.

Type Locality - New Castle County, East Delaware.

The northern fox squirrel is an inhabitant of the upland forests of the Upper Austrzal zone along into the borders of the Transitional zone. It is a rare species, and seems to have difficulty in holding its own. The race has been extinct in Connecticut and New Jersey for some time; however, Goodwin (1935 p. 18) reports (1842) a record for that state. A few are yet to be found scattered throughout Central Virginia, West Virginia, to Pennsylvania. In 1903, it was considered rare in Pennsylvania, but it was

reported to be not uncommon in the counties bordering the lower Susquehanna and in the northwest part of the State (Rhodes 1903 pp. 57-61). It is doubtful if the species was ever plentiful in Northern New York as Bachman (1849 pp. 30-33) saw only two in fifteen years of observation. He found it to be more common in the southern part of the State.

The Northern fox squirrel, unlike its western relative, is primarily an inhabitant of the forest rather than the woodlot. It has not pioneered new territory nor maintained its numbers as did the race rufiventer.

Here then, is a race of fox squirrel that is even less adaptive than the gray squirrel to the changed conditions brought about by the settlement of the wooded areas of the East. Its primitive habitat was the more heavily wooded lands of the Allegheny Mountains and at the present time it can only be found in localized parts of the more heavily wooded and unsettled parts throughout a portion of its past range (Bangs 1896 p. 145).

Sciurus niger byranti (H. H. Bailey)

Type locality - Dorchester County, Maryland.

Distribution - (see map).

Little is known about this race that has developed from the northern fox squirrel. The sub-species is only found in a limited area and its haunts are not well known, though its general habitat is the upland hardwood forest of the region.

The Black Mangrove Squirrel - Sciurus niger avicennia

Distribution - (see map).

The black mangrove squirrel, as it is locally called, is found in the dark, damp forests of black and red mangrove of the southwest and south coast of Florida. It is, perhaps, the most localized of all the fox squirrels. The race is reported to be not uncommon, although Howell (1919 pp. 36-37) saw only one in several days of hunting.

While this squirrel arose from Sciurus niger niger, its environment corresponds more closely with that of the Western sub-species at its Southeastern limits of distribution.

The Carolina Fox Squirrel - Sciurus niger niger (Linn.)

Type locality - Southern South Carolina.

Distribution - (see map).

This squirrel is a dweller of the dry pine forest and is seldom found in the bottom-lands which is the environment of the gray squirrel (Howell 1921 pp. 64-67). Audubon and Bachman (1849 pp. 30-33) considered it to show a preference for the lighter stands of pine interspersed with oak and hickory, and in the mountainous region of Northern Alabama they range into the oak-pine-hickory forests of the moist situations. The sub-species is also occasionally found in the cypress swamps along the coast. The Carolina fox squirrel is said to be only locally common,

and may be absent from large areas as the result of over-shooting and the destruction of the environment.

The Texas Fox Squirrel - Sciurus niger texianus (Bachman)

Type locality - Coast of Louisiana or Mississippi.

Distribution - Coast regions of Louisiana, Mississippi, and Alabama.

Like the Carolina fox squirrel, this race also makes its home in the pineries of the South, but it is not entirely confined to this vegetation as it likewise enters the upland deciduous forests (Bailey 1905 p..75). In spite of its name, this squirrel is not found in Texas, but occurs in Southern Louisiana, through Mississippi and the greater part of Alabama. Again like its eastern relative, it is only common locally.

Sciurus niger limitis (Baird)

Type locality - Devils River, Valverde County, Texas.

Distribution - Western Texas and Northeastern Mexico.

The sub-species inhabits the timber along the streams of the half-forested mesquite region where it feeds upon the nuts of cypress, pecan, walnut, hickory, and oak. They are quite closely limited to the stream and ravine forests, but are occasionally found on the ridges between the rivers.

PAST HISTORY

Little information on the primitive numbers is to be found in the accounts of the old-time observers. Seton ('29 p. 86) is of the opinion that the species was always less numerous than the gray, which he thinks outnumbered it 10 to 1. Bachman ('49 p. 135) writes to the effect that when field corn was green in the milk stage, farmers were forced to guard their cornfields with guns and - "In this way thousands of fox squirrels were destroyed during the green corn season."

Steere (1880 p. 198), in a "List of Birds and Mammals" Ann Arbor "reports that he had seen at least fifty gathered together (in this way) in the spring of 1877 near Professor TenBrook's house and others speak of still larger gatherings. He did not know the reason for these congregations.

An account of squirrel abundance in Missouri for the year 1919, is given by Seton (p.26) where one observer estimated that he saw 100,000 fox and gray squirrels during one day while hunting in the hill country of that state. The same author reports that "it is not unusual for a gunner to get 40 or 50 fox squirrels a day even yet." (1929).

The more solitary habits of the species, together with the fact that unlike the gray, fox squirrels migrated only

sporadically and locally and in much smaller numbers, undoubtedly accounts for the fact that little literature on past numbers is to be found. The total population of the western race is perhaps as great now or possibly greater than it was during primitive times as a result of the extension of the range.

LIFE HISTORY

Mating

Mossman ('32 p. 891) and his co-workers found that the cyclic atrophy and hypertrophy of the genital organs are not marked in either the male fox and gray squirrels as shown from the following records. Gray and fox squirrels with large testes and genital glands, although not all active sexually, but "not markedly atrophied, were taken on the following dates of the year:

Fox Squirrels		Gray Squirrels	
2	taken January 18	1	taken January 4
1	February 11	2	February 5
1	April 6	1	April 27
1	April 16	1	May 15
1	May 15	1	May 29
1	October 18	1	December 16
1	November 8	1	December 19
1	December 22		
1	December 27		

In addition to these sexually well developed individuals, the authors reported to have taken sexually immature males at all times of the year.

Allanson (1933 pp. 79-96) working with the gray squirrel in England, also found sexually active individuals

throughout the year and she states that "there is no regular period of quiescence in the male." She also reports that of 112 male squirrels, ranging in weight from 240 grams to 705 grams, that were examined, the weights of the two testes varied from 0.062 grams to 7.4 grams and that spermatozoa are always present in testes that weigh more than two grams per pair. The writer is of the opinion that it is possible that individual males do not remain continuously in reproductive activity.

The female gray squirrel, however, has a rather definite reproductive cycle. Deansley and Parks (1933 pp. 77-78), also working with the species in England, found that of a total of 24 pregnant females collected; 13 were found pregnant during the period of January and April; and 11 pregnant during June and July. All female specimens collected from August to the middle of January were "prepubertal or anestrous with the exception of five which were still lactating in autumn. Parous squirrels were found to commonly breed in spring and sometimes again in summer, while of the first-year squirrels some may breed in spring while others do not freed until summer. It was also discovered that for this species at least, there was no oestrus immediately after parturition or during lactation.

The reproductive cycle, or what approximates it, is therefore similar in the males of both the fox and gray squirrels and existing literature indicates that it is also quite as similar in the females of the 2 species.

Reporting on Sciurus niger in Texas, Goodrum (1938 p. 670) found from records of 550 specimens examined that there are two litters per year; the first brood develops principally during the period of December 15 to May 15, and the second, July 15 to December 15. Bennitt and Nagel (1937 p. 85), although they have no definite proof, are also under the impression that in Missouri there are two broods of young annually. Svihla (1931 p. 155) reports that in young fox squirrels in Michigan"at least six months old and perhaps not more than eight," the testes become noticeable and that about a month later the testes measured approximately three centimeters in long diameter; at which time the young males would attempt copulation. This was during the latter part of October.

TIME OF BREEDING

As might be expected, the breeding season of the species in the southern portions of its range preced those in the northern area though only slightly. Some breeding dates, taken from reported observations in young are:

State	Dates	Observers
Texas	Nov. 1 to April 1	Goodrum
2nd	June 1 to Sept. 1	Goodrum
S. Carolina	Middle Nov. to Dec. 15	Audubon Bachman
S. Carolina	Christmas week	Audubon Bachman
Kansas	End December	Linsdale
Missouri	Christmas week	Seton
Indiana	December - March	Stoddard
Indiana	December or Jan.	Ward

While the above data are very incomplete, they do show that for some reason latitude has little effect on the time of the breeding season. The more complete recdrds for Michigan show the long breeding season quite well. Data taken from reports of young squirrels, and subtracting 60 days as the gestation period, and an estimated period for the nursing period gives us the following data:

Some chronology records given by Seton ('29 p. 46) on the gray squirrel provide the following: duration of

the blind period is 37 days, and the reported age when fox squirrels are forced to leave the home den is 10 or 12 weeks. Dr. A. J. Nicholson of Austin, Texas, writes me that the blind period of young fox squirrels is approximately 5 weeks and that they are approximately 9 weeks old when they first leave the nest. Both reports are quite similar to those of Seton for the gray squirrel.

Dr. H. W. Mossman of the University of Wisconsin writes me that he has definite evidence that fox squirrels in Wisconsin may produce two litters per year. He has records on 55 female fox squirrels as well as 49 female grays. He writes:

". . . Also there are two fox squirrels taken May 22, 1931, and June 9, 1936, which were lactating and in proestrum. Another on July 14, 1934, had embryos in the early limb-bud stage and large nipples indicating that she had recently nursed a litter. These five animals (two grays) show beyond a doubt that both fox and gray squirrels may breed twice in one year, or perhaps more accurately, twice in one breeding season. Evidence from both males and females in my collection indicates that in Southern Wisconsin, the breeding season extends from about the middle of December to August with occasionals at other times. In regard to the latter, there is one fox squirrel taken on October 2, 1938, which was lactating profusely, but had very small placental scars. Of course, she might have bred as early as mid-August."

Mossman's earliest cases of estrum or of embryos too early to detect grossly are:

Gray squirrel 17 1/25/32 "Late unattached uterine morula."

Fox squirrel 39 1/16/33 "Estrum (by gross examination)"

Fox squirrel 29 1/21/32 Vaginal plug and 1-cell embryo in tube.

Mossman goes on to say that his ". . . general belief about breeding season of the gray and the fox squirrels in Southern Wisconsin is that they normally breed from mid-December to August with the peaks in January and February, and in June and July. Most of the very early or very late and intermediate ones (that is in April and May) are first mating, probably of young born very early or very late the preceding year. I don't believe young born in the spring breed the same summer. Female chipmunks do this, although the males do not mature until the following spring. It seems to me that the winter and summer peaks of reproductive activity cannot be regarded as properly representing two separate breeding seasons, for I have no evidence that the testes of the males degenerate in the interim. In red squirrels, this condition does occur, although even here the genital organs of the males do not regress as completely during the late spring as they do in the fall. Perhaps the fox and gray squirrels at the more central or southern part of their range do have two distinct seasons. The

reds are more hardy and might be expected to be more completely adapted to this climate than the others."

Gray squirrels and fox squirrels have, therefore, very similar reproductive habits as seen by the above work and its comparison with that done on the gray squirrel. That these data hold true for Southern Michigan is indicated from the following breeding observations:

Approximate Time	Observer	How Determined
Late December to Jan.	D. L. Allen	General, direct report
Late March	D. L. Allen	1 observation
May - June	D. L. Allen	1 report. Estimated from young
June-July	F. M. Gaige	1 report. Estimated from young
January to February	R. Svihla	1 report. Estimated from young
January	Hartman	1 report. Estimated from young
Late January	Hartman	1 report. Estimated from young
Late March	Hartman	1 report. Estimated from young Observed female building nest.
May 13	Hartman	Observed

In conclusion, then, we make the following assertions:

1. There is but one breeding season and that it extends from December to August (testes of the male do not degenerate).

2. The gestation period of the fox squirrel is about 60 days while that of the gray squirrel is approximately 45 days.
3. Two litters of young may be produced during a breeding season.
4. The peaks of breeding activities are in January and February and in June and July.
5. Most of the very early or very late and intermediate ones (April and May) are first matings, probably of young born very early or very late the preceding year.
6. Young born in the spring probably do not breed the same summer.
7. Evidence shows that the males at least do not become sexually mature until they are at least six and possibly eight months old.

Mating Practices

During the courting season as many as a dozen males may be seen chasing a single female. As the season progresses all males but one are rejected. An account taken from my field notes describes mating practices.

On April 21, 1940, I observed a male of the previous year, not yet quite fully grown chasing a large female. He would chase her from ten to thirty feet. When she stopped and turned around to watch him, he would squat down and move his tail and hind quarters in rhythmic motions.

When the female again ran, he would follow, remaining a few feet behind, running over the ground, up and down tree trunks, and through the crown of trees. When the female ran out to the end of a limb, the male would sit at the base of it and wait for her to return.

Another male, much larger in size, also tried to court the female, but the younger and smaller individual chased him away and forced him to remain in the background. After an hour the young male also gave up the chase. Evidently the female makes the final selection.

Another mating attempt was observed on May 13, 1940, when a male was seen chasing a female and attempting to copulate with her, but was unsuccessful at least during the time of the observation. It is thought that the mating was later successful.

Goodrum (May 1937, pp. 7-8) reports that according to W. D. Meece of New Willard, Texas, has found the oestrus period of a two-year-old female fox squirrel to be 4 days; she having taken the male on the 4th day, May 7, 1937, after the initiation of oestrus.

Gestation Period

Dr. A. J. Nicholson of Austin, Texas, who had worked on the species while here at the University, writes me that the gestation period is 60 days. Other workers have assumed it to be the same as that of the gray squirrel, 45 days.

Marital Status

Goodrum (1938 p. 675), Kennicott (1857), Seton (1929 p. 95), and Bachman ('40 p. 148) all have evidence that the fox squirrel is monoganous even though a dozen males may be seen chasing but one female. To this, Bachman also adds that they might possibly mate for life. Other observations and written accounts, however, indicate that the species mates but for one season.

Number of Young in Litter

Broods examined in 1940 had two, three, four, and five young respectively. The average number of young is said to be three. Kennicott ('57 p. 60): "Litters of two and four occur quite frequently; one and five quite rarely."

In Southern Michigan, as might be gathered from the discussion on breeding, most of the young are born during the months of February and March. April and May, however, also figure quite largely and a few individuals may be born as late as August and September.[1]

The young at birth are described by Seton (p. 95) as ". . . as usual with the group [the young are] blind, naked, helpless undeveloped little pink bags of vital possibilities. It would be hard to say what family they belong to at first . . . they are so rudimentary and small. Stoddard (1920 p. 22), speaking of the young in Northern Indiana, writes, "the three or four young, blind and nearly naked, are born in late February or March in this region."

[1] From reports, given by D. L. Allen (1938 p. 388) and Gage, unpublished, and a Female collected on Oct. 10, 1939, and still lactating.

Nicholson (unpublished) adds that "when born, they are very immature, naked, and blind."[1]

The eyes open when they are about 37 days old, and existing evidence indicates that fox squirrels are also about this age or a week older when their eyes begin to open. The weight of the young at this time, as shown by Svihla (1931 p. 155) and from my own records is from 90 to 100 grams. The following growth curve (Fig. 3) is drawn from statistics presented by Svihla in the above publication.

Even when the young weighed but seventy grams, "they were quite hairy, particularly about the head and neck" and had the characteristic color of the adults. The posterior portion was covered with blackish short hair, the feet, belly, and tail were also already rufous color (Svihla, 1931 p. 153). The young squirrels had the entire characteristic color of the adult when they weighed 90 to 100 grams.

The female nurses the young until they are about ten or twelve weeks old and during this time does not carry solid food to them. (Seton '29 p. 45). At about nine or ten weeks, the young wander out of the den for a few feet. Four young estimated to be about this age were observed on April 21. The more aggressive individuals of the litter would wander two or three feet from the den, and nibble on

[1] Seton (1929 p. 44). Lives of Game Mammals V. 4, pt. 1. From an account given by Dr. Powers, and in a letter of Dr. A. J. Nicholson of the Game, Fish and Oyster Commission, Austin, Texas (May 28 1940).

buds, twigs, and bark and return to the den. The female cares for the young until they are about twelve or fourteen weeks old, when she forces them to shift for themselves (Seton '29 p. 26). McCartney ('35 p. 265) reporting on a pet squirrel, found a female to still be caring for a young individual as late as October 10 although at this time the young was old enough to wander several hundred feet from the nest. The young mentioned above were observed to leave the home den on April 21, and were still seen together on May 19 although at this time they would wander away from the home tree.

Relations of Male to Young

During the nursing period, the adult male lives in a neighboring den or nest and evidently does not share in the care of the young. In the above observations, the last year's male that was courting the large female, ran up the tree and onto the branch where the den was located. At this time, one of the four young had wandered several feet from the den opening. The other young were sitting in the entrance to the den. Upon seeing the male these young quickly disappeared into the den, while the other individual did not notice the old male until his retreat back to the den had been cut off. When the young individual saw the male, it ran several feet up the tree and circled to the other side of the branch. The male, however, did not stop at the den but climbed further upon the branch, thus allow-

ing the young to escape back into the den. Other similar observations also show this fear of the young for strange adults. As the father does not share the home den, the young also would in all probability be afraid of him.

Nest Sanitation

The young while in the nest have very clean fur, although they may be heavily infected with fleas. Dung was present in the nests examined although not in large quantities. In one nest examined, a dead young squirrel, already putrefied, was still found with the two living and very active young. It seems unlikely that the old female would continue to raise the young in a nest containing a dead individual. Seton ('1929 p. 94) says, "Collateral evidence would imply that, when a nest gets too filthy or overcrowded, the mother moves the brood to a new lodging."

J. P. Jones (original from Dr. Burt's files) reports of a young female, of the year, falling from a tree and being killed. Later on "an adult female evidently the mother" came to the ground, picked up the dead youngster, and carried it up into the tree. Later on she allowed the body to fall again to the ground.

More study should be given to this question, for if young are permitted to be raised in nests containing dead individuals, the unsanitary conditions may on occasion cause a high mortality.

Transporting Young

Occasionally if the young are disturbed, or if the den is not quite suitable, or perhaps due to filthy conditions, the brood den is abandoned in favor of another. When this occurs, the female grasps a young by the nape of the neck, carries it to the newly selected den or nest and returns for the others and carries them to the new home in the same manner. If when the young, though able to leave the den and forage for food, are unable to make a jump to return to the nest; the female grasps the young in the above manner and makes the jump (Jones loc. cit.) and Mc Cartney (1935 p. 266).

Time of Family Group

Seton (1929 p. 96) is of the opinion that the family group (female and young) remain together until the young are over three months old. A study of the weight given (Svihla 1931 p. 155) together with field observation show that they are this age or perhaps several weeks older when they are forced to shift for themselves. Kennicott (1857 p. 61) evidently thinks that the family group remains together for a much longer time, or may even reassemble as he says:

"While the females and young are together in early autumn, it is amusing to watch the movements of a party on any pleasant day, when their enjoyment of the abundant food, and things in general, is testified by a degree of sprightliness and agility quite astonsihing."

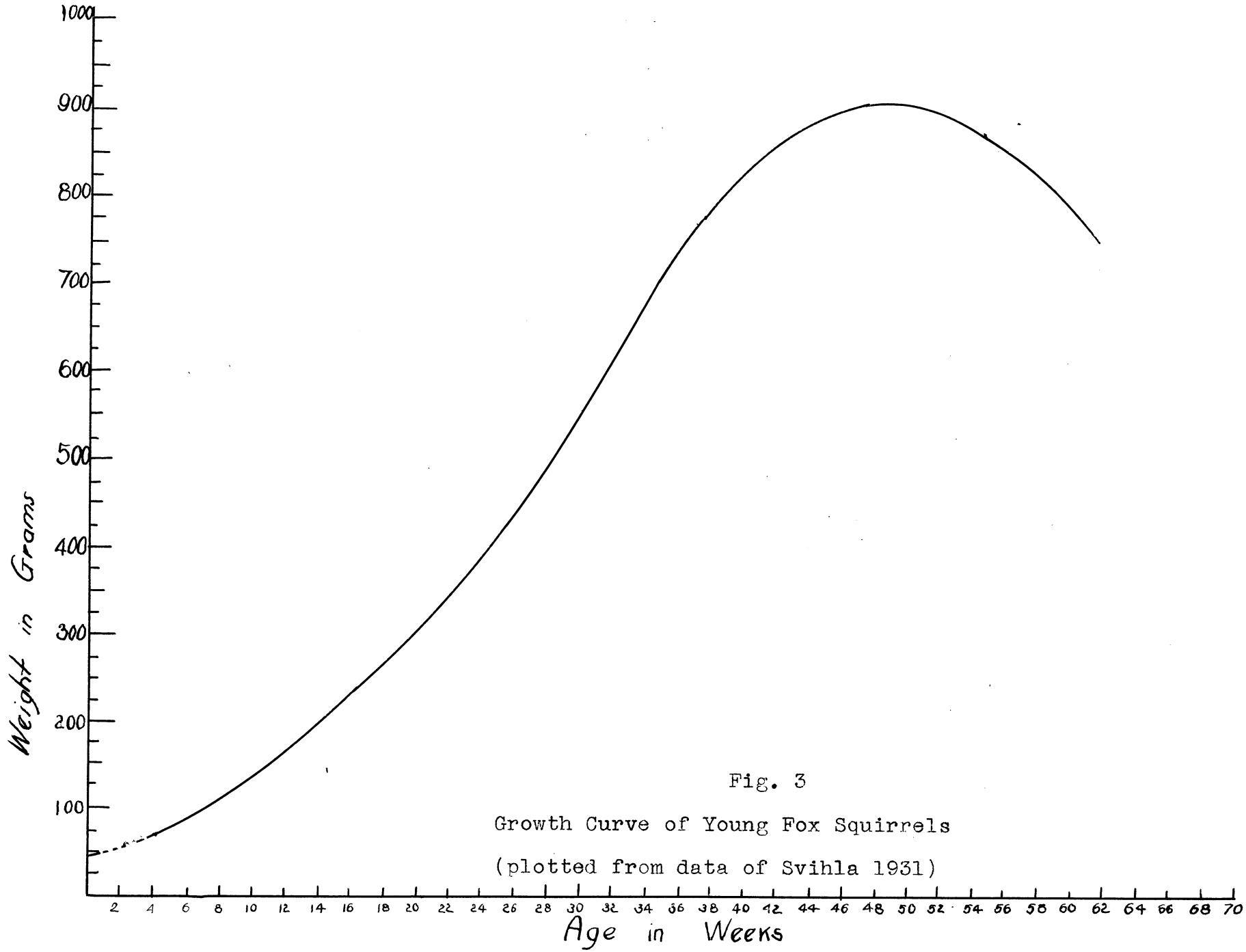


Fig. 3

Growth Curve of Young Fox Squirrels

(plotted from data of Svihla 1931)

Weight and Sizes

From the growth chart (Fig. 3) it is seen that the spring-born young have attained approximately adult size in the fall of the same year, when they are six to eight months old. Allen (1938 p. 388) reports that records on 71 individuals showed the average weight to be 1 lb. 9.6 oz. or as computed, 624 grams. Evidently immature individuals were also considered in these weights. Twenty-five specimens, classed as adults, found in the collection of the University Museum had an average weight of 765 grams. These records considered a few individuals that were not quite mature. There is no difference in the sizes of the sexes.

Fig. 4

The following measurements for Ohio fox squirrels are given by Baumgartner, '38 p. 685.

Specimens Taken from April to December

Age	Sex	Number	Total Length	Tail Length	Hind Foot	Weight
			mm.			gram
Adult	Male	8	538	248	75	812.6
Adult	Female	18	532	241	72	815.6
Juvenile	Male	12	491	234	71	551.4
Juvenile	Female	6	510	245	74	588.8
All Juvenile	Both	18	501	240	72	570.1
All Adults	Both	26	535	244	74	814.1

Specimens Taken during October, November, and December

Age	Sex	Number	Heaviest	Average	Lightest
			grams	grams	grams
Adult	Male	41	980	840	728
Adult	Female	46	960	827	728
Juvenile	Male	26	756	715	560
Juvenile	Female	24	784	680	644
All Juvenile		50	784	701	644
All Adults		87	980	833	728

Voice

The fox squirrel uses his voice less than does the gray squirrel. When approached by man it hides and remains silent, but if it is frightened when up a tree that contains no den or nest and with no adjacent tree to jump to, it will utter sharp, angry, barking notes. It also has a shorter chucking call-note, and utters a similar though angry call when in a live trap.

The young captive fox squirrels when hungry would often utter a low, chuckling grumble, or a very loud shrill squeal, which can be heard for a distance of several hundred feet.

Seton ('29 p. 103) describes another call, the "love song," which he says is comparable to that of the gray squirrel, but that it is "hoarser and more gutteral and has little or none of the long, final note. It sounds like quak-quak-quaaaaaaaa with many repetitions and few variations, uttered from some commanding perch, for an hour or more at a time when the weather is inspiring, or the love-fire setting his frame aglow."

Longevity

Seton ('29 p. 106) gives two records of the age fox squirrels may attain, both of which were from captive animals. One died at the age of 9 years and the other one ten years. The older of the two individuals showed evidence of extreme age when it died. Apparently fox squirrels in their normal habitats seldom reach these ages,

but an occasional individual may. The writer has collected two skulls that had the incisors worn down to small stubs. One of these individuals weighed but 650 grams and showed other signs of advanced age.

ECOLOGICAL REQUISITES

General Range and What Determines It.

As has been pointed out, the western fox squirrel, under primitive conditions reached its peak of abundance in the "oak openings" of Wisconsin and Michigan. Work carried on by Chapman,(1937 p. 1) found that under present day conditions, the ideal fox squirrel habitat consists of 70 percent woodland and 30 percent open or cultivated land. Therefore, unlike the gray squirrel, this species is classed as farm game rather than forest game.

As one might expect, a definite type periphery and squirrel population. An examination of a hundred and sixty acre woodlot in Scio Township, Washtenaw County, showed very few fox squirrels living within the center of the woodlot; while along the bordering 150 yards, the approximate cruising radius of the species, squirrels were not uncommon.

Food and Food Habits

Owing to the rather thorough mastication of the foods found in squirrel stomachs, quantative analyses of these substances are not to be found in literature. The most complete food habit study done to date was done by Baumgartner (1939 pp. 579-584) who, working throughout the State of Ohio has records from more than 1,000 hours of food-habit observations covering a continuous period of 29 months.

The observation data are supplemented with the analyses of the contents of seventy-eight fox squirrel stomachs collected by him and analyzed in the Food Habits Laboratory of the Biological Survey. Only two additional vegetable foods were found by the analyses that were not shown in the observation records. However, stomach analyses did show a number of previously unrecognized animal foods, which consisted chiefly of insects and made up one percent to three percent of the total food."

It is common knowledge to most observers that the fox squirrel's diet is variable and consists of many food species.

Baumgartner (ibid.) lists 4 vegetables and rates them according to their importance by the use of index numbers of from 1 to 10, with the latter figure indicating the highest degree of utilization. He also classifies them as staple, auxiliary, or emergency foods, or if they serve in more than one of these capacities they are indicated by the use of two or three letters (A, E, or S). The time of the year the food is available is also given. Figure 5 gives the vegetable foods eaten and Figure 6 the animal foods. Baumgartner thinks that there may be some significance to the fact that most of the animal matter found in stomach contents is found during the spring and summer months. This list of food, with a few exceptions, is approximately the same as the foods found in Michigan. The general rating, whether foods are classed as staple,

auxiliary or emergency items change with the biotic variables such as type-composition, amount of mast produced annually, and the commonness of the species.

Staple foods (S) are defined as "those (foods) which appear most essential to the year-round survival of a squirrel population." Baumgartner found that unless two or more of the staple foods were present in adequate quantities, squirrel populations did not thrive. It is also pointed out that in other parts of the United States, other foods are substituted for these staples.

Those foods that are utilized only after or at least chiefly after the staples are exhausted, are designated as being emergency foods (E); and species eaten when available, though not essential to squirrel numbers are called auxiliary foods (p. 252).

Baumgartner recognizes the fact that it is often impossible to distinguish between the three types of foods and that in certain habitats auxiliary foods are so varied and abundant that they may well be classed as staples for the few weeks or months that they are available. Certain auxiliary foods may serve as emergency articles if available during critical periods of the year.

On the Northville area, in Wayne County, the dominant upland forest is the beech-maple type interspersed with occasional oak, hickory, butternut, elm, and basswood trees. During the late winter squirrels were largely dependent on an area where a few remaining burr oaks of what was formerly

an "oak opening," and the near-by, though isolated in a bare field, were two black walnut trees. Beech produces but one good crop in five years, and so the burr oaks and black walnuts are especially important during the years of poor nut crops. 1939 was a poor mast year, and the supply of beech nuts was depleted already in early winter. Old midden piles underneath the isolated nut trees within the stand, show that nuts of these trees were already taken by the first of February. During the latter part of February, March, and April fox squirrels were forced to journey to the rather open burr oak grove and the completely isolated black walnut trees for food. One individual journeyed, as determined by observing and tracking in new snow, frequently a distance of a half-mile to feed on the walnut tree. Approximately three-fourths of the distance traveled had been across open country; after feeding for an hour or two, the squirrel would again return over the bare fields to the home woodlot. Although sources of food were inconveniently located, the squirrels of the area appeared to be in good health.

I have on several occasions seen what I am sure is the same long ranging individual feeding upon waste corn, barley, wheat and oats found in barnyard manure that was spread on a field adjacent to the woodlot. The squirrel would enter the field at almost any point and would wander about until he found waste grain and would then feed. An examination of these feeding spots showed that only the embryos were taken from the corn, and the endosperms were left. On one

occasion I had counted a dozen spots where the squirrel had fed on waste grain. This was after he had made the long trip to the black walnuts and fed on the nuts. In Michigan, as well as in Wisconsin and Minnesota, the fox squirrel is to be found in many major forest types, consequently staple food species vary in kind, abundance, availability, and distribution.

Table 7 gives the importance of these species for the various forest types in which fox squirrels are to be found.

Table 5

VEGETABLE FOODS OF OHIO FOX SQUIRRELS

General Class	Index Number	Item	Availability Period of
S	10	Hickory nuts (*Carya spp.*)	Entire year
S	10	Beechnuts (*Fagus grandifolia*)	Aug. to May
S	10	Acorns (*Quercus spp.*)	Entire year
S	10	Corn (*Zea mays*)	July to April
S	8	Black walnuts (*Juglans nigra*)	Entire year
S	3	Butternuts (*Juglans cineria*)	Sept. to Apr. 1
S&E	(6)	Buckeyes (*Aesculus spp.*)	Sept. to Apr. 1
E	10	Maple seeds & buds (*Acer Sp.*)	Mar. to Nov.
E	10	Elm leaves & buds (*Ulmus spp.*)	Mar. to Nov.
E	3	Willow (pistillate catkins *Salix*)	April
E	3	Aspen (*Populus spp.*)	April
E	3	Oak buds (*Quercus sp.*)	May
SE&A	(2)	Hackberries (*Celtus occidentalis*)	Sept. to March
A&E	(5)	Soy beans (*Sova Max*)	Sept. to Feb.
AE	(2)	Hawthorn Apples (*Crataegus spp.*)	Nov. to Jan.
AE	4	Tulip seeds (*Liriodendron tulipifera*)	July to Sept.
SA	8	Hazelnuts (*Corylus spp.*)	Nov. to Dec.
A	8	Wheat (*Triticam aestivium*)	June to Aug.
A	8	Mulberries (*Moras spp.*)	June
A	7	Witch Hazel (*Hamamelis virginiana*)	Nov. to Dec.
A	7	Sour Gum (*Nyssa sylvafica*)	July to Aug.
A	6	Dogwood (*Cornus spp.*)	Nov. to March

Table 5 (continued)

General Class	Index Number	Item	Period of Availability
A	5	Blackberries (Rubus spp.)	Aug. to Sept.
A	4	Wild grape (Vitis spp.)	Aug. to Nov.
A	4	Apples (Malus sp.)	Aug. to Sept.
A	4	Huckleberries (Gaylussacia sp.)	August
A	3	Hop-hornbean (Ostrya virginiana)	Nov. to March
A	3	Wild Raspberries (Rubus sp.)	Aug. to Sept.
A	3	Fungi (chiefly Agaricaceae)	Aug. to Sept.
A	2	Bittersweet fruits (Celastrus scandens)	Sept. to March
A	2	Sycamore (Platanus occidentalis)	Dec. to April
A	2	Wild black cherries (prunus sp.)	Aug. to Sept.
A	2	Green leaves	May to Sept.
A	2	Breen briar (Smilax sp.)	August
A	2	Blue beech (Carpinus caroliniana)	Nov. to Jan.
A	1	Wahoo (Evonymus atropurpureus)	Oct.
A	2	Blueberries (Vaccinium sp.)	August
A	1	Sedge (Carex sp.)	June to Aug.
A	1	Knotweed (Polygonium sp.)	August
A	1	Oats (Avena sp.)	August

Table 6

ANIMAL MATTER FOUND IN FOX SQUIRREL STOMACHS
From Baumgartner 1939

Items Found	15 stomachs spring		42 stomachs summer early autumn		16 stomachs winter	
	No. stomachs in which found	% of total vol.	No. stomachs in which found	% of total vol.	No. stomachs in which found	% of total vol.
Undetermined insect chitin	3	0.20	13	0.68	5	0.23
" " "	1	0.07	3	0.03	1	Trace
Spiders (Araneidae)	2	0.13	-	-		
Thrips (Thysonoptera)	-	-	1	Trace		
Scale insects (Coccidae)	1	0.07	-	-		
Beetles (Coleoptera)	3	0.20	-	-		
Mud Beetles (Heterocerus)	-	-	1	0.74		
Flat Beetles (Cucujidae)	-	-	2	0.06		
May Beetles (Phyllophaga)	1	0.07	1	0.06		
Weevils (Curcalionidae)	1	0.07	-	-		
Nut Weevil (Halininus sp. and Curculio sp.	-	-	2	0.03		
Flies (Diptera)	2	0.13	3	0.09		
Moths & Caterpillars (Lepidoptera)	-	-	2	0.06		
Insect Eggs	-	-	1	0.24		
Ants Formicidae	-	-	1	0.15		
Total	14	0.94	30	2.14	6	0.23

Value of Species

FOREST TYPE

Food Species	Oak-hickory	Beech Maple	Birch-Maple-Hemlock
Ash (*Fraxinus* sp.)	Not very important	Good	Good
Aspen (all *Populus*)	Good (spring food)	Good (spring food)	Good spring food
Basswood (*Tilia americana*)	Fair	Fair to good	Good
Beech (*Fagus grandifolia*)	Not important	Excellent	Seldom if ever found
Birch (*Betula spp.*)	--	Fair (spring food)	Good spring food
Black Cherry (*Prunus serrotina*)	Fair summer	Good summer	Good summer
Black Gum (*Nyssa sylvatica*)	Rare	Unimportant	
Black Locust (*Robina pseudocacia*)	Not native	Unimportant	
Black Walnut (*Juglans nigra*)	Good	Excellent	Excellent though rarely found
Blue Beech (*Carpinus caroliniania*)	Unimportant	Unimportant	Unimportant
Box Elder (*Acer negundo*)	Unimportant	Fair	Fair
Buckeye (*Aesculus spp.*)	Good	Good when found	Not found
Butternut (*Juglans cinerea*)	Excellent	Excellent	Excellent
Catalpa (*Catalpa sp.*)	Unimportant	(introduced)	
Chestnut (*Castinia dentata*)	Very rare	Unimportant	Not found
Coffee tree (*Gymnocladus diocus*)	Not native and of no value		

Food Species	Oak-hickory	Beech Maple	Birch-Maple-Hemlock
Dogwood (*Cornus spp.*)	Fair	Fair	Good
Elm (*Ulmus spp.*)	Excellent (spring food)	Excellent (spring food)	Excellent (spring food)
Hackberry (*Celtus occidentalis*)	Unimportant	Unimportant	Unimportant
Haw (*Vibernum spp.*)	Of little value		
Hawthorn (*Crataegus spp.*)	Of little value		
Hickory (*Carya spp.*)	Excellent	Excellent	Excellent when found
Honey locust (*Gleditsia triacanthos*)	Not native	Unimportant	
Hornbean (*Ostrya virginiana*)	Of little value	Of little value	Good
Maple (*Acer spp.*)	Excellent spring	Excellent spring	Excellent spring food
Mulberry (*Morus rubra*)	Excellent spring	Excellent spring	Not found
Oak Black (*Quercus velutina*)	Excellent	Excellent	Excellent when found
Bur (*Q. macracarpa*)	Excellent	Excellent	Excellent when found
Black Jack (*Q. marilandica*)	Excellent	Excellent when found	Not found
Chinquapin (*Q. muhlenbergii*)	Excellent	Excellent	Not found
Northern Pin (*Q. ellipsoidalis*)	Excellent	Excellent	Only infrequently found
Pin (*Q. palustris*)	Excellent	Excellent	Not found
Red (*Q. rubra*)	Excellent	Excellent	Excellent
Scarlet (*Q. coccinea*)	Excellent	Excellent	Not found
Shingle (*Q. imbricaria*)	Excellent when found	Excellent when found	Not found

Food Species	Oak-hickory	Beech Maple	Birch-Maple-Hemlock
Swamp-white (Q. bicolor)	Excellent	Excellent	Excellent
White (Q. alba)	Excellent	Excellent	Excellent
Sassafras	Unimportant	Unimportant	Unimportant
Service Berry (Amelanchier spp.)	Of little importance		
Sycamore (Platanus occidentalis)	Fair	Seldom found	Not found
Tulip popular (Liriodendron tulipifera)	Rare, not important	Rare, not important	Not found
Willow (Salix spp.)	Of little value	Of little value	Fair spring
Witch hazel (Hamamelis virginiana)	Fair	May be important	Not found
Fungi	Fair	Fair	Fair
Wild grape (Vitis spp.)	Fair to good	Fair to good	Fair to good
Sumac (Rhus spp.)	Fair to good	Fair to good (emergency food)	Good emergency food
Bittersweet (Celastrus scandens)	Fair	Fair	Fair
Hazelnuts (Corylus spp.)	Good	Excellent	Excellent
Greenbriar (Smilax spp.)	Unimportant	Unimportant	Unimportant
Wahoo (Evonymus atropareus)	Unimportant	Fair autumn	Fair autumn
Blueberries (Vaccinium spp.)	Fair late summer	Fair	Fair
Blackberries (Rubus spp.)	Good, late summer	Good	Good
Raspberries (Rubus spp.)	Good, late	Good	Good

Food Species	Oak-Jack Pine	Hardwood Swamp	River Bottom
Ash	Good when found	Fair-good	Fair
Aspen	Good	Good	Good
Basswood	Good	Good	Good
Beech	Unimportant seldom found	Seldom found	Excellent
Birch	Good spring food	Good spring food	Good spring food
Black Cherry	Good	Good	Good
Black Gum	-	-	-
Black Locust	-	-	-
Black Walnut	Not found	Seldom	Excellent
Blue Beech	Unimportant	Unimportant	Fair
Box Elder	Unimportant	Unimportant	Unimportant
Buckeye	Not found	Not found	Not found
Butternut	Unimportant	Unimportant	Excellent
Catalpa	-	-	-
Chestnut	-	-	-
Coffee Tree	-	-	-
Dogwood	Fair to good	Fair to good	Good
Elm	Excellent spring	Excellent spring	Excellent spring
Hackberry	Not important	Not important	Not important
Haw	Not important	Of little value	Of little value
Hawthorn	Good	Not important	Good
Hickory	-	-	-
Hornbeam	Fair	Excellent	Excellent

Food Species	Oak-Jack Pine	Hardwood Swamp	River Bottom
Oaks	} Excellent when found		
Sassafras	Not found	Of no value	Of no value
Service Berry	Little importance	Rare	Good when found
Sycamore	Not found	No value	No value
Tulip popular	Not found	-	-
Willow	Fair spring	Fair	Fair
Witch hazel	Usually not found	Fair	Fair when found
Fungi	Fair	Fair	Fair
Grape	Good emergency	Unimportant	Unimportant
Sumac	Fair	Fair	Fair
Bittersweet	Excellent	Good	Good
Hazelnut	Important	Important	Important
Greenbriar	-	Unimportant	Unimportant
Wahoo	Fair	Unimportant	
Blueberries	Fair	Unimportant	
Blackberries	Good late summer	Good	Fair to good
Raspberries	Good late summer	Good	Fair to good

Availability of Foods

The availability of foods is subject to great variation from year to year as well as during the year proper, depending on the periodic abundance or scarcity of the nut crop and the number and kind of nut trees found in the woodland. During poor nut years, squirrels are forced to subsist on emergency foods. This is particularly true at the northern extremities of fox squirrel range in the beech-maple and in the birch-maple forest types. Beech produces on the average but one abundant nut crop in five years, and therefore, in these as well as in the other northern hardwood types, the fox squirrel population is necessarily dependent upon the often scattered butternut, bitternut, red, white, swamp white, and northern scrub oak trees which occur singly or in small groups through the stand. To contain adequate fox squirrel populations, a woodlot of the northern hardwood type, must necessarily have three or more nut species present, as total nut failure, affecting two or even three species, may occur during the same year. Foods of the non-nut bearing trees may in instances serve as an auxiliary or emergency foods, but their periods of availability are often short.

The dispersion of nut trees throughout the stand may be another factor limiting fox squirrel densities, although the above-mentioned case where a fox squirrel went approximately one-half mile for food seems to show that this animal is quite adaptive to food-getting. Tracking and direct field

observations showed that if food was poorly distributed individuals frequently went three hundred to five hundred yards for food. However, it is well known that during periods of cold, windy weather, fox squirrels remain in their dens for days at a time. This was frequently noted to be so on the Northville tract, but if they did move about during unfavorable weather, activity was restricted to the immediate vicinity of the den tree, where they took what little food the area had to offer.

Year-round Feeding Habits

During early and mid-summer, stored nuts, fresh fruits of mulberries, raspberries, blackberries, wild cherries, leaves and buds and similar foods are eaten. During the latter part of August, 1939, when berries were still abundant I observed squirrels in Southern Wisconsin to be feeding on green hickory nuts (Carya ovata). Kennicott (1857) and Seton (1929 p. 88) also mention this habit of the species. Storage for the winter is not begun until these nuts are ripe. During the fall the diet shifts to such species as corn, hickory nuts, and acorns with such succulents as apples, thornapples and grapes, being supplemented. During the mid-winter nuts and corn are the staple items of the diet. In late winter and early spring the cached foods and fallen nuts are often covered with snow, and the corn is usually removed from the adjacent fields. Thus during this time, the most critical period of the year, the squirrels seem to be unable to find a sufficient quantity of nuts and consequently they are forced

to subsist largely on buds, twigs, and bark. When the snow thaws from the ground, the animals can usually again find an abundance of nuts.

Food Caches

During October ripe nuts are cached. Unlike the red and the gray squirrel, this species stores but a single - occasionally two - nuts in a place. Many of the nuts are stored just under the forest litter, although some may be placed in the soil to a depth of three or four inches (Seton 1929 p. 91).

Observations made by Cahalane (1930 p. 78) show that caching is evidently not limited to the fall of the year, as he has records on the following dates:

December 31.	Observed a fox squirrel on the campus cache shagbark hickory nut.
Early March 1929	A captive squirrel cached a few hickory nuts in the litter of the cage.
March 6, 1929	Observed a squirrel in Ann Arbor cache an unknown item.
March 12	Observed 2 squirrels cache food items, one of which was a pignut hickory.
March 17	A wild squirrel was observed caching a hickory nut.
April 23	Saw a wild squirrel cache an acorn.
April 26	Saw a squirrel cache a hickory nut.

Squirrels are also noted to cache peanuts throughout the

year if given to them in excessive number. Very possibly out-of-season storings are more temporary than are the fall cachings.

Experiments carried on by Dice (1927 p. 55), and Svihla (1931 p. 151) with captive fox squirrels showed that the species could not find nuts that were buried in dry sand or in shavings, but that they could do so if the materials in which the nuts were buried were moistened. The poor ability of the animals to find cached foods in the winter time when the ground is frozen and covered with unmelting snow, can very possibly be explained by the fact that a physiological dry condition exists; and hence the squirrels cannot smell the buried nuts.

In the beech-maple woodlots of the Northville area, much feeding on buds, sumac, with hazel fruits, and waste apples found in adjacent orchards was noted during March and the fore part of April, when the ground was covered with snow. It was also during this time when fox squirrels were observed to travel beyond their normal ranges to sources of food. Later on when the snow was gone, the daily cruising ranges shortened, evidently as a result of greater availability of the cached food and the higher nutritive value of buds.

Food Preferences

Corn seems to be the preferred food during the fall months. Even though there was a fairly good acorn crop last fall, squirrels were observed to frequently wander several

hundred feet into corn fields, take ears from the shocked corn, and return to some tree or stump to eat it. A kettle hole adjacent to the corn field and connected to Eberwhite woods by a woody fence row, was a favorite site to which corn was taken and eaten. Other very desirable foods are black walnuts, butternuts, and hickory nuts. Although corn is highly desirable, it is never stored.

Corn while in the milk stage is reported by Seton (1929 p. 90) and Kennicott (1857 p. 58) to be very desirable. Kennicott also writes that in parts of Indiana and Illinois, when most crops have failed, he had heard of large corn fields being destroyed by fox squirrels. Seton (ibid.) does not consider ripe corn to be a desirable food.

The following table (Fig. 8)[1] shows the relative food values of various squirrel foods.

The chief purpose of the table is that it shows the value of nuts in comparison to corn. The figures also show that corn is of primary importance because of its protein and vitamin content and that nuts are chiefly important as a fat supply and general food value content.

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[1] From Morrison, F. B. "Feeds and Feeding." Morrison Publishing Company and supplementary data from Bulletin 28, U. S. and from Food Products by H. C. Sherman 1937 and presented by Chapman and Baumgartner 1939.

Fig. 8 Food Values of Various Squirrel Foods

	Corn	Corn Germs	Black Walnuts	Hickory Nuts	Beech Nuts	Dried Chestnuts	Acorns	Sunflower	Butternuts	Peanuts
Water content	% 12.	% 7.	% .03	% .4.	% 4.	% 6.	% 44.	% 7.	% 4.	% 5.
Total dry matter	88.	93.	97.	96.	96.	94.	56.	93.	96.	95.
Total protein	10.	20.	28.	15.	22.	11.	.03	16.	28.	30.
Digestible protein	7.	14.	-	-	-	-	.06	15.	-	27.
Fats	4.	8.	56.	67.	57.	.07	.07	25.	61.	48.
Total Digestible nutrients	84.	79.	-	-	-	-	33.	88.	-	40.
Vitamins	ABg[1]	-	aB	B	-	bG	-	-	aB	aBg
Fiber	2.0	9.	-	-	-	-	11	28	-	.02
Minerals	.01	.03	.02	.02	.03	.02	.01	.03	.03	.02
Nutritive ratio 1:	10	4	-	-	-	-	50	.05	-	4
Fuel value per lb. in calories	1645	-	3012	3238	2980	1828	-	-	3068	2490
No. Analyses made	2602	14	-	-	-		4	11	-	104

1 "B" important source of vitamin.
b less important source, but present.

Minerals and Water

Minerals and mineral salts in the form of bone and tree bark are quite regularly taken by squirrels. It is not uncommon to find several gnawed bones at the base of a den tree, and almost every den tree examined showed where the squirrels had gnawed bark. Baumgartner (1939 p. 583) in addition to the above observations reports that fox squirrels were observed eating soil particles and that soil was also found in the stomachs analyzed.

Just how important these substances are for the animals well-being is unknown, but the habit of gnawing bones indicates a calcium deficiency which might act on the health and condition of the young.

The soil eating habit is not confined to squirrels alone as MacLulich (1937) reports that the snowshoe hare is known to eat soil. Reports of this habit are also recorded for other species.

Fox squirrels evidently are not dependent upon a supply of free water, as relatively high populations are to be found in woodlots in which no surface water exists. Probably they receive sufficient water from succulents. If free water is present fox squirrels will frequently drink, particularly during the nursing periods and during the hot days of summer.

It is interesting to note here that a sharp decline in abundance occurred in 1936, following a very dry year. A decrease in numbers was also noted in Missouri following the drouth of 1934, while gray squirrels, a species said to need

free water did not decrease as greatly, as they were able to obtain moisture from stream pools. Fox squirrels have been observed to take free water at different times throughout the year.

Cover

Cover requisites for fox squirrels are somewhat different from those of other species. It has been observed on the Northville area, as well as in several oak-hickory woodlots in Scio Township, that woodlots, so poorly stocked that the crowns of the trees did not interlace, contained very few fox squirrels. Several woodlots where trees stood completely isolated, contained no squirrels at all. This seems to show that squirrel habitat must have trees close enough together to permit lines of escape through the crowns. However, the fox squirrels will journey to such woodlots for food.

Ground cover, on the other hand, does not seem to be very important. Both Goodrum (1938 p. 673) and Baumgartner (1938 p. 687) found that grazing may actually be beneficial. Goodrum states that: ". . . squirrel counts in two adjacent woodlots, one moderately grazed and the other ungrazed, showed a greater population in the lightly grazed area than in the ungrazed." He goes on to explain that overgrazing prevents suitable tree and vine reproduction, chiefly grape (Vitis spp.) and supple jack (Berchemia scandens) which are vitally important in providing escape cover.

Turning to the work of Baumgartner and his study of the effects of grazing on ten woodlots totaling 128 acres of unpastured woodlots and 237 acres of grazed woodlots, he found the average population of fox squirrels on the ungrazed woodlots to be 65 squirrels per 100 acres, while on the grazed the population was but 45 squirrels per 100 acres. In considering both red and the fox squirrels, a population of 79 individuals was recorded for the ungrazed woods and only 67 per 100 acres for the pastured areas.

Neither of these workers discuss the length of time the areas had been grazed, the age, composition, and sizes of the two types of woodlots or other similar variable factors.

It is well known that large-crowned, open-grown trees produce larger, better and more frequent nut crops. Grazed woodlots being understocked have more of these types of trees and, therefore, may perhaps have better mast crops. This could very possibly result in greater squirrel abundance. It would be interesting to know why, under primitive conditions, the species preferred the "oak openings." Was it because of a greater and more regular food abundance, or was it due to some physical factor?

The minor importance ground cover plays was observed on the Northville area, where, as previously mentioned, fox squirrels were quite frequently seen feeding on manure in an open field, and one squirrel frequently traveled a mile, three-fourths of which was across open country, journeying to and from its feeding grounds. However, this individual as

well as others, when making extensive trips across open country would follow the fence rows which often were as barren of escape cover as the fields themselves. Fence posts undoubtedly offered some escape cover from dogs and possibly cats, but the animals had to rely on the scanty ground cover for protection from hawks. I have also noted that when commuting between the home woodlot and the feeding grounds, the animal would follow the denser fence rows if a selection was permitted.

Another interesting example of the value of cover is the use of a branch or tree trunk for hiding. Every squirrel hunter is familiar with the animal's habit of sliding around to the other side of a large branch or the trunk, of lying flat on the top of a branch, when a hunter approaches. I have watched squirrels, unaware of my presence, do this when a dog came into view.

Dens and other holes in trees are also used for escape cover. Their use of protection cover will be discussed later.

Loafing grounds for fox squirrels is perhaps limited to large sheltered branches, exposed to the sun and nests or leaf platforms situated in a similar position. Favorite trees used for this purpose are frequently trees that produce good nut crops or in the immediate vicinity of the chief food supply. Another feature of the "loafing tree" seems to be that it either contains an escape den or has one easily accessible to it. The use of loafing grounds is discussed under, "Daily Ranges."

Kennicott ('57 p. 60) considered pin oak (Quercus palustris), because of its leaf retaining qualities, to be of great importance as escape cover. White oak (quercus alba), and shingle oak (Q. imbricaria), because of this same characteristic are doubtlessly also important.

Den Trees

In Southern Michigan, as in other parts of fox squirrel range, den trees are important both as homes and as refuges. Even in the southerly latitude of East Texas Goodman (1937 p. 502) states that : "It is rare to find very young squirrels of either species (fox or grays) in the twig and leaf nests." It is his opinion that the absence of den trees encourages the use of leaf nests as brood quarters.

Fair squirrel densities were found in 40-50 year old coppice oak-hickory woodlots in Scio Township, although only an occasional den tree was to be found in the stand. Squirrels in these woodlots were therefore forced to winter and raise young in leaf nests.

In the beech-maple woodlots of the Northville area, which contained much mature and over mature timber, all fox squirrels wintered over and raised young in dens. There seemed to be a surplus of suitable dens in these woodlots.

A very intensive study of dens and their formation was done by Baumgartner (1939a pp. 556-565) who examined 169 dens in the study: Summarizing his work on the processes of den formation we have:

1. A tree with a limb that has a diameter of approximately 3 1/2 inches.

2. Failure of the leaves, because of excessive shade, to synthesize enough food to maintain life in the limb.
3. Lacking food the limb dies and its cambium layer and bark sloughs off.
4. The unprotected sapwood begins to weather and is attacked by various decay organisms, bacteria fungi, and insect larvae.
5. Scar tissue in the form of a healed scar is formed at the base of the dead limb and may extend an inch or more away from the main trunk.
6. The weakened decayed limb eventually breaks off, leaving a small butt near the trunk.
7. Decay organisms, through the exposed butt, attack the heart of the tree.
8. The wood is soon disintegrated and becomes punky and ready to be cleaned out by the squirrel.

These processes are contingent upon the following factors:

1. Rate of tree growth.
2. Rate of tree decay.
3. Age of the tree.
4. Method of scar tissue formation.

Important conditions necessary for den formation are:

1. Size of limb (age of limb from 30 to 60 years).
2. Location of tree (dying of lower branches).

3. Habitat factors which condition growth (physical, biotic, chemical, and nutritional).
4. Presence of squirrels (to keep den open).
5. Water drainage of tree trunk (correct amount of water brings on decay, an excess may split the trunk by frost action).
6. Age of forest (the younger tree-growth is primarily height growth.

The study also showed that the use of a den "is probably never over 50 years" and usually no more than 10 or 20 years.

Value of Tree Species

The Ohio investigation showed that some species produce more dens than do others. This is undoubtedly due in part to the percentage the species constitutes of the stand, to, as Baumgartner points out, the healing characteristics of the species or the method the scar tissue grows - if it extends out on to the limbs or ends abruptly at the base of the butt. The distribution of the 169 den trees as to species is given in Figure 10.

Openings to the dens are usually of constant size and are round to slightly oval in shape, having diameters ranging from 2 1/2 inches to approximately 4 inches in size. Occasionally dens may have openings much larger than this. One located in a white oak on the campus, was approximately six inches square and was situated on the upper side of a

large limb that was at a diaganol to the tree horizontal, thus exposed to the rains. At the time of observation, this den contained four young that had just previously been moved there from a nest several hundred feet away. One month later, on May 20, 1940, the young were still using the den.

The average den cavity measures 6.3" x 6.9" x 15" deep (excluding that portion of the den above the opening). The average height above ground of the 25 dens studied was 36.8 feet and were found in trees having an average diameter of 21.2 inches. Den trees were located on an average of 58.6 yards from the nearest woodland border. Heal scars showed that the dens had been used for an average period of 6.2 years (Baumgartner, 1938 p. 688).

To maintain a sufficient number of suitable dens, the area should never be over shot for if the openings to the most favorable dens are not kept opened by the constant gnawing of the squirrels, the wound tissue will soon close the den opening. Care must also be taken to allow trees to remain in the stand that will make suitable dens in the future. These may be the large crowned "wolf trees" that the forester insists are detrimental to the welfare of the stand.

Fig. 9 Formation of Fox Squirrel Dens (from Baumgartner 1939a)

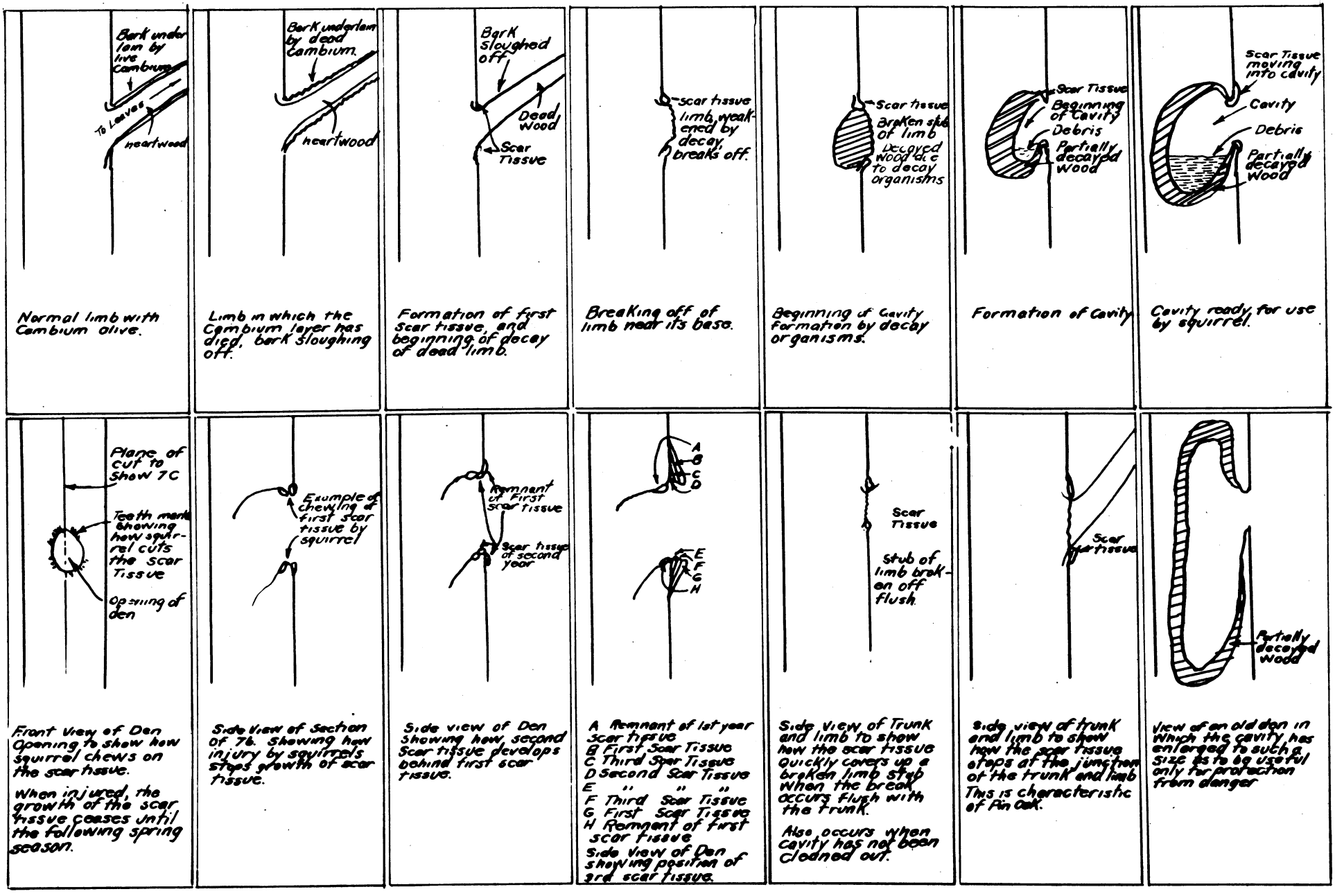

Fig. 10

DISTRIBUTION OF DENS BY SPECIES

Tree Species	Number	Percent of Total
White Oak	51	30.18
Elm	22	13.02
Beech	17	10.06
Red Oak	15	8.88
Black Oak	10	5.91
Burr Oak	8	4.74
Sugar Maple	8	4.74
Sour Gum	8	4.74
Hickory	6	3.55
White Ash	5	2.95
Tulip	4	2.37
Chinquapin Oak	4	2.37
Red Maple	3	1.77
Silver Maple	2	1.18
Black Jack Oak	1	.59
Black Ash	1	.59
Wild Black Cherry	1	.59
Linden	1	.59
Buckeye	1	.59
Sassafras	1	.59
Total	169	100.00

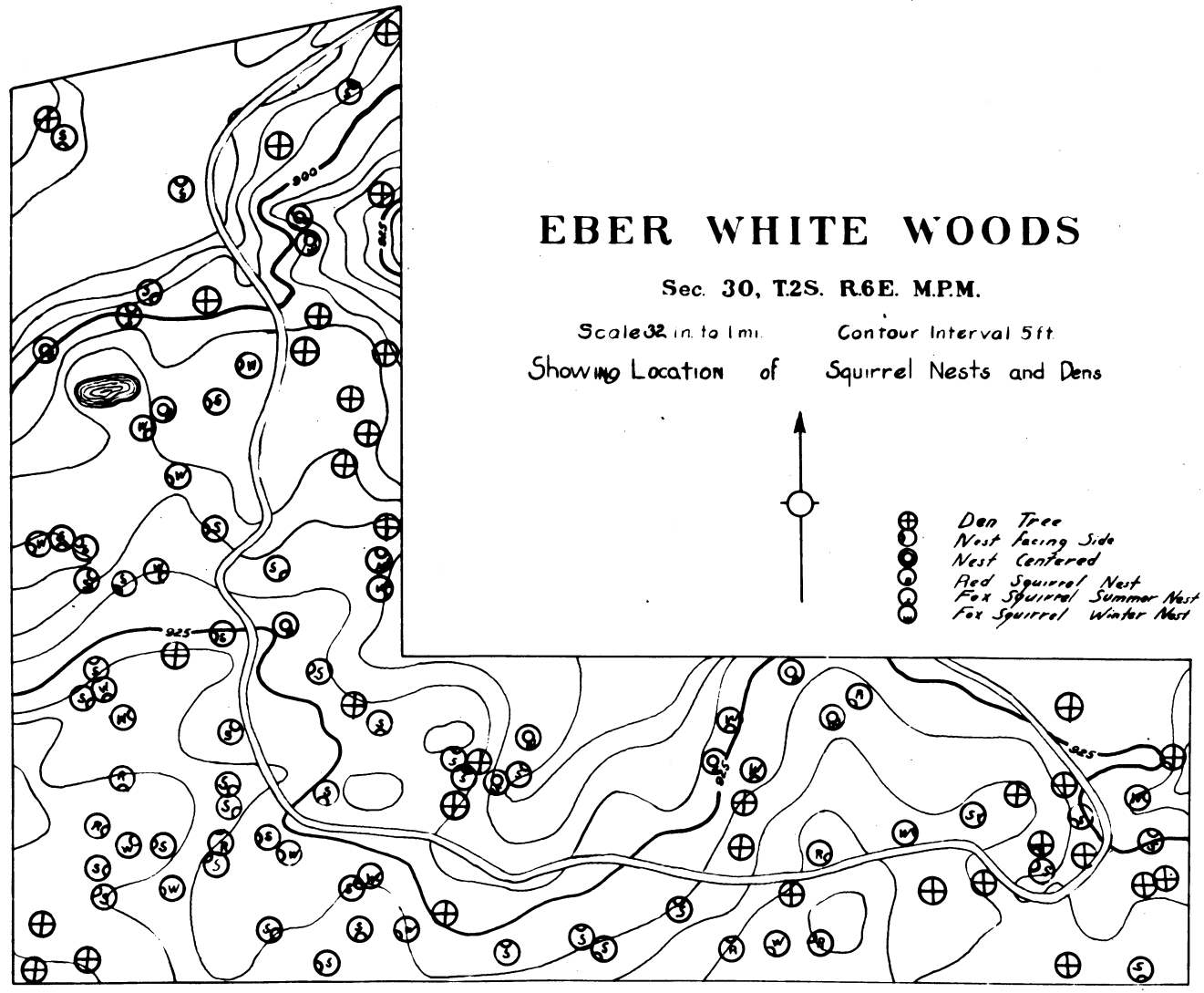
EBER WHITE WOODS
Sec. 30, T.2S. R.6E. M.P.M.
Scale 32 in. to 1 mi.
Contour Interval 5 ft.
Showing Location of Squirrel Nests and Dens
Den Tree
Nest facing Side
Nest Centered
Red Squirrel Nest
Fox Squirrel Summer Nest
Fox Squirrel Winter Nest
900
925
925

Fig. 11

Distribution of Den Trees

From the map (Fig. 11) showing distribution of squirrel nests in Eberwhite Woods, one can readily see that there is a sufficient number of well-distributed, large, open-grown white oaks, veterans of the bygone "oak opening" days. Eberwhite Woods has been managed on a selective cutting basis, with the sole intention of producing wood products for a period of 23 years. Many similar stands, although not as well stocked, can be found in Washtenaw County. Dens, therefore, are usually present in a sufficient quantity in the uneven-aged woodlots of this portion of Michigan.

In the younger stands, those under 60 years old, and which are frequently of coppice origin, the lack of dens may limit squirrel abundance. Because of the youth of the trees little can be done to encourage immediate den formation. The used small branches, as pointed out by Baumgartner (ibid.) would not make it feasible to girdle limbs to induce decay. To obtain and keep adequate squirrel populations in these woodlots, we are forced to rely on the leaf nests or shelter boxes.

Den Temperature

From March 13, 1940, to April 19, 1940.

Two sets of maximum and minimum temperature records were taken: one in a tree cavity that was comparable to a squirrel den and the other in the open at a corresponding height above the ground. The data showed the following to be true:

1. The average minimum temperature inside the den was 24°F. for the outside.
2. The average maximum temperature was slightly higher within the den than on the outside, being 39.7°F. and 38.0°F. respectively.
3. Of perhaps greater importance is the fact that of all comparable readings, the maximum and minimum temperatures were less within the den than on the outside.

Fig. 12
Typical Fox Squirrel
Summer Leaf Nest
As Viewed from the Ground

Fig. 13
A Large Fox Squirrel
Winter Nest

LEAF NESTS

Broadly speaking, there are two types of fox squirrel leaf nests: the loosely constructed nests and the very compactly built winter nests (Figs. 12 and 13). Both types serve uses other than those the names indicate. Young are quite frequently born and raised in the winter nest, and the other type may serve as a shelter for the male squirrel during the time the young are born. As pointed out previously, both types of nests may also serve as escape cover and loafing places. Several of the nests examined each contained a dozen to two dozen hazel and hickory nuts, indicating that food might possibly be temporarily stored in them. Fox squirrels were flushed from these nests and so it is unlikely that red squirrels had stored this food. While examining nests squirrels flushed from them would often take shelter in adjoining nests.

Have not found food in nests examined R.D.W.

Winter Nests

Winter nests are approximately spherical in shape, although extending leafy branches may give them the appearance of being shapeless. They have a diameter of from fourteen to twenty inches. The outside is made of oak or other branchlets, which still retain the mature leaves and are rather tightly woven together. "Within this exterior shell, there is a thick, compact mat of large leaves." (Stoddard 1919 p. 123) Species used to make these two walls are usually oak, though occasionally other species are used. Oak, however, seems to

be preferred, which may be due to the large size of these leaves, their toughness, and the characteristic of the leaves to remain on the cut branches probably accounts for their selection. Within the leaf mat is the nest proper, which is made from soft shredded dried grasses and sedges, large fibrous inner bark, bits of twine and cloth, and other similar materials. The opening to the nest is on any side but that directly opposite the trunk and may be almost closed by the materials of the walls. Nests of this type are as Stoddard (ibid.) describes as "entirely different from the loosely constructed summer nests and are so compactly built that they frequently remain in place for several years, the squirrels using them a great deal even in the coldest weather.

It is often impossible to distinguish fox squirrel nests from those of red squirrels and it is also sometimes difficult to tell the used from the unused nests. I have noted that red squirrel nests which are usually a little smaller, approximately a foot to 14 inches in diameter, often have moss, dried grass or detatched leaves interlaced with the external layer of twigs, and that quite frequently this layer is composed of bare twigs alone. Winter nests are to be found in almost all tree species, including the conifers and Stoddard (1920 p. 123), found that in the Dune Region of Northwestern Indiana and in the Sand Region of South-central Wisconsin, nests had ". . . invariably been placed in pine trees from 20 to 40 or more feet above the ground."

In addition to the above characteristics of red squirrel nests, the habitat might also indicate the species of the owner. I have found that red squirrels preferred the ravines and other lowlands, while the fox squirrel sticks to the higher ground. A common place for red squirrel nests and uncommon for those of fox squirrels is the crown of a grapevine covered tree. Stoddard also found that winter nests are placed "near to some good den tree to which the squirrel can retire if disturbed." Surrounding trees are likely to contain one or more of the temporary nests used in summer, simply twigs and leaves. Just how good the "adjacent old den tree" is, is a matter of question. Its great utility doubtlessly lies in its value of providing for the purpose of bearing and raising young.

The weather-repelling qualities of the winter leaf nests cannot be questioned. One day last December, following a two-day rain I examined a winter nest and found the inside to be perfectly dry. The nest had been observed for about an hour previous to the examination. Although no squirrel left the nest during this time, it still retained the body heat of the animal.

Occasionally these nests fall from the trees, thus injuring the adults and young they contain. Just how often this occurs and how important it is as a mortality factor is unknown, but one might imagine that at times losses from such accidents might be quite large especially if severe wind

storms occur during the brooding season. An accident of this kind occurred on the campus May 1, 1940, in which the adult female was fatally injured, while the five young the nest contained were uninjured and are now being raised by hand. If this accident had occurred under natural conditions - say in a ten acre farm woodlot - it would have meant a loss of possibly six squirrels, which might have been the total fall population on a woodlot of that size.

The number of summer nests an individual squirrel may have varies and an occasional individual may have as many as four or five of these nests, one or two of which may be but partially completed. Kennicott (1857 p. 60) states that: "Fox squirrels build nests wherever they stop even for a day or two and I have several times observed individuals to appear in a grove of young oaks, build a nest, remain a few days and then disappear perhaps to return again in a week and build other nests."

Nest Construction

The outside layer of the winter nest is built first, followed by the wall of leaves which holds the nest proper. As Stoddard (1911 p. 123) describes, the inner wall of leaves seems to be pressed into shape while damp, or green, thus making for the smooth, tough, weather-resisting wall. The entire nest is made during the summer or early autumn, while the trees still retain leaves. The nest proper is remade, or another one made, during the period preceding

the brooding season. A female was observed constructing one of these nests on May 13, 1940. She would gather small balls of dead grass and twine, shape it into a small ball and carry it to the nest and return again for more material. She spent the better part of the day at this task. The following diagram illustrates the plan of the winter nest.

The summer nest is but a loose aggregate of leaf-retaining twigs that the animals may gather and build in several hours.

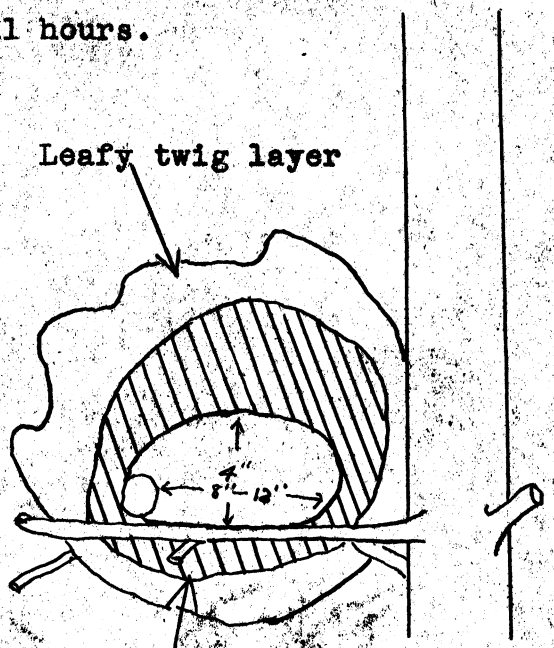

Fig. 14 Cross Section of Nest

Distribution of Nests

The map (Fig. 11) of Eberwhite woods shows the location and distribution of various types of squirrel nests with respect to the stand, the trees, and woodlot periphery. Baumgartner (1938 p. 688) in studying 235 leaf nests found 134 to be winter nests and 101 summer nests. Winter nests were located in trees with an average diameter of 13.1 inches and were on the average 38.5 feet above the ground. 45.71 percent of the winter nests were on the side of the tree nearest the edge of the woods and a little over 25 percent were on the opposite side of the tree. The remaining 29 percent were in the very top of the main trunk. The 101 summer nests were in trees having average diameters of 15 inches and were at a height of 42.7 feet. Of these approximately 44 percent were on the side of the tree nearest the type periphery.

Of the total of 121 nests examined in Eberwhite woods, 25 were classed as winter nests, 84 as summer nests, and 12 as red squirrel nests. The fact that this study was done following snowfalls, frequently permitted me to determine, by tracking, to what species the nest belonged. Though some of the nests classed as fox squirrel summer nests may have belonged to red squirrels and others of them were unfinished winter nests. Occasionally one of these species may use a nest of the other, especially for escape cover. The average diameter of the trees containing the summer nests was 17.4 inches and for the winter nest trees, 18.3 inches.

MOVEMENTS

Migrations

Fox squirrels do not generally migrate, or more correctly, emigrate as do the grays. Local migration movements, however, occasionally occur and they might be better classed as erratic movements; the direct result of insufficient food supply and population pressure. Seton ('29 p. 84) writes: "Arlington Cemetery has always been a haven for fox squirrels (Sciurus n. neglectus). About 20 years ago, they had increased to surprising numbers. Then, one day, they seemed to be possessed of a migration craze; they all set out eastward. At once, they were met by the broad Potomac, but plunged in, swimming over toward Analostan Island, the nearest wooded tract. Here many of them stayed, but many moved on, and were lost sight of. They still frequent Arlington Cemetery."

Returns on a questionnaire sent out in Missouri to determine squirrel movements for various parts of the state, showed that (Bennitt and Nagel 1937 p. 85):

1. "Reports of heavy concentration came from individual farms, while elsewhere in the same counties, at the same time, fox squirrels were often scarce.

2. "The migrations were not well synchronized.

3. "Migrations involve nowhere near so many animals as the migrations of the gray squirrel of the same year, but is a sporadic migration of small groups out of unfavorable territory, and it is believed that they were due only seconda-

rily to population pressure through failure of the food and water supply."

Several instances of individual fox squirrels crossing prairies 4 or 5 miles wide are recorded by Kennicott ('57 p.62).

In addition to migration or erratic movements, seasonal and daily movements are recognized.

Seasonal Movements

There seems to be rather definite seasonal movements of this species, which are perhaps better designated as being spring and fall "shuffles." Both may be the direct result of population pressure, although the spring movement may be the result of a limited food supply as it occurs immediately after the spring breeding period. I have observed fox squirrels in Dane County, Wisconsin emigrating from woodlots during the month of October, the time at which food is most abundant. John Topercer, a student in Wildlife Management, tells me that during the latter part of March he saw five squirrels chasing another individual in an open field approximately 1,000 feet from the home woodlot. As this is too late for the breeding period, and the fact that the home woodlot was less than an acre in area, points to population pressure or an insufficient food supply as the cause of the shuffle. Mating activities, in instances, may also be the cause of spring movements.

Daily Movements

Fox squirrels are rather sedentary in their habits and may perhaps spend their entire lives within several hundred yards of the place they were born. The radii of the daily movements, as might be expected, are the smallest during the fall and early winter months, when food is most abundant.

Baumgartner ('38 p. 685) reports that 35 repeats on live trapped squirrels (taken from latter Sept. to Dec.) showed the average distance traveled to be 149 yards; the greatest distance 375 yards, while 8 were caught in the same place. Tracking and observations, following snow falls showed daily ranges to be approximately 100 to 200 yards in the oak-hickory woodlots of Southern Michigan during the fall and early winter. Unfavorable weather often limited daily movements to a smaller area than this.

Similar, though more intensive studies carried on in the Northville area, showed an increase in the size of the squirrel ranges. In the more unfavorable woodlots daily ranges of 220 to 440 yards were found to be common, and daily cruising circuits having a total length of 3/4 to 1 mile were several times observed. Typical ranges are shown in Fig. 14 and an exceptionally large one in Fig. 15.

Time of Daily Activity

The species is active through the day, and, it is the opinion of both Kennicott (1857 p. 60) and Seton (1929 p. 101) that it is most active during mid-day. My field notes

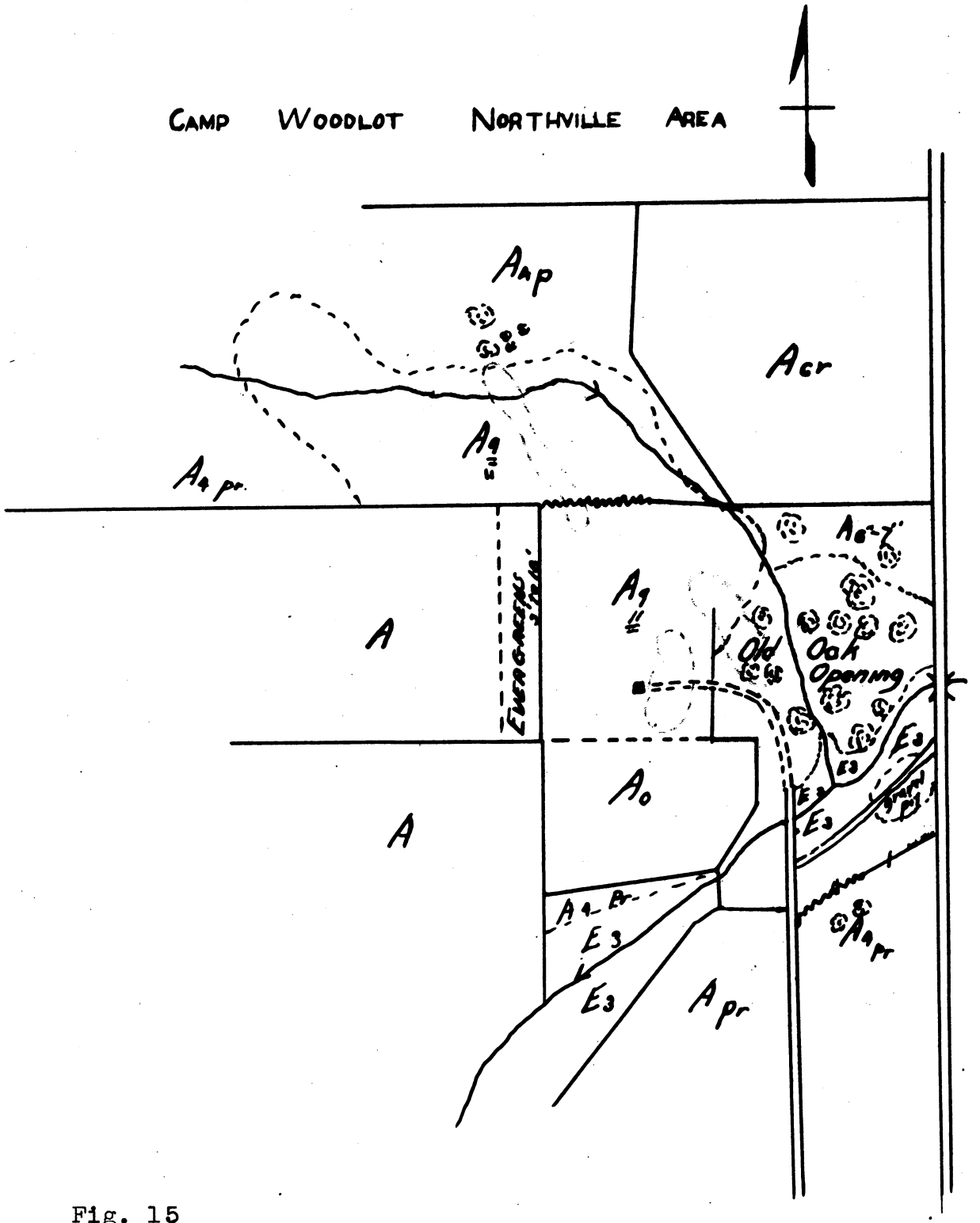

Fig. 15

Showing Normal Daily
Fox Squirrel Ranges

Scale 8" = 1 Mile

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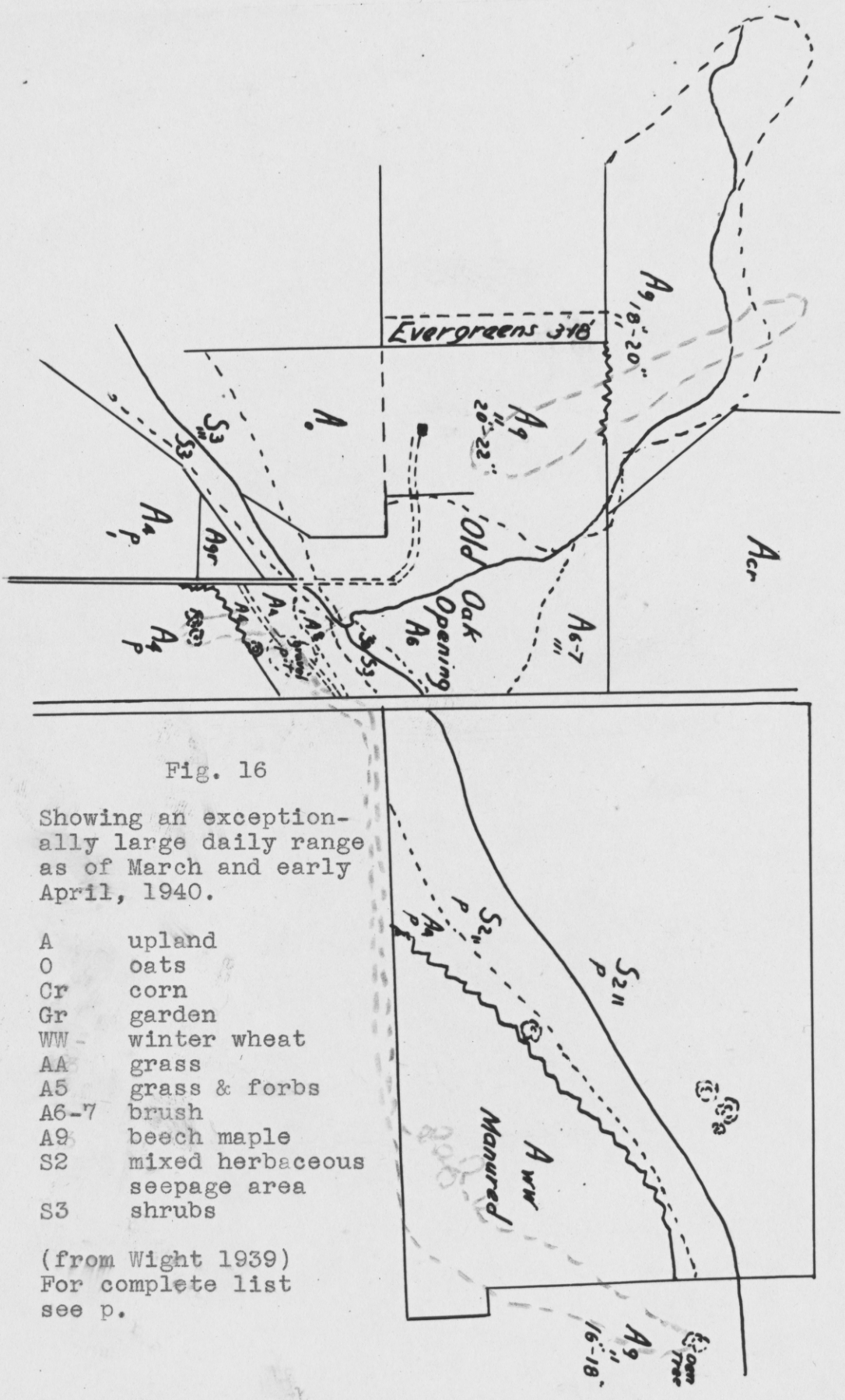

Fig. 16

Showing an exceptionally large daily range as of March and early April, 1940.

A	upland
O	oats
Cr	corn
Gr	garden
WW	winter wheat
AA	grass
A5	grass & forbs
A6-7	brush
A9	beech maple
S2	mixed herbaceous seepage area
S3	shrubs

(from Wight 1939)
For complete list see p.

show the period of greatest activity to be between 7:00 and 10:00 o'clock in the morning, for the spring months at least. General activity was noted to occur throughout the day, and even the longest cruises to feeding grounds were frequently made during mid-day. As might be imagined, much of the sunning and loafing was done during the late morning and early afternoon.

Home Range

The size of the home range varies with the composition of the stand, the availability, and proximity of food, location of den trees, and size of the woodlot. The above mentioned area of approximately 1 acre, held 5 squirrels; the size of the home range was necessarily small. Another woodlot near Northville, though over 20 acres in size, contained but two or possibly three squirrels.

Under normal conditions, the approximate cruising grounds of a fox squirrel, is approximately 20 acres (as calculated from an average cruising radius of 150 yards.)

The territory (that part of the cruising range the animal protects), seems to be very limited and might possibly be only the home den. Seton ('29 p. 92) found that if an individual was approached by another while, or 2 or 3 minutes after burying nuts, the owner would chase the intruder away; but after a period of 5 to 10 minutes the other squirrel was permitted to run over the place where the food was cached.

The observation of a young male climbing up into a tree containing a den with four young, and not being chased by the female also seems to show that there is no protected territory. I have in several instances witnessed a wounded fox squirrel escaping into a den containing another individual, only to be repulsed by the rightful owner. Dens and nests, therefore, might possibly be the only protected part of the range.

Relations to Other Species

Fox squirrels are said by Bachman (1849) to compete with the wood-duck and the red-headed woodpecker for dens. Red squirrels are reported to drive these larger members of the family from den trees although on one occasion at least I had witnessed a fox and a red squirrel to use the same den tree, though of course, different dens. Later on, the red squirrels produced a litter of young in their den.

Raccoon and 'possum do not compete with squirrels for dens, as they require larger ones and squirrels may even aid in the formation of suitable dens for these animals. Wight (1933a pp. 77-78) found that quail and pheasants fed extensively on particles of nuts and corn that were dropped by squirrels.

This discussion brings up the age-old myth that red squirrels castrate fox squirrels, that fox squirrels castrate gray squirrels, that gray squirrels castrate fox squirrels; or what-have-you. The findings of Svihla ('31 p. 155) which shows that the males do not become sexually mature until they

are 6 or 8 months old together with the fact that the bot fly Cutereba, occasionally attacks the scrotum before the testes have descended, explains this myth. The hunter shoots an immature squirrel, and finds the scrotum without testes and punctured by the newly emerged Cutereba; and draws the conclusion that another species of squirrel castrated the individual (Bachman, 1859 p. 135).

Populations

As has been pointed out, populations of the various subspecies vary greatly and that rufiventer is the most widely distributed and the most common. Its range is also increasing at the present time. Leopold ('36 p. 182) speaks of this species as being cyclic, and the graphs (Fig. 16) tend to show this to be true.

Leopold (1938 p. 110) has also found that there is a tendency for the cycle in Southern Wisconsin to occur a year or two after its occurrence in the more northern regions. The graphs show this to be quite true with fox squirrels, a species that has a more southerly distribution than the snowshoe rabbit.

The game kill records for the state of Wisconsin, from which the graphs were drawn, show also the importance of fox squirrels as game species. As a comparison, the reported take of fox squirrels in the state of Wisconsin shows the species relative importance as a game animal.

Fig. 17

A comparison of the fox squirrel and snowshoe rabbit kill for the state of Wisconsin

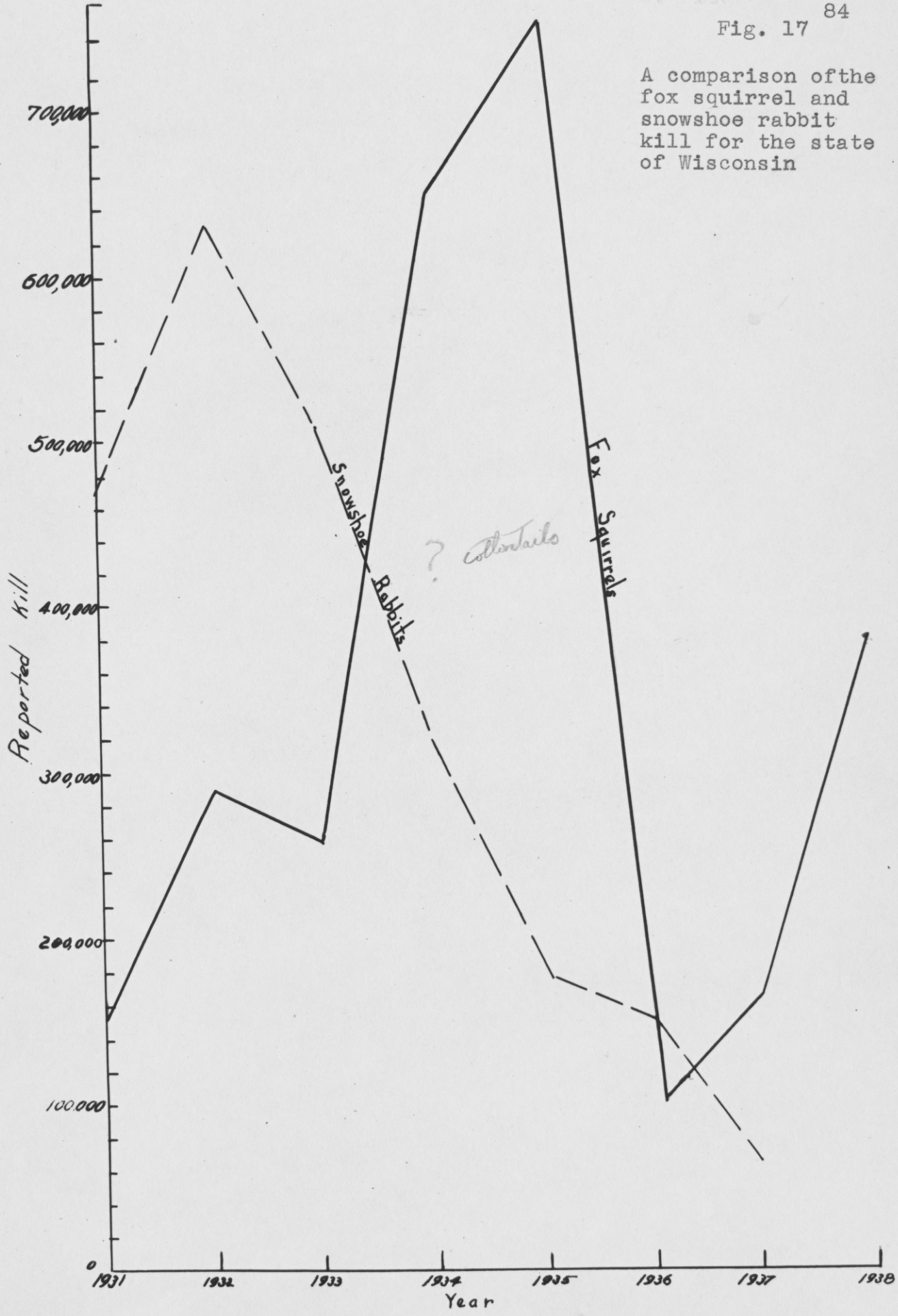

Fig. 18

Number of Fox Squirrels Killed Annually in Wisconsin as Compared With That of Other Species

Year	Fox Squirrel	Pheasant	Ruffed Grouse	Cottontails
1931	149,722	none	38,885	1,075,591
1932	291,125	40,450	317,007	2,474,125
1933	259,424	154,915	318,410	2,338,360
1934	648,693	103,640	131,762	1,728,230
1935	745,873	135,717	72,778	1,429,192
1936	103,274	144,670	no season	935,880
1937	164,676	174,616	no season	528,911
1938	Figures not available			

Populations per acre vary greatly. The beech-maple woodlands of Southern Michigan may have but a very few or no fox squirrels on areas up to 400 acres in size, while a small, mature, oak-hickory woodlot in the same area may contain as many as 5 or 6 squirrels per acre. Bennitt and Nagel (1937) found maximum fox squirrel density in Missouri to be one or two per acre, but this population is seldom found.

Allen (1937 p. 388) by extensive live-trapping and tagging methods found a population of two squirrels per acre on a woodlot of 39 acres within the Kellogg Sanctuary. This and the adjacent woodlots had been in sanctuary since 1927. During the following year the population was greatly reduced by a disease. Evidently a winter population of two squirrels

per acre is too great for an area to safely carry; although one might not consider 1937 to be a representative year, as it is at the depth of the game cycle.

Representative woodlots throughout Ohio contained populations that varied from 18 to 94 fox squirrels per 100 acres of fox squirrel range, with the higher figures being found only on winter fed areas.

Fall populations preceding the hunting season of as high as two squirrels per acre can perhaps be safely attained. The kill should perhaps thin it out to one squirrel per one or two acres.

Sex Ratios

The following data show some very interesting facts in sex ratios given by Bennitt and Nagel (1927 p. 85) for squirrels collected in the following places.

Year	Locality	Males Number	Females Number	Sex Ratio
1934	Missouri Hill country	1,016	251	4:05:1
1934	Missouri Riverbreaks	296	164	1.8:1
1934	Missouri Ozark border	705	70	10:1

The authors suggest that this distorted sex ration may have been caused by the drouth and excessive heat suffered during the brooding season. It might also possibly mean a segregation of sexes during the hunting season.

Of 362 squirrels examined in Ohio during the period of September 1 to January 1, 1938, 48.89 percent were males. Great variations were however recorded for various times of the year. During August of all squirrels handled 83.3 percent were males; during October only 38.7 percent were males; November, 53.1 percent; December, 56.1 percent; April, 51.1; May, 50.0 percent; June, 40.0 percent; July, 52.4 percent; and August, 83.3 percent.[1] These data are not of sufficient quantity to be statistically sound. They do show, however, that there is a definite differential seasonal activity of the sexes. Baumgartner (1938 p. 686) also found that of 954 squirrels taken from September 25 to October 10, 55.5 percent were males.

In conclusion we find that of the squirrels shot, males predominate and the excess of females is probably eliminated by disease or accidents.

EFFECTS OF FORESTRY PRACTICES

The best forestry practice for the management of uneven-aged woodlots is the selective cutting method. Studies in Eastern Texas showed that when cuttings took 30 percent of the trees from the virgin woods, the squirrel carrying capacity of the range was reduced. This was found to be especially true when trees of the mast bearing groups such as oaks, gums, beech and pecan were taken.[1] In another area where not more

[1] Work done by Baumgartner, 1938.

than 20 percent of the vigorous middle-aged trees were taken, cutting favored squirrel abundance. The data from Eberwhite woods, an area of 40 acres and containing a population of perhaps 30 squirrels, showed that good forestry practices and squirrel management can be carried on together. Even in this woodlot there are enough dens and the opening up of the stands by cuttings, undoubtedly increases mast production.

Logging activities carried on during the latter part of January, February, March and April would often result in the destruction of some new-born young as well as an occasional female.

The effects of grazing, which seemingly are not harmful to at least the present squirrel population, has been discussed under Cover.

Possible modifications of forestry practices are discussed under Management.

Effects of Crops and Farm Practices

Cornfields bordering a woodlot furnish squirrels with an abundance of food from the middle of August until possibly spring, depending upon the time, and way the crop is harvested. This practice doubtlessly results in a larger population for the woodlot, and also keeps the animals in a better condition during the winter. The additional food resulting in better condition might in turn mean an earlier and shorter first breeding period, which would be desirable as it would allow more time for the production and care of the second brood.

The introduction of the mechanical corn picker is apt to be very beneficial to squirrels as well as to other forms of wild life. One field of corn that had been harvested by the use of this machine was used quite extensively by fox squirrels as well as pheasants and rabbits. The field was connected to the woodlot by a brushy gully and fence row approximately 300 feet long. The squirrels were observed to follow the line of communication until they reached the field where they would range for waste grain. A quantitative study of the amount of waste corn left in these fields, together with observations on the species feeding in these areas would be valuable to determine the exact benefits wildlife derives from these machines.

Orchards

Baumgartner (see food habits) limits the period of availability of apples to August and September; however, squirrels in Southern Michigan at least, were quite frequently observed to feed on the fruit all through the fall and winter months. In one woodlot on the Northville Area, they took apples daily until the middle of April; possibly the result of an insufficient supply of better foods as they traveled fairly great distances daily to the orchard.

PARASITES AND DISEASE

Disease and parasites perhaps are the chief factors in limiting squirrel abundance, but as yet little is known about them. Perhaps the best techniques known so far to prevent disease is to keep the population at a level that is not too high, and to furnish the animals with an abundant and well distributed food supply.

Perhaps the most well-known disease of fox squirrels is mange; caused by the mite Sarcoptes scabiei. While this parasite may not kill the animal directly, it may do so when aided by other diseases, a limited food supply and cold and wet weather. Under these conditions it doubtlessly is a contributing high mortality factor. The high population for the woodlot of the Kellogg Sanctuary was, according to Allen, reduced to small numbers by an epidemic of mange in the spring of 1936 and during 1937. During the winter '36-'37 a more intensive trapping-tagging program showed only 39 individuals. One should perhaps remember that the winter of 1936 was exceptionally cold and that during this year the reported kill for Wisconsin was 103,274 while 1935 showed a take of 745,873 fox squirrels.

The decomposed carcasses of 3 fox squirrels were found in the camp woodlot of the Northville Tract; and while they were too decomposed to make any accurate diagnosis, the condition of the skin of one at least pointed to mange. Another

individual, seemingly on the road to recovery was observed on April 3 feeding in an apple tree. Although the animal seemed to be of normal weight, it also appeared to be dull and sluggish and was easily approached. The hair on rear 2/3 of the back had been apparently lost, although at the time of the observation, new hair, much lighter in color, and about one-third as long as the old hair, covered this part of the body.

Of 332 squirrels examined in Ohio during the fall of 1939, seven or 2.11 percent were found to have mange, (Baumgartner '40 p. 1).

Coccidia of the genus Eimeria are found in both fox and gray squirrels (Katz '39 p. 1). This disease undoubtedly causes some losses especially to young individuals. The exact part this disease plays is of course unknown, and what little is known about it in squirrels has been found from autopsies of advanced juveniles and adults.

Tularemia undoubtedly also causes some losses although the author is aware of only one instance in which it had been reported for fox squirrels (Kirkwood '31 pp. 941-942).

Plague caused by Bacillus pestis has not been reported in fox squirrels although it has been found in the gray.

Parasites

Some of the parasites reported from fox squirrels are:[1]

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[1] Reports taken from the bibliography and records of A. J. Katz, Ohio Release No. 13, Dec. 1, 1939, an annotated Bibliography Reference concerning parasites of squirrels.

Arthropoda - Hoplopleura sciuricola

Cuterebra - bot fly

Ceratophyllus fasciatus

Cestoda - Catenotaenia sp. vanich

Cysticercus fasciolaris (in liver)

Coenurus serialis

Capillaria sp. (Zeder 1800)

Citellinema bifurcatum

Dermacenter variabilis

Echinorhynchus moniliformis

Enderleinellus longiceps

Fasciola hepatica (liver and gall bladder)

Moniliformis (Moni intestine)

Multiceps serialis (frequently reported)

Mites Trombidiidae

Heligmodendrium Hassalli (Prince 1928)

Lenognathoides montanus

Hymenopelis sp. (Weinland 1858)

Nematoda-Ascaris lumbricoides Linn. 1758

Noehaematopinus scicirinus

Pentostomida Linguatula serrata (Frolich 1789)

Sarcoptes scabiei var. Latreille

Ticks

Trombidiidae

Sporozoa Eimeria sp. (Sciurorium?)

Taenia taeniaformis larva

Taenia hydatigera

PREDATORS IN CONTROLLING POPULATION

The following records show the small part predators play as decimating factors in squirrel abundance.[1]

601 Marsh hawks stomachs contained six squirrels (not spermophiles) McAtee 1935

994 Sharp-shinned hawk stomachs - 1 squirrel

261 Coopers hawk stomachs contained 22 squirrels (not spermophiles)

243 Goshawks- 22 squirrels

754 Red-tailed hawks - 80 squirrels

145 Broad-winged hawks - 2 squirrels

99 American rough-leg hawks - no squirrels

17 Ferruginous rough-leg hawk stomachs - no squirrels

26 Golden Eagle stomachs - 2 gray squirrels

When one considers that at least 5 species are grouped together under the headings "squirrels" and that all are smaller than the fox squirrel, it is evident that the hawks were not very successful in taking even the smaller gray squirrel, and that these rodents would injure the feet of the birds. Seton ('29 p. 52) quotes from an observation made by Merriman (1879), in which a gray squirrel readily outwitted a goshawk.

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[1] These statistics are taken from the unpublished compilation of Food Habits of Common Mammals, by Members of the Class in Wild Life Management during the years 1935 and 1936 and 1937, under the direction of Prof. H. M. Wight.

Owls, with the exception of the great horned, perhaps take fewer squirrels than do the hawks.

Errington (1935) found that both red and gray foxes occasionally take fox squirrels, but that the number as compared to the total diet is small, only two fox squirrels being found in the contents of 56 stomachs, , 3 squirrels in the food items of 113 Iowa fox dens; and none in 1,175 fecal samples.

In cities, villages and parks, dogs and cats occasionally catch squirrels but such acts occur so infrequently that they, as well as predation by other species, can be classed as the "sucker list" type.

John Craighead of the School of Forestry and Conservation tells me that a family of red-tails he has under observation is feeding largely on fox squirrels. This is probably the result of a scarcity of the buffer species such as mice and ground squirrels together with a local abundance of fox squirrels, particularly young of the year. It might possibly be that the larger hawks do take larger numbers of fox squirrels than existing data on food habit studies indicate.

Highway Mortality

Another mortality factor is highway accidents. The author is unaware of any quantative studies on this factor but one knowing the ground habits of the species, might imagine that in woodlots bordering highways this is a serious mortality factor. For other woodlots this factor does not exist.

Fig. 19

Burr oaks, relics of what was possibly an oak opening which was the primitive habitat of the fox squirrel in Wisconsin and Michigan

Fig. 20

The dead Burr Oak in foreground is also a relic of an oak opening. Red Oaks in the background

Fig. 21

An even-aged stand of Red Oak found in what was formerly an oak opening or prairie site in Southwestern Wisconsin. The age of these trees was found to be 70-80 years, which corresponds with the time of settlement and the breaking up of the prairie monotype by plowing. This in turn prevented prairie fires from burning over these lands annually and allowed a forest to become established. Acorns cached by fox squirrels possibly directly accounted for the woodland

ECONOMICS

The economic status of the species is contingent upon several variables, chief of which are: their relation to the forest and farm products, and the hunting demand on the species. As to forest products, fox squirrels, as well as their relatives, are considered to be both beneficial and harmful. Everyone interested in wildlife or forestry has on occasion heard individuals speak of squirrels as destroying the nut crop and thus preventing tree reproduction, or by their gnawing, deform trees. The naturalists like to speak and write of squirrels as being "Little Four-Footed-Foresters." Work done by Olmsted (1937 pp. 209-300) shows conclusively that squirrels play a large part in assisting black oak trees to establish themselves on new ground, and Baker ('21 pp. 19-20 also states that the ". . . characteristic of walnut reproduction makes it appear likely that in many of the mixed stands containing walnut, the walnut was the first to start, originating from nuts buried by squirrels in open meadows and prairies. . . ." He also points out that squirrels are perhaps responsible for the even aged groves of walnut.

It might possibly be that fox squirrels together with the cessation of prairie fires accounted for the even ages stands of red oaks to be found along the prairie edges of Southern Wisconsin and Southern Michigan.

The damage fox squirrels do to trees is usually neglible, although individual trees, often horticultural varieties or exotics are damaged by these animals. Damage of this kind is usually done in the spring of the year when the buds and bark are taken for both food and nesting material. Yeager (1936 p. 417) tells of a female squirrel that stripped the bark from the sides and tops of the branches of a three-inch elm. He reports that the bark was stripped from nearly all of the branches. His estimate for the bark removed was 60 percent. The author also mentions a similar case where catalpa was the species damaged. He thinks that this practice was done on only certain trees ". . . trees with a flat top, the bark of which may suit the taste or fancy of individual squirrels."

Occasionally squirrels do damage to newly planted or sprouting corn. During the latter part of May, 1939, I accompanied Aldo Leopold in examining a field of a valuable new type of hybrid seed corn that was just sprouting. Approximately 20 to 30 percent of the sprouting seeds were destroyed. The agronomist, having had similar losses in past seasons, suspected the damage was done by pheasants, but the manner in which the kernels were dug, indicated rodents and observations showed it to be fox squirrels. In some cases almost entire rows were destroyed. The corn, a new strain, was considered too valuable to use other than direct control measures. The damage was perhaps the result

of an excessively large population, as the woodlot, as well as the rest of the University farm, had been given complete protection for a long time. If similar damages occurred to ordinary newly planted cornfields, perhaps artificial feeding along the woodland border would correct it.

As has been previously discussed, cornfields bordering woodlots which contain high fox squirrel densities, are often damaged. Kennicott ('57 p. 58) speaks of large cornfields in Indiana and Illinois as being destroyed by fox and gray squirrels during the years the mast crop had failed.

Even during normal nut years, a certain amount of damage is done to neighboring cornfields. In Iowa, during the year 1935-1936, a 2.2 acre food patch of corn was left standing around a deciduous forst sanctuary next to a 35 year old stand of conifers. Hendrickson and Schlesselman (1937 p. 236) reported fox squirrels to be the most frequent visitors to the food patch. The authors found that wildlife used 5.4 percent of the estimated total yield of 88 bushels. This report is of particular value because: (1) the area was a sanctuary and therefore probably contained a large squirrel population; (2) the winter of '35-'36 was as reported abnormally severe; and (3) the time of the experiment was in the "low" of the cycle. The remaining corn was gathered in late winter, thus terminating the experiment.

Quantative data on the number of corn cobs found in selected woodlots would throw some light on the damage wildlife does to the corn crop; or to put it positively, would

indicate the value of cornfields and corn food patches to wildlife.

A report of fox squirrels damaging the pear and apple crop in the city of Saginaw is given by Seton ('29 p. 92).

Value as Game

The figures discussed under Population taken from hunting returns, supplement the following statistics of Baumgartner and Bennitt and Nagel, and show the value of the fox squirrel as a game species.

According to the report of Hicks ('38) there were 221,496 squirrel hunters in Ohio, who hunted in the state's total woodland acreage of 3,159,882 acres. From these statistics the density of squirrel hunters is computed to be 7.01 per hundred acres.

A survey carried on by Baumgartner (1937) showed from a sample of 439 hunters in 27 different counties that hunters hunted about a total of 3 1/2 days and killed approximately 5 squirrels per hunter for the season.

Using the above figures, an average of 5 squirrels killed per hunter and 7.01 hunters per 100 acres, to remain on a sustentative basis, the range must produce 35 "harvestable" squirrel per 100 acres per year. Statistics also found by the same author, show that a crippling loss of about 5 percent normally occurs, or about 1.65 squirrels are crippled per 35 taken. The above statistics consider both fox and gray squirrels but the workers found that by a

"conservative calculation," there was a total of 51,000 squirrel hunters in the 27 counties sampled, of which only 750 were gray squirrel hunters.

Methods of Hunting

Perhaps most fox squirrels killed in Michigan are taken as incidental small game by the small game hunters. The next largest percentage is undoubtedly accounted for by the "still" hunters, and the remainder by specialized squirrel hunters using dogs. This is perhaps also true for Ohio as Baumgartner (1937 pp. 1-8) found the following guns to be used:

64.48 percent of the hunters used 12 gauge shotguns.
19.14 " used .22 rifles.
7.81 " used 16 gauge shotguns.
6.80 " used 20 gauge shotguns.
1.80 " used 10 gauge shotguns.

From these figures we find that a total of 80 percent of the hunters used shotguns, and so the species is considered to be a poor game animal.

MANAGEMENT AND MANAGEMENTS TECHNICS

To put fox squirrels on a management basis, the first requisite is the taking of the inventories of the existing squirrel population and squirrel habitat.

Ideal fox squirrel habitat consists of a fairly lightly stocked stand of the oak-hickory forest type species with many of the individual trees being large crowned, mature individuals. The ideal habitat of the species consists of woodlots of not more than 40 acres in area, if square, or in any event, woodlots not more than 300 or 400 yards wide at its narrowest dimension. This size allows the animals to reap the maximum benefits from the "edge effect." Among other things, ideal habitat contains a good number of all of the following trees well distributed throughout the stand.

1. White oaks (several species of the group; for food, cover, and dens).
2. Black oaks (several species of the group; for food and dens).
3. Hickories (several species for food).
4. Black walnut (for food).
5. Butternut (for food).
6. Mulberry (for spring and summer food).
7. Elms (for buds, seeds, bark, and dens).
8. Maple (for buds, seeds, and dens).

9. Shrubs and herbaceous fruit bearing plants of the ground cover and woodland borders.

In addition to the above food species, the ideal woodlot has an accessible cornfield bordering it on one or more of the sides.

Of course there are very few woodlots of the ideal nature, although a few of the old "openings" of Scio Township approach it. We cannot set up our objectives in squirrel management to attain this optimum, but, rather, we must place the species in the small niche that is its due, and manage it along with the major forms of woodlot utilization such as wood production, and to a lesser extent, grazing. This can be done with no, or but few, modifications of present forestry and other land-use practices.

OTHER MANAGEMENT PRACTICES

Leopold (1936 p. 4) points out the sequence of game management practice to be:

1. Restriction of hunting.
2. Predator control.
3. Reservation of game lands.
4. Artificial replenishment.
5. Environmental controls.

Restriction of Hunting

Included under this heading is the limitation of the

season, the time and methods of hunting, and the number of squirrels that can be killed daily by the individual hunter. Seasons in the Lake States are limited to but one a year, which is in the fall, and therefore after the rearing season. In some of the Southern States the hunting season coincides with at least one of the reproductive periods.

In Michigan the bag limit is 5 per day, with the season extending from October 15 to November 5. This is satisfactory from the sportsman's point of view, and the squirrel population seems to be able to withstand the annual hunting losses. During 1938 there was no open season on either fox or gray squirrels, and as this is but a year or two after the low of the cycle, it will be interesting to know how it affected the kill of the following season, 1939. Will it indicate that the season should be closed or that the bag limit should be reduced to 2 or 3 squirrels during the low years?

Predator Control

Predator control has no place in squirrel management, for as discussed under enemies, predators take only an occasional individual. A rigid predator control program may even be harmful, for predators feed largely on the non-game species such as red squirrels and chipmunks, which compete with fox squirrels for food and possibly shelter.

Refuges

Refuges, like those of the other types for farm game, should be of small size and administered by the individual land owner. Small woodlots containing favorite food species, or portions of larger woodlots of the same nature, and in instances, kettle holes (Fig. 22), all of which may be used for feeding grounds, could well be set aside for refuges.

Fig. 22

A kettle hole, lying adjacent to a cornfield which was extensively used by squirrels and other wildlife when feeding on corn

Artificial Replenishment

Artificial replenishment has not as yet been extensively practiced, and perhaps will and should never be included in any conservation program. While the species has been successfully raised in captivity, litters are small and the costs are high (Goodrum, 1937 p. 7-8). Another drawback

to the use of this method would be the great danger of spreading disease to wild individuals. In good habitats that are completely depleted it may be advisable to restock with live trapped individuals.

Environmental Control

Environmental control, therefore, offers the greatest possibilities in squirrel management. Methods for this phase of management are discussed later.

Census Methods

There are eight census methods that are feasible under certain variable conditions. They are: (1) the exhaustive trapping method; (2) the spot count method; (3) the intensive tracking method; (4) the leaf nest count method; (5) the mathematical computation methods; (6) the nest examination method; (7) the dog census method; and (8) a combination of several of the above.

The Intensive Trapping and Tagging Methods

This is undoubtedly the most accurate census method, but it has many drawbacks, chief among which are time, cost, and a high mortality rate. The method is, therefore, only applicable where other data such as sex ratios, behavior, weights and movements are also wanted. Its place, there-by is limited to life history studies and as checks for other census methods. Even for these uses, the method has its drawbacks, as areas of a relatively large size cannot, under

normal conditions, be exhaustively trapped in a period of less than two or three months.

Success of this technic depends largely upon the food conditions of the woodlot, condition of traps, number of traps, and the amount of money and time that can be given to trapping.

There is also a serious mortality factor with which to contend. Traps have to be examined in the late afternoon or evening as squirrels cannot be permitted to remain in the traps over night. (Another drawback is that it brings an unnatural food supply on to the area).

The Spot Count Method

This technic is, as Baumgartner (1938 p. 687) defines: "the recording of all squirrels seen per unit time on a given area." It is of value only on small, open areas, 5 acres or less in size. Even here the accuracy depends on squirrel activity which varies with the season, time of day, weather, availability of food and other similar factors.

When using this method, work should be done under comparable conditions, and perhaps on more than one day. The best time to take a census in this manner would be during the first breeding season, which occurs during January. At this time squirrels are the most active, and tend to congregate. Also during this time visibility is very good.

The Leaf Nest Count Method

There are two possible ways of using this method. One way is to count all squirrel nests found, assume that squirrels build an average of 4 nests, and divide the total number counted by this number. Another method is to count all used nests, assuming that there is but one used nest per squirrel. Baumgartner (1938 p. 687) considers this technic to be the most practical of all methods. By extensive trapping and tagging methods he found that the number of used leaf nests is equal to the adult population. He also points out that the accuracy of the method depends upon the ability of the worker to find leaf nests, to distinguish winter from summer nests, to separate used from non-used nests, and to recognize similar nests made by other species.

Both types of leaf nest censuses, as seen by the Eberwhite data total (p.) show fair results for the oak-hickory woodlots of Southern Michigan, but in the beech-maple woodlots of the Northville area only one used winter nest was found on seven woodlots, which contained a total population of over 20 fox squirrels. Evidently there is an over abundance of suitable dens in these areas and the squirrels preferred them to leaf nests.

The results of a study of 9 woodlots are given in the following table:

Fig. 23

The Population of 9 Woodlots as Determined by the "Leaf Nest-count" Method and by the Exhaustive Trapping Method in Ohio

Woodlot	No. Adult Fox Squirrels	No. Adult Red Squirrels	Number Adult Squirrels	Number Used Nests
B	4	7	11	13
R	3	0	13	2
K	16	0	16	18
S S	52	0	52	51
O	60	0	60	59
U	38	0	38	32
J	19	0	19	21
T	6	6	12	12
F	19	(8) 2 grays	27	31

Nest Examination Method

This technic which can be used in the younger coppice woodlots, where den trees are not to be found, consists of recording all winter nests, and examining the more accessible ones. Squirrels can be chased out of nests by shaking the tree, if small, climbing the tree and shaking it, or by striking the nest with stones. All flushed individuals are recorded and the total population is computed as follows: Number of flushed squirrels: Number of nests examined :: X: total number of leaf nests

Fig. 24

Examining a winter nest that was found to contain two young

Fig. 25

Examination of two nests, the lower one a summer nest and the other a winter nest. An adult was flushed from the winter nest. No young found

The accuracy of the method depends on: (1) the total number of nests the stand contains; (2) the number of nests examined; and (3) weather conditions. It assumes that all squirrels are in nests, and for this reason should be done on cold, windy days.

This technic was only used on two occasions, showing fair population figures in both instances. An examination

of nests during the brooding season showed valuable information on the young and from the number of broods the population can also be computed. However, it is in error in that it assumes all females are brooding young.

Tracking

Tracking as a census method can be used following snow falls in areas containing a sparse squirrel population. This technic showed good results under such instances, especially when done over a period of several weeks. The great variation in activity prevents the use of tracks as an index of squirrel abundance.

Dog Census Method

Goodrum (1937 p. 501) has used dogs in studying squirrel population of Eastern Texas, but he has found it to be of chief value only in determining relative abundance and character of squirrel activity. He terms the method "Time-space area with hunting dog." With this method the number of squirrels the dog trees are recorded. The area is approximated by comparing the length of time it takes to cover it with that required to cover a tract of known area of the same type. Here again accuracy depends upon many variables. Seton (1929 pp. 99-100) reports of hunting squirrels with the use of a dog on a 100 acre area that had an estimated population of 500 squirrels, but the dog was only able to tree "7 or 8." Further experimenting should be done on the method before any conclusions on its accuracy can be drawn.

Forestry Practices

The woodlot has its place in the economy of the farm, being used chiefly for fuel production and summer pasture. Its esthetic and recreational value is seldom considered by the owner. How many of them can compare a brace of squirrels, a sack of hickory nuts, or a bouquet of wild flowers with the dollar increase of the milk check? Or (for that matter), how many individuals can see the importance of having a wood supply 30 years hence? Straight economics show that woodlots can best be used for the production of forest products and that its value for pasturage is in most instances small.

Overgrazing, if carried on for a long period of time, is detrimental to squirrel numbers, and intensive forestry may in instances also be. Slightly modified forestry practices, or it together with only light grazing, would furnish the most ideal squirrel range.

Eberwhite Woods, a 43 acre area typical of Southern Michigan woodlands, has been under intensive forest management since 1917. This stand is composed chiefly of oaks and hickory with smaller volumes of hard maple, elm, cherry, basswood, black walnut, ironwood and ash. Open grown "wolf trees," chiefly white oak, which are relics of the oak opening days, are scattered throughout the woodlot. Under the present management plans, the area is divided into 10 equal compartments of 4.3 acres each, and the entire area is cut on a ten year cutting cycle, with two compartments being

cut annually by a modified single-tree selection system.

Farrington[1] found the following to have resulted from 22 years of management:

1. "That species have during the past 22 years decreased in numbers, mostly in the least desirable species while the more desirable oaks and hickories have increased in numbers and volume.

2. "Older veterans have also been stimulated in growth to some extent.

3. "It is indicated that production of 100 bd. feet per acre per year and 1/4 cords per acre per year can be maintained.

4. "It seems probable that a farmer could make a profit of about $142 per year, exclusive of interest, taxes, and other costs."

In addition the owner would receive $64 for his labor, or a total net revenue of $206.75.

Data compiled by Farrington showed that the cut was distributed in the following manner:

	Number of Trees Left Per Acre			
Size Class	1917-'21	1922-'26	1927-'31	1932-'36
Reproduction 1'-3"	521.8	411.	573.1	493.3
Small Poles 4" - 7"	55.6	53.6	70.6	75.6
Large Poles 8'-11"	27.1	25.8	25.2	25.3
Standards 12" - 23"	23.5	25.2	28.1	28.0
Veterans 24" over	3.8	3.2	3.4	2.7
Total	631.8	518.8	694.	

[1] From the unpublished report on "The Results of Twenty Years of Management on the Eberwhite Woodlot by R. A. Farrington, May 26, 1939. In the files of Professor L. J. Young of the School of Forestry and Conservation.

Size Class	Number of Trees Cut Per Acre 1917-'21	1922-'26	1927-'31	1932-'36
Reproduction 1' - 3	147.3	133.0	73.8	26.0
Small Poles 4" - 7"	18.5	5.0	4.2	5.6
Large Poles 8' - 11"	2.3	.7	.7	1.4
Standards 12" - 23"	.3	.7	1.2	.7
Veterans 24" over	.1	.6	0.6	.5
Totals	168.5	140.5	80.5	30.2

From these figures we can see that the number of "Standards and Veterans" which are the chief den trees, remains fairly constant, and in all probability there will be a sufficient number of dens on the area for the next 40 years. In spite of the fact that the woodlot had been under management for 22 years the cull percent is estimated to be 20 percent,[1] a figure which also indicates an abundance of dens. Correct selective cutting methods as practiced in the all-aged woodlots of Southern Michigan do not necessarily destroy squirrel habitat.

In the younger woodlots frequently of coppice origin, there usually is a deficiency of suitable dens, and squirrels necessarily are forced to use leaf nests for shelter and protection from hawks. While good populations were found on such areas, they were the exception rather than the rule. Nests do not offer complete protection from the weather,

[1] Farrington, 1939, and voiced by Frank Murray of the School of Forestry and Conservation.

predators, or bullets. Perhaps the habit of hunters of shooting through leaf nests, hoping to flush the squirrels they might contain, is the most important factor in limiting abundance in these areas.

The true conservationist would of course not do this, and on these lands, one can perhaps rely on leaf nests for winter shelter. On public shooting grounds, unless well patrolled, nest boxes, made of hardwood lumber would be of value. As has been previously discussed under "Dens" it is not feasible to attempt to develop natural dens.

Fig. 26
Eberwhite woods. An area managed by intensive forestry practices for 23 years showing a large white oak "wolf" tree, a veteran of the original stand, and younger trees of other species. Note the stand is sufficiently open to favor squirrel numbers

Fig. 27
A beech-maple woodlot of the Northville area. Food supply is usually the factor that limits squirrel abundance in this type

The annual growth on the 43 acre tract is 15 cords of firewood and approximately 4,000 board feet of lumber per year. Non-defective, vigorous growing trees are allowed to attain a diameter of 26 or more inches before they are cut.

The yield figures indicate that a 15 or 20 acre woodlot is of a sufficient size to be put on a modified tree selection management basis and still produce a sufficient quantity of fuel wood, posts, timbers, and lumber annually for the needs of owner. The diameter limit of 26 inches would seem to insure a sufficient number of dens.

On small woodlots it is necessary to use an individual tree selection system or in areas of 40 acres or over it may be advisable to use a selective cutting system with a five-year cutting cycle. A ten-year cycle would take too many favorable trees, and would decrease the annual growth.

Food Supply

In instances cutting operations can well favor the more valuable nut trees such as black walnut, butternut, and the hickories, without greatly lowering the income obtained from the stand. An occasional large crowned tree of one of these species, although of little value for lumber, should be left standing. Other individuals of these species holding oppressed, intermediate, or co-dominant positions in the stand may be favored by release cuttings without lowering net returns at all.

Occasionally where but a few food species are present

in the stand it may be desirable to make plantings of nut trees such as black walnut, chestnut, or butternut chiefly for timber production and the value of the nuts. It would hardly be good practice to plant these trees for the primary purpose of furnishing squirrels with a food supply.

Black walnut is a very valuable wood, is fast growing, and has salable nuts, which it starts to produce when the tree is 15 to 20 years old. The use of nuts for plantings is the cheapest and usually best method, although occasionally seedlings are used. Nuts should be planted at a depth of 1 to 1 1/2 inches in rich, moist, but well drained ground. The species is intolerant and should be planted in open, though sheltered places. It grows fairly rapid if planted on a suitable site. Baker (1921) found the rate of growth as measured in Central Indiana and Ohio to be as recorded in the following table:

Fig. 26

Growth of Black Walnut

Age	Height in feet	Diameter in inches	Age	Height in feet	Diameter in inches
10	13	1.2	90	81	23.8
20	35	5.0	100	82	25.0
30	53	8.8	110	84	26.0
40	62	12.5	120	85	26.9
50	68	15.7	130	86	27.8
60	72	18.3	140	87	28.5
70	75	20.6	150	88	29.5
80	78	22.2			

These figures show that some material large enough for saw logs can be cut when the trees are 50 years old, and very possibly post material and firewood can be taken at an earlier age. The most desirable place to plant walnuts is in well-drained swales adjacent to, or in open areas within, woodlots. Butternut requires approximately the same type of soil, although it is not as exacting in its requirements. The hickories are quite intolerant and should be planted in well-drained uplands. Chestnut and Chinese chestnut offers some possibilities for nut species plantings. Both are hardy in the latitude of Ann Arbor although the American chestnut is attacked by blight. Chinese chestnut (Castanea mollissima) is blight resistant, but the tree is small and bushy, although it produces good quantities of large nuts.

Cost of Plantations and Value

It would take approximately 140 lbs. of walnuts to seed an acre using 4' by 4' spacing. The close spacing would perhaps approximately care for losses in the young plantation and still leave the area adequately stocked. Seed could be gathered from near-by trees or be purchased at a cost of 1¢ to 3¢ per pound. The approximate cost of planting per acre would be:

Cost of seed at 2c per lb.	$2.80
Cost of furrowing and planting	5.00
Total	$7.80

The annual cost of administration, protection, and taxes would be approximately 30¢ per acre.

Prorating the costs over the rotation of 100 years, the cost would be:

Initial cost = $\$7.80(1.04)^{100}$ = $393.90

Annual cost = $\frac{30(1.04^{100} - 1)}{04}$ = 371.25

Total cost at end of the Rotation (including 04% interest = $765.15

This amount could be realized if a volume of 15,000 board feet per acre on a stumpage value of $60.00 per thousand were obtained. These data do not include the income that could be obtained from thinning when the stand is from 30 to 60 years old. However, here again the figures are sufficiently accurate to show that it is possible to receive a good economic return on the investment.

While the land owner is usually unwilling to plan ahead for 100 years, the figures do show that such plantings, if located on good sites will have a value at the end of 20 or 30 years, equal to or above the costs involved.

Note: Formulae for the above calculations were taken from Matthews, 1935 p. 225. Seed and Spacing figures are from Toumey, 1931 pp. 163 and 442. Yield values are based on present day prices.

Fence Rows

Fox squirrels frequently use fence rows as a line of communication between the home woodlot and such feeding areas as cornfields and nut trees. Grapes, hazelnut, greenbriar, and similar species are frequently found standing along such fence rows. While fence rows are of great importance to squirrels, their value for other forms of wildlife should also encourage fence row development.

Perhaps the easiest and quickest way to bring about fence row development is to prevent them from being grazed or cut. Another fence row impnovement that in addition has a high esthetic value, and serves in protecting the crops of the adjacent fields, is the planting of evergreen windbreaks. Healthy 2-1 or 2-2 stock of such species as Norway spruce, white spruce or red cedar should be used. A good fence row leading to a food patch would make food patches not adjacent to the woods of value to fox squirrels.

Cost of Evergreen Fence Row Development

Cost of evergreen plantings for fence row development vary with the amount and kind of stock used and with the cost of planting. 2-2 stock of the above species is approximately $5.00 per thousand. Some approximate costs are:

Cost of stock per 100' with spacing, single row 12¢

Cost of stock per 100' with 4' x 4' spacing, double row -25¢

Cost with same spacing triple row -38¢

Labor would of course vary greatly with the amount of planting to be done, type of stock used and nature of the soil and vegetation. A conservative estimate would be 25¢

or 30¢ per 100 linear feet. Expenses of fence row development could not be charged to wildlife alone, as the esthetic value is also very high and such plantings offer protection to adjacent fields, and also there is often a good market for Christmas trees that could be thinned out of the stand after 10 to 20 years. This is especially so in multiple-row plantings where competition for light is very great. This alone may often pay for the cost of plantings and the interest. As an example, it may be necessary to thin out a three-row planting of Norway spruce after a period of 15 years. The number that should be taken would be 10 to 20 trees per 100 feet of fence row. As the trees are open-grown they would be very desirable for Christmas trees and would have a stumpage value of 35¢ each.

Assuming the cost of planting to be $1.00 per 100 feet, the cost, including 04 percent interest would at the end of 15 years be:

$$1.00\ (1.04)^{15} = 1.00\ (1.80) = \$1.80 = \text{cost of}$$

planting at the end of 15 years.

The gross income at this time would be 10 x .35 = 3.50 for 10 trees or 20 x .35 = 7.00 for 20 trees, leaving a net return of $1.70 and $5.20 respectively over and above the interest on the initial investment.

While the above figures do not consider the cost of upkeep, they do show that the improvement would pay for itself.

Fig. 27

White oak along an excellent fence row

Fig. 28

An isolated black walnut. Six different fox squirrels fed extensively on the nuts of this tree during March and early April

Fig. 29

A rail fence which offers sufficient cover for fox squirrels. Restricting grazing would greatly increase its value for other forms of wildlife

Food Patches

By far the most important food patch species, and one of the most important items in the diet of the squirrel, is corn. Its value for other forms of wildlife is well known. A well-placed food patch containing corn may serve the following species: quail, pheasants, prairie chickens, rabbits, muskrats, raccoon, ducks and squirrels. The following sketch maps (Fig. 30) and (Fig. 31) show where food patches should benefit most species. Food patch mixtures as given by Wight (1933) containing corn and other species are good for Southern Michigan.

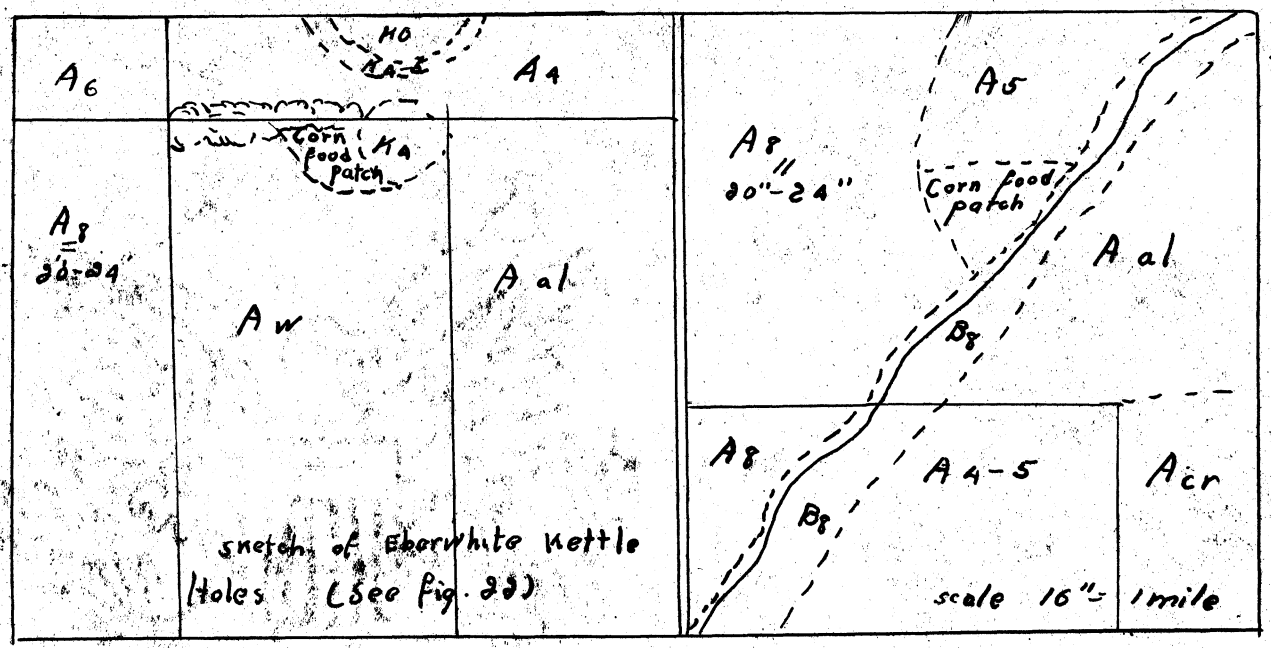

Fig. 30

Fig. 31

It would be a good policy to have several of these food patches located in such a way that their crops could be put on a rotation, using such legumes as soy beans, sweet clover, alfalfa, vetch, and cow peas, all of which are good wildlife foods.

While the exact value of food patches for squirrels is unknown, it is thought to be very high. As previously mentioned, Hendrickson and Schlesselman ('37 p. 236) found fox squirrels to be the most frequent visitors to a food patch that was adjacent to an oak-hickory woodlot and that squirrels, together with other forms of wildlife, used 5.4 percent of the estimated crop yield of 84 bushels. Unfortunately the remainder was gathered in late winter, the period when food patches are of most value.

Baumgartner (1938 p. 685) found an average population of 83 squirrels per 100 acres on winter-fed areas and only 45 per 100 acres in woodlots where no winter feeding was carried on. Moreover, the range on winter-fed areas was 75 to 90 squirrels for 100 acres while it was 16 to 66 individuals per 100 acres on the unfed area. This would indicate that a good food patch would be very favorable to squirrel numbers and unlike direct artificial feeding, the food supply is more stable and also more natural.

Winter Feeding

The above figures show the favorable higher population brought about by winter feeding, but as stated, the practice

has its drawbacks. Its practice could well be followed during exceptionally cold winters or when the snow is exceptionally deep. When this is done it is best to use ear corn, impaling the ears on spikes which are attached to a board. The board should be nailed to a tree or high stump above the snow line.

Crop Rotation

Crop rotations have both good and bad effects on squirrel abundance. When the crop is planted next to a woodlot, it means an additional supply of food, which, because of the way the crop is harvested, is often available to late winter and spring. Consequently woodlots so situated often have a large spring population. If, however, the mast crop fails the following year, and no corn is to be found in the vicinity of the woodlot, the increased squirrel population may be likely to starve the following winter.

Crop rotations also have their effects on other forms of wildlife, again both good and bad. Pheasants are more mobile than squirrels, and for this reason can utilize cornfields that fox squirrels cannot. However, the locations of such fields may disseminate pheasant and quail numbers, by the fact that the birds are often exposed to predators in their journeys to and from the field, and may be unable to make the long journey during unfavorable weather. Other less mobile species such as raccoon and muskrat are unable or do not prefer to use the far-off cornfields.

Often it is possible to plan crop rotation so that a field of corn is bordering the woodlot every year. In Southern Michigan the most common crop rotation is as follows:

Corn	1 year (sometimes two)
Small grain	1 year (sometimes two)
Hay	1 year (often two or three)

Thus the shortest crop rotation used is 3 years while the longest is six or seven years. Good land use would command the planting of corn and small grains for but 1 year each and then allow the land to remain in some leguminous hay crop such as clover or alfalfa for 2 or possibly 3 years. To have a cornfield bordering the woodlot annually, it would therefore be necessary to have at least four crop fields bordering the woodlot. Unfortunately, many woodlots have only one or two crop fields bordering them. In such cases it is necessary to rely on corn food patches for the additional food supply.

The following maps (Figures 32, 33, 34, and 35) taken from an area mapped by J. E. Topercer, shows that the locations of the various fields would permit a crop rotation that would favor wildlife:

To manage squirrels and other wildlife more successfully, it is desirable for several adjoining land owners to cooperate with each other. A 20 acre woodlot may be surrounded by lands of as many as four individuals; particularly in localities where farms are small. By cooperation and

Blue = Corn Green = Woodland Scale 3" = 1 mile

Fig. 32
Crops of 1940. Note that all cornfields are rather isolated. No. 1 is connected to the cornfield to the north by a dense fence row. Few squirrels used this as a means of communication. This woodlot contained a poor squirrel population. Woodlot No. 2 with no cornfield accessible contained an excellent squirrel population as did also woodlot No. 3.

Fig. 33
Possible distribution of crops as of 1941. Note that to place cornfields next to woodlots, it was unnecessary to deviate from the general rotation plan and that cornfield (A) furnishes a food supply to both woodlots 1 and 2 and that it lies in the close proximity of a willow swamp and is therefore a valuable feeding area for pheasants and possibly quail

Fig. 34 Showing cornfields lying 1942 adjacent to all woodlots. Note also that the modified rotation allows corn to be planted in fields situated at a distance from woodlots and that the total crop land of the section remains constant

Fig. 35 1943
This would be the last plan of a 4 year rotation. A 5 or more year rotation would require that above fields given to alfalfa or clover be allowed to remain in those crops for 3 to 6 years

planning accordingly, a favorably situated corn field can be had each year. In instances where other owners are unwilling to cooperate, food patches offer the only possible solution although on large farms the owner often has a sufficient number of fields adjoining the woodlot to carry out a complete rotation plan alone. There is also the possibility of using a combination of both crop rotation plans and food patches, with the food patches being used in the off years.

The amount of grain taken is in comparison with the total yield, small. As mentioned, the loss on a 2.2 acre corn patch, which was adjacent to an oak-hickory woodlot and evergreen plantation was 5.4 percent of the estimated total yield of 88 bushels, or the total loss of 4 1/2 bushels. There is doubtless this much corn normally wasted on a 10 or 15 acre field no matter where it is situated. The economic loss as the result of placing of a cornfield adjacent to woodlots would perhaps be less than one bushel per acre. With the use of the mechanical corn picker, the grain is harvested soon after it ripens. Consequently when this machine is used, losses from wildlife of harvestable corn are further lowered. The greater amount of waste grain that is the result of the use of this implement favors squirrel numbers.

Control of Diseases

As yet we know little of squirrel diseases, and so of course, we have no way of directly controlling them. Records seem to indicate epidemic diseases occur most frequently

when the squirrel population is high, the food supply inadequate, and shelter unsuitable. Shooting takes its place in the management program both as the objective of management and to limit the winter population density of one squirrel per two or three acres.

SUMMARY AND CONCLUSIONS

There are 7 fox squirrels found in the United States. These are: Sciurus niger niger (Linn.), Catesby's Black Fox Squirrel; Sciurus n. avicennis (Howell), Mangrove Fox Squirrel; Sciurus n. neglectus (Gray), Northern Fox Squirrel; Sciurus n. byrant (H. H. Bailey), Byrant Fox Squirrel; Sciurus n. rufiventer (Geoffrey), Western Fox Squirrel; Sciurus n. texianus (Bachman), Bachman Fox Squirrel; and Sciurus n. limitis (Baird), Texas Fox Squirrel.

The 7 subspecies differ principally in coloration and to some degree in size though the latter is relatively unimportant in distinguishing between the races. For all general purposes, the various subspecies may be separated according to the locality in which they were collected.

The eastern races seem to be less able to cope with civilization and their numbers have been seriously depleted. The western and southern forms, however, seem to have adapted themselves very well to the changes brought about by civilization. One race, rufiventer, to which our Michigan fox squirrels belong, has pioneered on to and become established in new areas as the result of the settlement of the country.

Fox squirrels are primarily inhabitants of the Alleghenian forest types, although under primitive conditions,

the animals reached their peak of abundance in the "oak openings" of the prairie edges. Unlike their gray relatives, the species requires that approximately 20 percent of their range be in open lands. With the opening of the country, fox squirrels entered habitats that formerly belonged to the grays.

Habitat requirements vary both with the sub-species and the region an individual sub-species is found.

Important data on the life history of the species which are unpublished[1] are as follows:

1. There is but one breeding season for the latitude of Southern Wisconsin at least and that it extends from December to August (testes of the male do not degenerate).
2. The gestation period is approximately 60 days whereas that of gray squirrels is 45 days.
3. The blind period is about 5 weeks, which is approximately the same as that of the gray squirrel.
4. Young are first able to leave the nest when they are 9 weeks old.
5. The peaks of breeding activities are January and February and in June and July.
6. Young born in the spring probably do not breed in the same summer.

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[1] From letters of Drs. H. W. Mossman of the Department of Anatomy and A. J. Nicholson of the Fish and Oyster Commission of the State of Texas to the author.

7. Evidence shows that the males at least do not become sexually mature until they are at least six and possibly eight months old.
8. Most of the very early or very late and intermediate matings (April and May) are first matings, probably of young born very early or very late the preceding year.
9. One family group (the female and young) that I had under observation remained together until the young were at least 15 weeks old instead of 10 or 12 weeks as reported.

Observations carried on by the author showed among other things the following:

1. There is a decided preference for woodland edges in large woodlots (assuming a normal daily cruising range distance of 150 yards as the periphery). In small woodlots the edge preference is not noted excepting in areas containing a small population and a limited food supply.
2. In years when the beechnut crop fails, in the beech-maple forests fox squirrels are largely dependent upon isolated nut trees for subsistence and in these areas such trees should be included in the management plan.
3. With other things being equal, higher squirrel populations were to be found in woodlands that had cornfields adjacent to them.

4. In areas containing a poor supply, squirrels would journey over open ground to an isolated food tree, although they would follow fence rows if a selection of the route were permitted.
5. Good woodlot management and squirrel management can be carried on together. Both purposes favor the use of the individual tree selection system or a modified tree selection system with the use of a cutting cycle of 5 years.
6. A 15 or 20 acre woodlot, if put on a sustained yield management plan and kept out of grazing, will furnish a sufficient amount of wood products to the owner indefinitely and will also keep squirrel habitat in a favorable condition.
7. The maximum density of the winter population found was 5 squirrels per acre. This number was recorded for only one area, which was small.
8. The maximum number of fox squirrels found in a beech-maple habitat was .7 squirrels per acre and on several woodlots of this type up to 20 acres in size, the species was not found at all.

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