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Fox Squirrels and Gray Squirrels

In Illinois

LOUIS G. BROWN
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Squirrel hunting is highly prized by those who participate in it, both for its recreational value and because it means "meat on the table." Illinois hunters kill approximately 1,400,000 squirrels annually, of which about 70 per cent are fox squirrels.

Fox Squirrels and Gray Squirrels

In Illinois[*]

LOUIS G. BROWN
LEE E. YEAGER

Since the passing of big game in Illinois, fox squirrels and gray squirrels have never ranked lower than second among game mammals of this state in importance to hunters. First place is now a toss-up between these tree squirrels and cottontail rabbits, with the latter declining in public esteem because of recent epidemics of tularemia (Yeatter & Thompson 1943), a disease more commonly associated with rabbits than other game.

Despite the long-standing importance of squirrels, very little information has been available upon which to base Illinois hunting regulations, management and restoration measures relating to them. Laws in regard to hunting seasons have been varied, and at times grossly unsound biologically. The most common problem pertaining to seasons is that of mid- or late-summer hunting. Such hunting is demanded by many hunters, particularly in the southern part of the state. The Illinois squirrel season for the biennium of 1939-41 opened, in this area, on July 15. The date was set back to August 1 in 1941, but again advanced to July 15 in 1943.

These early opening dates, as would be expected, resulted in numerous complaints from conservation organizations and from some sportsmen. Lawmakers and administrative personnel, in coping with the situation, were greatly handicapped by the lack of specific information, despite recent investigations in Ohio, Michigan and other states. In particular, information on squirrel breeding was scarce, and it was feared that such as was available was not fully applicable to Illinois conditions. A season similar to that in Ohio or Michigan, considered sound, would retard the opening date in Illinois 2 months or more; and Illinois hunters, to whom summer squirrel shooting is traditional, could be expected to oppose strongly and in good faith such a restriction on their sport. For educational purposes as well as for administrative use, therefore, a fact-finding study was needed in Illinois.

The Federal Aid Project on which this report is based was proposed jointly by the Illinois Natural History Survey and the Illinois Department of Conservation. Formally known as "Squirrel-Raccoon Investigation and Management in Illinois, Project 14-R," the study was initiated on July 1, 1940, and terminated as a project on June 30, 1942, although some field work, in connection with other projects, was continued through 1944. Early in the investigation it was found that, despite the similarity in some squirrel and raccoon habitats, the two phases of the study could not be carried on adequately at one time by one man; only the senior author was available for field work during the greater part of the investigation. Accordingly, the raccoon phase was dropped except for observations that could be made incidentally or as a part of regular squirrel studies.

OBJECTIVES OF PROJECT

The project had two main objectives, as follows:

1. Determination of squirrel breeding seasons and related biology, the information derived to be used in recommending biologically sound squirrel hunting seasons.

[*]Illinois Federal Aid Publication No. 4.

2. Determination of the environmental requirements of Illinois squirrels, the information on this subject to be used in management and restoration practices.

METHODS OF STUDY

Illinois, with a north-south length of 385 miles, is subject to greater seasonal variations than any other midwest state. In the formulation and administration of fish and game laws, these variations are partially compensated for through the division of the state into the northern, central and southern zones, fig. 1, each comprising about one-third of the state and each representing a difference in season of 6 or 7 days.

The necessity for determining seasonal variations in squirrel breeding and related phenomena in each of the three zones was recognized at the beginning of the project.

Fig. 1.—Map of Illinois showing the three zones on which the game and fish code of the state is based.

It appeared, therefore, advisable for the senior author to spend the first 10 days of each month in the southern zone, the second 10 days in the central zone, and the last 10 days in the northern zone, collecting and studying during each period a sufficiently large number of fox and gray squirrels to determine seasonal differences in reproduction. Because such a plan, however sound theoretically, was expensive in travel time, only the first year was given to this periodical study by zones. During this time the zonal differences in the seasons of reproductive activity were determined approximately. The second year was devoted to intensive field study on representative central zone areas, on which both fox and gray squirrels occurred.

In general, data on breeding and other seasonal phases of this study relate to the central zone, except where otherwise stated, and practical utilization of the information in the northern and southern zones necessitates appropriate allowance in time.

Sample material yielding information on squirrel biology consisted of freshly shot, steel-trapped and live-trapped specimens. Study of dead specimens was carried on mainly in several improvised field stations, although some material was examined in Natural History Survey or University of Illinois laboratories. Live-trapped squirrels were examined in the field, usually at the site of capture. Both fox and gray squirrels were available for study every month for the duration of the project, although it was of course impossible to obtain equal numbers of squirrels each month, either in species or sex. Fox squirrels far exceeded gray squirrels in number, amounting to about 70 per cent of the total examined.

Each collecting method has its advantages. Over much of the study period guns and steel traps were employed simultaneously. Hunting was most effective during the main mast-feeding months, from mid or late August into October. Trapping was particularly successful during the winter and early spring, when corn was readily taken as bait. Traps were set, uncovered, on logs and each was baited with a half ear of corn, usually impaled on a nail a few inches above the trap. Twenty-five to 50 traps

were employed, and they were visited at least daily, and, as often as possible, twice daily. The most serious disadvantage of this trapping method was that of taking animals other than squirrels. These included skunks, foxes, raccoons, opossums, woodchucks, cottontail rabbits and a variety of birds. Since No. 1 traps were used, practically all mammals caught except squirrels and rabbits were uninjured and were released at the point of capture. Most birds caught in the traps were dead when found. Blue or red corn was found to attract fewer birds than yellow corn, but it appeared to be somewhat less attractive to squirrels.

Fig. 2.—Live trap, baited with shelled corn, in a typical set location. Fifty live traps, used in three Pike County areas, yielded useful information on squirrel populations and life history.

Live trapping, which was conducted in three wooded areas in Pike County, involved both fox squirrels and gray squirrels. Shelled corn was used for bait. Fifty live traps of the type described by Baumgartner (1940) were used, fig. 2. Squirrels so taken were not killed, but were examined in the field for evidence of breeding, pregnancy and lactation. Many squirrels were taken repeatedly. This phase of the study supplied information on species ratio, sex ratio, population density, movements and home range, in addition to breeding and related data. Various animals, including woodchucks, cottontail rabbits, skunks and opossums, and a few birds, were captured in the live traps. These were unharmed and were released. The period of continuous trapping was from October 16, 1941, to August 7, 1942.

Prior to each of the two hunting seasons, 1940 and 1941, covered by this project, copies of a questionnaire were distributed throughout the main squirrel hunting regions of the state. This questionnaire contained blanks to be filled by hunters before the copies were returned to the project leader. It was hoped that from the returned forms information pertaining to kill, distribution, species ratio and population trends could be obtained. A total of 3,300 forms were distributed

during the 2 years, of which only 236, or 7 per cent, were returned. The writers consider that the most valuable information yielded by the questionnaire pertained to population trends and hunters' opinions of squirrel seasons.

Data pertaining to breeding were obtained directly from examination of squirrels of all age classes and of both species. Such information was recorded systematically under appropriate headings, as shown in fig. 3. For males, the information particularly sought was size and weight of testes and size of Cowper's glands; for females, evidence of oestrus, pregnancy, lactation and placental scars. The age of all specimens was determined with as much accuracy as possible, and, throughout the study, special efforts were made to develop aging criteria. Weights and general measurements were taken of nearly all specimens. Other records related to locality and date of collection, condition of pelage, parasites, disease and stomach contents. Supplementing these data were detailed observations on foods and feeding habits, activity, behavior, habitat requirements and other matters of ecological interest.

Unfortunately, no fully satisfactory technique has been developed for censusing squirrels. That such a tool is important is obvious because the first information needed in management relates to the number of animals present on each study unit. This information is most useful when it supplies numbers at a definite time; for example, population in the fall. In the absence of standardized methods for determining squirrel numbers, it becomes necessary to make the best estimates possible. These estimates are generally made by rules-of-thumb, or by using one or more of the various techniques that have been described. The result is often expressed in reference to the population by such terms as "plentiful," "common," "scarce," or "heavy," "medium," "light."

Dice (1931) proposed, as the best method of determining mammal abundance, the listing of individuals observed in each ecological unit of the habitat. This

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Zone_____ County_____ Town_____ Location_____

Ecology_____

Food Types_____

Date	Species	Sex	Weight	Body Length	Total Length	Hind Foot	Molt	Mange	Testes			Cowper's Glands	Age			Oestrus	Pregnant	Nursing	Stomach Contents	Comments
									Length	Width	Weight		2nd	1st	Ad.					

Fig. 3.—Field form used for recording biological data, Illinois squirrel study, 1940–1943.

method gives more properly an index of relative abundance in the various units rather than a true census. Later, Dice (1941) summarized various census techniques, some of which were applicable directly or indirectly to squirrels. Leopold (1933) discussed census methods for both game birds and mammals. Like Dice, he suggested techniques that could be used in squirrel census.

Goodrum (1940) developed three census techniques for gray squirrels in Texas, which probably would be equally applicable to fox squirrels. These methods were as follows:

1. Time-area counts, using number of squirrels observed during definite time period on random plots of known size in each ecological type.
2. Nest counts in each ecological type, multiplied by a factor of two.
3. Hunting with dog, using number of squirrels treed per hour.

The first method is based on the average distance a squirrel can be seen, and thus the size of the territory that may be observed from a stationary position. Goodrum, using three-fourths of this territory as the unit that could be watched effectively, calculated populations in each ecological type by multiplying the average number of squirrels seen per acre on each observation territory by the number of acres in the type represented. The second method involved counting all twig and leaf nests, preferably in the fall and winter, in each ecological type and multiplying by two. The third method, employed only when squirrels were active on the ground, gave the number of animals treed per hour in each ecological type. In each of these methods, the greater the number of counts and the more uniform the vegetational types, the more nearly accurate is the census.

It should be noted that Goodrum's first two methods result, theoretically at least, in a true census; the third, unless several factors not given are known, could not be more than an index of relative abundance. The present writers made limited use of the time-area method and were convinced of its possibilities provided the investigator had time for making a large number of counts. In agreement with Allen (1942, 1943), who worked with fox squirrels in Michigan, we are uncertain of the value of of the nest-count method. The hunting-with-dog method was not tried. It is probably significant that Goodrum refers to these census techniques as " . . . methods found most effective in estimating gray squirrel populations in eastern Texas."

Chapman (1937, 1938*a*) in Ohio, and others, have used data taken directly from hunters as a means of determining trends in populations. This is a rapid and useful method, and, if based on many samples, may indicate trends for large areas, even for a state as a whole. However, most kill data are subject to too many variations to yield more than very general information, thus limiting materially their use.

Baumgartner (1940), Allen (1942, 1943) and the present writers determined, by exhaustive live trapping, and with a relatively high degree of accuracy, squirrel numbers on small study areas. This technique, however, is too time consuming for practical, large scale censuses. Estimates of the population made by less exacting means, if based on experience and judgment, serve many purposes of management; and, if made uniformly year after year, may indicate population trends satisfactorily. Some experienced hunters develop almost uncanny accuracy in judging squirrel numbers on areas with which they are familiar.

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POPULATIONS

During the second year of the investigation, considerable time was given to study of squirrel populations on representative areas in Pike County, in the central zone. From data gathered there, from questionnaires returned by hunters and from kill records supplied by the Illinois Department of Conservation, detailed information on squirrel distribution, kill, sex ratios, species ratios and related subjects was obtained and added to the more general information gathered in the first year.

Distribution

The western fox squirrel, *Sciurus niger rufiventer* (Geoffroy), the northern gray squirrel, *S. carolinensis leucotis* (Gapper), and the southern gray squirrel, *S. c. carolinensis* Gmelin, are listed by Necker & Hatfield (1941) as occurring in Illinois. The fox squirrel has statewide distribution; records for the northern gray squirrel include counties in approximately the northern two-thirds of the state and for the southern gray squirrel several of the southernmost counties, fig. 4. Both subspecies of gray squirrels undoubtedly extend beyond the range given.

The red squirrel, *Tamiasciurus hudsonicus loquax* Bangs, is listed by Necker & Hatfield as still being present in the wild in Illinois, but no observations or other records of it were obtained during the present study. If red squirrels occur here, it is believed that they do so only in reduced numbers and in quite restricted localities. Kennicott (1857) gives a good account of their early abundance in the northern parts of the state.

Fox squirrels are found on farm and forested areas, and in cities and villages. Outside of some urban communities, gray squirrels are restricted to heavily wooded areas, generally those having abundant ground cover and brushy understory.

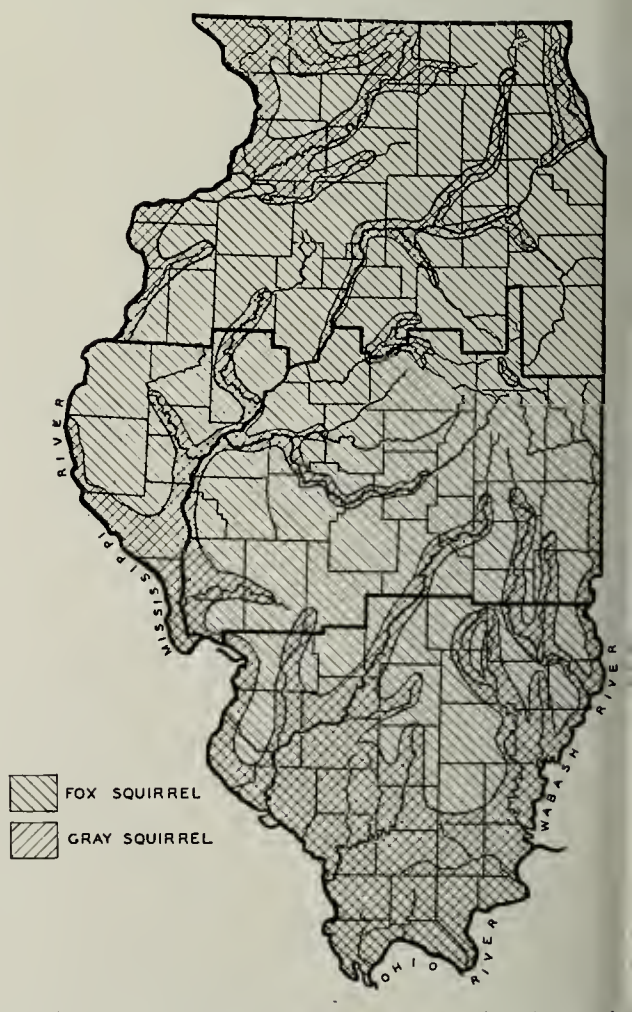

Fig. 4.—Distribution of fox squirrels and gray squirrels in Illinois.

Woodland of this type is found in Illinois principally along the main river valleys and in the southern and southwestern parts of the state, fig. 4. Further discussion of the preferences of the two species are given under "Illinois Habitats."

Density

During this study squirrel population density was determined with a high degree of accuracy on only one area. This area, however, was typical of the large region of good squirrel habitat in southern and southwestern Illinois, where both squirrel species often occur in mixed populations. On three other areas, all representative of extensive Illinois habitat types, rough estimates of the population were obtained. Population estimates of the four areas are presented in table 1 and are discussed below.

Great differences in population density were found in Illinois fox squirrel habitats. Comparable data are not available for the gray squirrel. This species, however, is known to occur in varying densities, although not in the extremes found in the fox squirrel. The lack of extremes is due probably to relative uniformity in the habitat occupied by gray squirrels, which, as stated previously, is mainly heavily wooded areas. The populations given per acre for the Harshman and Urbana Township areas, table 1, probably represent the highest and lowest densities for fox squirrel habitats likely to be encountered in the state. On the Mason County area, which is of the black oak type, composed of all ages and degrees of stocking, it was found that fox squirrels may occur in varying densities in the same general habitat. The censused populations in 16 black oak stands in this area ranged from 0.02 to 2.20 squirrels per acre.

Although many areas were found where both species were present, as well as many areas carrying only fox squirrels, none were encountered that held gray squirrels alone over a relatively large tract. Local concentrations of gray squirrels were often seen. The junior author counted 16 of these animals late in the afternoon of October 16, 1942, on an area of less than 3 acres. All were foraging in an oak-hickory stand that bordered a young river-bottom forest in Coles County. It was known that fox squirrels frequented this site. The figure of 1.49 individuals per acre for the Wade area, table 1, probably represents for gray squirrels the upper density limit found on the better Illinois range.

The figure of 2.23 fox squirrels per acre for the Harshman area represents the density on a small, very favorable area. A density of half this figure is considered as probably representative for large areas, even of the better habitats.

No evidence was obtained to show conclusively that either fox or gray squirrels are cyclic in Illinois. Fluctuations in populations from year to year, as long observed by hunters and reflected in kill records, suggest that these squirrels may be cyclic, although the degrees of fluctuation are only minor. If squirrel cycles operate at all in Illinois, they show little of the spectacular nature common in hares and other species in northern regions. Edminster (1937), at least by implication, suggested that the gray squirrel is cyclic in the New England region.

Species Ratios

From data presented in tables 2 and 3, and from general observations throughout the state, it is evident that the fox squirrel is more abundant than the gray squirrel in Illinois.

All of the squirrels listed in table 3 and 86 per cent of the 4,597 animals included in table 2 were obtained by hunting. Because of two differentials associated with hunting, the relative abundance of fox squirrels may be actually somewhat lower than the figures indicate. First, fox squirrels may be easier to kill than gray squirrels; they are so considered by many hunters, although the writers found little difference between the species in this respect. Second, there is a small difference in the accessibility of habitat preferred by the two species, that for the gray squirrel being, in general, the more remote and the more difficult and time consuming for hunters to reach.

On areas harboring presumably typical populations of fox and gray squirrels, both steel trapping and live trapping showed a preponderance of fox squirrels in the catch, table 2; in live trapping the difference was small. In view of the first

Table 1.—Squirrel density in four representative Illinois habitats, 1941 and 1942.

Area	County	Number of Acres	Type of Habitat	Date of Census	Populations				
					Fox Squirrels		Gray Squirrels		All Squirrels Average per Acre
					Number	Average per Acre	Number	Average per Acre	
Wade	Pike	41	Upland oak-hickory, with shaded runs and heavy understory; fox and gray squirrel habitat of high quality.	October, 1941, to August, 1942	35	0.85	61	1.49	2.34
Harshman	Pike	13	Upland oak-hickory, open and parklike; fox squirrel habitat of high quality.	October to December, 1941	29	2.23	0	0.0	2.23
Mason County State Forest	Mason	2,900	Black oak sand plains; fox squirrel habitat of good quality.	February, 1942	1,500*	0.52	0	0.0	0.52
Urbana Township Wildlife Area	Champaign	2,560	Intensively farmed black prairie; fox squirrel habitat of very low carrying capacity.†	December, 1942	40	0.02	0	0.0	0.02

*Population estimated on basis of census by Dr. Jessop B. Low, and on supplementary observations by Frank C. Bellrose, Jr., and the writers.
†Although of low carrying capacity due to the small area suitable for habitation, the squirrels present showed excellent condition and high fecundity.

Table 2.—Species ratio in Illinois squirrels as determined from 4,597 animals, some of them shot by hunters and others collected by the writers, 1940, 1941 and 1942.

How Taken	Fox Squirrels		Gray Squirrels		Total	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Hunters (throughout Illinois)						
1940 (over-all season, July 15–November 15)	955	62.3	577	37.7	1,532	100.00
1941 (over-all season, August 1–November 15)	1,413	75.8	452	24.2	1,865	100.00
Collected specifically for study						
Shooting (all zones represented)	381	67.7	182	32.3	563	100.00
Steel traps (all zones represented)	341	66.6	171	33.4	512	100.00
Live traps (Pike County)	64	51.2	61	48.8	125	100.00
Total	*3,154*	*68.6*	*1,443*	*31.4*	*4,597*	*100.00*

hunting differential discussed in the paragraph above it is suspected that the figures yielded by steel trapping, which was conducted in all three zones and in many areas, are a somewhat more reliable indication of the relative abundance of the species than the data derived from hunters' questionnaires. Of the steel-trapped squirrels, 66.6 per cent were fox squirrels and 33.4 per cent were gray squirrels. Live trapping gave a percentage of 51.2 for fox squirrels and 48.8 for gray squirrels, but the figures upon which these percentages were based are believed to be too small for reliability.

Fox squirrels, table 3 indicates, were much more numerous than gray squirrels in the northern and central zones, but not in the southern zone when the survey was made; fox squirrels averaged more than 85 per cent of the kill in these first two zones in the 1940–1941 period. In the southern zone, the two species were taken in about equal numbers, indicating populations of nearly equal density. Reports received from hunters chosen for their reliability indicate that, for the state as a whole, fox squirrels made up two-thirds or slightly more of the annual kill. These ratios are roughly in proportion to the acreages of fox squirrel and of gray squirrel habitat in the three zones, fig. 4.

Table 3.—Species ratio in Illinois squirrels, by zones, as determined from questionnaires returned by hunters, 1940 and 1941.

Zone	Fox Squirrels						Gray Squirrels					
	1940		1941		1940–1941		1940		1941		1940–1941	
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Northern	92	73.6	268	88.0	360	86.1	33	26.4	24	12.0	57	13.9
Central	472	84.7	758	89.1	1,230	87.4	85	15.3	93	10.9	178	12.6
Southern	391	46.0	387	53.6	778	49.5	459	54.0	335	46.4	794	50.5
Total	*955*	*64.6*	*1,413*	*75.8*	*2,368*	*69.7*	*577*	*35.4*	*452*	*24.2*	*1,029*	*30.3*

Sex Ratios

The sex of 4,651 squirrels, 3,197 fox squirrels and 1,454 gray squirrels, as determined during the investigation is shown in table 4. These data were derived largely from hunters' questionnaires, and were therefore subject to whatever differentials there may have been in bagging the sexes.

It appears that Illinois squirrel populations either have a preponderance of males, or that males are more easily bagged by hunters, who invariably shoot at squirrels in the order of their appearance until the limit is reached or the hunt is over. Fox squirrel males and females were taken in steel traps in approximately the ratios in which they were shot; gray squirrel males and females were steel trapped in more nearly equal numbers, but with males predominating, table 4. Live trapping, for which the samples are too small for reliability, yielded in both fox and gray squirrels more females than males, but in gray squirrels the numbers were nearly equal for the sexes. Litter counts, on the basis of a very few samples, showed slightly more males than females in both species. A summary of figures listed in table 4 showed a preponderance of males in both species, giving a male to female ratio of roughly 60 to 40.

The sex ratio of 17 litters of fox squirrels, totaling 43 young, recorded during the spring of 1941 was 105 males to 100 females, table 4. Of 179 first-season or spring juvenile fox squirrels taken by the writers and by hunters from May through November 15, 62 per cent were males and 38 per cent were females; of 109 second-season or summer juveniles taken during September and October, 57 per cent were males and 43 per cent were females. The sex ratio of all juvenile fox squirrels for which records were obtained, including litters, 195 males and 136 females, was 144 to 100.

In gray squirrels, the sex ratio of 3 litters, totaling 11 young, was 120 males

Table 4.—Sex ratio in Illinois squirrels as determined from sample litter counts and from animals shot, steel-trapped and live-trapped, 1940–1943.

How Taken	Number		Total Number	Per Cent		Sex Ratio Male: Female
	Male	Female		Male	Female	
Fox Squirrel						
Litters (all zones represented)	22	21	43	51.2	48.8	105:100
Shot (throughout Illinois; including writers' kill)	1,631	1,118	2,749	59.3	40.7	146:100
Steel traps (all zones represented)	202	139	341	59.2	40.8	149:100
Live traps (Pike County)	28	36	64	43.7	56.3	78:100
Total	*1,883*	*1,314*	*3,197*	*58.9*	*41.1*	*143:100*
Gray Squirrel						
Litters (all zones represented)	6	5	11	55.5	44.5	120:100
Shot (throughout Illinois; including writers' kill)	734	477	1,211	60.6	39.4	154:100
Steel traps (all zones represented)	89	82	171	52.0	48.0	109:100
Live traps (Pike County)	30	31	61	49.0	51.0	97:100
Total	*859*	*595*	*1,454*	*59.1*	*40.9*	*144:100*

to 100 females, table 4. Of 60 spring juveniles taken by the writers and by hunters, 55 per cent were males and 45 per cent were females; of 38 summer juveniles collected in late September and October, 58 per cent were males and 42 per cent were females. The sex ratio of all juvenile gray squirrels for which records were obtained, 61 males and 48 females, was 127 males to 100 females.

Fig. 5.—Juvenile (left) and adult male fox squirrels. Note smoothed, blackened appearance of scrotum in adult and the smaller, less conspicuous scrotum in juvenile. Piatt County, late January, 1944. Gray squirrels of the same ages show the same characteristics.

The actual sex ratio of Illinois squirrels may be more nearly equal in both species than shown in table 4. It seems that males, because of somewhat more active habits, offered hunters more opportunities for shots than did females, and probably for the same reason proportionately more males were taken in steel traps.

Fig. 6.—Juvenile (left) and adult female fox squirrels, Mason County, August 15, 1944. Juvenile was first-season young; adult had weaned a first-season litter, but was neither pregnant nor lactating. Note the inconspicuousness of the mammary glands of the juvenile, and the prominent, blackened nipples of the adult.

Age Classes

No simple, yet infallible, method of determining age classes in fox and gray squirrels has been reported. Such techniques are much needed, not only for squirrels but for many other animal groups. The nearest approach to a workable method for aging squirrels requires the use of a number of criteria introduced by several workers, and validity of the method is somewhat conditioned by the experience of the user. For fox squirrels, Allen (1942, 1943) and Baumgartner (in letter to writers) placed some value on comparative growth stages, skin texture, and development of pigment and hair on various parts of the body, particularly on the scrotal sac of the males and on the ventral region of females. Chapman (1938*a*, *b*) working with gray squirrels, found a correlation of age and weight classes.

In both species males were the more difficult of the sexes to age. Juvenile males born in late winter or early spring were easily confused with adult males by the October and November following; and by December, when weights and measurements of the two groups were approximately equal, they could scarcely be differentiated. In adult males the scrotal sac is more pendent, and is blackened and less nearly clothed by hair on the ventral surface, fig. 5. In December, appearance of the teeth, and of hair and skin on the soles of the feet, is very similar in the two age groups. Some juvenile males born in the

summer remain distinguishable from adult males until about May of the following year.

In females, the teats offer the best means of determining age classes. In individuals that have never bred, these structures are small, light in color, and with the entire gland more or less hidden in the growth of hair. Mature females, after breeding and nursing, have much larger and more conspicuous mammary glands, the nipples of which, in both species, are dark in color, fig. 6.

The criteria found useful in aging squirrels in this study are listed in table 5. Collectively, and when used by an experienced observer, they are believed to be reliable for most individuals of both species. No single criterion was found applicable to all individuals of a given species or sex, and in some individuals age could not be determined with complete satisfaction when all criteria were used.

Hunters distinguish young from adult squirrels by several criteria other than appearance. The skinning test is perhaps most common, young squirrels being "easy" to skin and old squirrels "tough." Young squirrels remain "easy" to skin well into the fall or into the following spring, according to time of birth. The ease with which the leg bones may be snapped when the animals are being dressed is another criterion sometimes used by hunters.

Squirrels may properly be classed as adults after they reach breeding condition, and on this basis first-season young, born in late winter or early spring, become

Table 5.—Criteria for distinguishing between adult and juvenile fox and gray squirrels.

ADULTS	JUVENILES
MALES	
1. Ventral surface and posterior end of scrotum blackened, and generally free of hair.	1. Posterior end only of scrotum with smooth skin, brown to black and free of hair.
2. Cowper's glands one-half inch or more in diameter from November to following July (in other months about same size as in juveniles).	2. Cowper's glands undeveloped.
FEMALES	
1. Mammary glands large and noticeable, not hidden by hair growth; teats (in bred fox squirrel females) black tipped.	1. Teats inconspicuous, more or less hidden in growth of hair.
2. Uterus contracted in posterior position of coelom, horns about 2 mm. wide and flattened.	2. Uterus threadlike, extending forward toward kidneys.
MALES AND FEMALES	
1. Body length (tip of nose to anus) over 280 mm. for fox squirrels and over 250 mm. for gray squirrels.	1. Body length (tip of nose to anus) under 280 mm. for fox squirrels and under 250 mm. for gray squirrels.
2. Tail rectangular, block shaped; sides parallel or nearly so.	2. Tail pointed, triangular; sides not parallel.
3. Tips of guard hairs on tail rufus to red (fox squirrels only).	3. Tips of guard hairs on tail silvery until first tail molt in fall (fox squirrels only).

Table 6.—Age classes of squirrels shot or steel-trapped by the writers in Illinois, by months, 1940, 1941 and 1942.

Age Class	Number													Per Cent											
	January	February	March	April	May	June	July	August	September	October	November	December	*Total*	January	February	March	April	May	June	July	August	September	October	November	December	*Total*
Fox Squirrel																									
Adults	72	36	32	25	46	25	26	53	34	16	17	35	*417*	79.1	67.9	68.1	83.3	73.0	54.3	53.1	39.0	48.6	30.2	48.6	71.4	*57.8*
Spring juveniles	0	0	0	0	17	21	23	83	32	13	4	0	*193*	0.0	0.0	0.0	0.0	27.0	45.7	46.9	61.0	45.7	24.5	11.4	0.0	*26.7*
Summer juveniles	19	17	15	5	0	0	0	0	4	24	14	14	*112*	20.9	32.1	31.9	16.7	0.0	0.0	0.0	0.0	5.7	45.3	40.0	28.6	*15.5*
Gray Squirrel																									
Adults	17	19	14	22	35	15	17	25	14	13	16	24	*231*	73.9	73.1	73.7	84.6	79.5	62.5	53.1	59.5	43.8	43.4	59.8	85.7	*65.4*
Spring juveniles	0	0	0	0	9	9	15	17	18	7	4	0	*79*	0.0	0.0	0.0	0.0	20.5	36.5	46.9	40.5	56.2	23.3	14.8	0.0	*22.4*
Summer juveniles	6	7	5	4	0	0	0	0	0	10	7	4	*43*	26.1	26.9	26.3	15.4	0.0	0.0	0.0	0.0	0.0	33.3	25.9	14.3	*12.2*

Table 7.—Age classes of squirrels shot or steel-trapped by the writers in Illinois during the hunting seasons of 1940 and 1941.

Age Class	Fox Squirrels											Gray Squirrels										
	Number						Per Cent					Number						Per Cent				
	July	August	September	October	November	*Total*	July	August	September	October	November	*Total*	July	August	September	October	November	*Total*	July	August	September	October	November	*Total*
Adults	26	53	34	16	17	*146*	53.1	39.0	48.6	30.2	48.6	*42.6*	17	25	14	13	16	*85*	53.1	59.5	43.8	43.4	59.3	*52.2*
Spring juveniles	23	83	32	13	4	*155*	46.9	61.0	45.7	24.5	11.4	*45.2*	15	17	18	7	4	*61*	46.9	40.5	56.2	23.3	14.8	*37.4*
Summer juveniles	0	0	4	24	14	*42*	0.0	0.0	5.7	45.3	40.0	*12.2*	0	0	0	10	7	*17*	0.0	0.0	0.0	33.3	25.9	*10.4*

adults in December, and second-season, or summer-born, young reach adulthood the following May or later. In this report, the first-season young are referred to usually as spring juveniles.

Age classes of fox or gray squirrels shot or steel-trapped by the writers are given by months in table 6. September, October and November were the only months in which shootable populations contained the three general age classes—adults, spring juveniles and summer juveniles. During the hunting months of August, September and October, spring juveniles were disproportionately represented in the kill, since young animals are more readily taken by hunters than are adults. Summer juveniles did not appear in the kill until late September or early October, after most of the kill had been made.

Data presented in tables 6 and 7 were obtained from squirrels shot or taken in steel traps by the writers. The totals, therefore, are not necessarily representative of the three age classes as taken by hunters. It is unfortunate that the several thousand squirrels reported by hunters could not have been classified according to age, since this sample would have permitted not only more reliable conclusions than the few hundred animals shot and trapped, but would probably have permitted analysis by zones. However, since the writers, after the invariable practice of hunters, shot animals in their order of appearance, the take for July–November, as given in table 7, may be accepted as fairly representative of age classes of squirrels bagged by Illinois hunters. The small number of steel-trapped animals included is believed to induce no appreciable age-class error.

In July and August, during the period of this study, Illinois hunters generally bagged only adult and spring juvenile squirrels. In September a few summer-born fox squirrels were taken, but grays, which have later birth dates, were not usually represented. In October, the kill of second-season individuals was heavy in proportion to the total number of squirrels bagged, but the total was small, since wide-scale hunting ended in September. Very few squirrels were taken by hunters in November. Second-season young, therefore, absorbed comparatively little of the hunting loss in their first season, leaving a large part of this age class for breeding stock. In view of the heavy kill of adult and first-season juveniles, the survival of large numbers of second-season young is important in maintaining the population.

SPECIES COMPETITION

No information was obtained during the squirrel investigation to indicate any appreciable degree of strife between fox

squirrels and gray squirrels. The occurrence of one or both species on a given area appeared to be due more to characteristics of the habitat than to interspecific competition or lack of it. Only two or three observations of belligerency, and none of actual fighting between the two species, were obtained, while, on the other hand, both were frequently observed feeding in the same area and sometimes in the same tree. Throughout the Illinois gray squirrel range, hunters often kill both species on the same grounds. In one Pike County area, live trapping revealed a squirrel population composed of 64 per cent gray squirrels and 36 per cent fox squirrels. Only fox squirrels inhabited an open, oak-hickory area a few miles away that was similarly trapped. Both species were collected with gun or steel trap on at least 50 areas throughout the state during the period 1940–1943.

That some competition exists between the two species for available food and cover is probable, but it seems equally probable that little if any more competition results from the presence of two species than from the presence of an equal number of individuals of the same species. The best evidence of interspecific competition at hand is that usually only one species occurs in a given urban community. Seldom were both species found in any one municipality. We observed that about as many urban populations consisted of gray squirrels as of fox squirrels, although the habitat afforded by parks and tree-bordered streets is obviously better suited to the latter.

DAILY ACTIVITY

Throughout the first 2 years of this investigation, squirrels were hunted at least weekly and often daily for the purpose of obtaining study specimens. The record kept of all hunts included the time of hunt (Central Standard), and the place and activity of each animal when seen. A total of 716 hours, 387 in the morning and 329 in the afternoon, were devoted to hunting. Of the 554 squirrels observed, 336 were fox squirrels and 218 were gray squirrels. These data are summarized in table 8.

Activity in both species of squirrels was decidedly greater in the morning than in the afternoon. In the forenoon, the hour between 6 and 7 o'clock, when an hourly average of 0.89 fox squirrel and 0.77 gray squirrel was seen, showed the highest activity figure for both species, table 8. The next highest activity hour in the forenoon was 7 to 8 o'clock for fox squirrels and 5 to 6 o'clock for gray squirrels. The greatest afternoon activity was between 4 and 5 o'clock for fox squirrels and between 5 and 6 o'clock for gray squirrels. Gray squirrels were active both earlier and later in the day than fox squirrels, but fox squirrels were definitely more active during midday hours.

The data in table 8 are not in accord with the observations of Hicks (1942), who found that the peak of activity in Iowa fox squirrels occurred between 8:00 and 10:00 A. M., and that the next highest peak was between 1:00 and 2:00 P. M. Hicks made only a limited number of observations before 8:00 A. M. and after 5:00 P. M. Most other writers discussing this subject have indicated early morning and late afternoon activity peaks.

The daily activity of both species was observed to reach the annual zenith during the mast season. At this time, storing appeared to be the main pursuit other than feeding, and in individual squirrels involved several hours per day. Gray squirrels were observed to be abroad during midday hours more during the mast season than at any other time of the year except at the height of mating in December and January. During the mast season, as at other times, there was more activity in both species during early morning and late afternoon hours than at midday.

Although the effect of various weather conditions on squirrel behavior was not studied in detail, both species were found to be active all year, but least so during unusually cold weather. In hundreds of observations made in winter examinations of wood duck boxes, it was noted that individuals of both species were somewhat sluggish and more or less reluctant to leave nest-boxes when the temperature was below freezing. A total of 680 boxes yielded 55 squirrels, 48 of which were fox squirrels; 32 of the fox squirrels showed noticeable reluctance to leave their nests. Many of these individuals, which remained in the boxes after the lids were removed, were observed to be sleeping,

Table 8.—Activity in Illinois squirrels based on 716 hours of hunting in which 336 fox squirrels and 218 gray squirrels were observed, June 1—October 31, 1941 and 1942. Hours specified are for Central Standard Time.

Species	Squirrels Seen per Hour										
	4–5	5–6	6–7	7–8	8–9	9–10	2–3	3–4	4–5	5–6	6–7
Fox squirrels	0.07	0.61	0.89	0.73	0.54	0.22	0.15	0.30	0.34	0.29	0.10
Gray squirrels	0.29	0.47	0.77	0.37	0.18	0.05	0.05	0.05	0.14	0.34	0.15
Total squirrels	0.36	1.08	1.66	1.10	0.72	0.27	0.20	0.35	0.48	0.63	0.25

tightly rolled in a ball with leaves pulled over them. In one box there were three such fox squirrels, stacked one on top of another. In numerous cases two squirrels occupied the same box. Every squirrel showing a state of lethargy could be induced to leave the nest by shaking the box or by gentle prodding with hand or stick. True hibernation, of course, does not exist in fox or gray squirrels, in Illinois or elsewhere.

A few occasions permitted activity observations during periods of deep snow. On January 21, 1940, fox squirrels were seen foraging aggressively in a large oak-hickory-elm woodlot in Pike County when snow was 8 inches deep. The observations were made between 2 and 3 o'clock in the afternoon. The day was clear; the air temperature was about 15 degrees F., and the preceding 20 days had been cold and with much snow. Five squirrels and innumerable tracks were seen. There was much evidence of squirrel digging in the snow for nuts and Osage orange fruits; many of the latter had been eaten on stumps and rail fences, and under trees in hedgerows. The senior writer found that deep snow tended to reduce steel trap and box trap catches, particularly on days of long-continued snowstorms. Both species were observed in mating chases under conditions of light snow or during snow flurries.

Squirrels apparently are affected by heat as well as by cold. Individuals of both species were observed on hot days lying quietly, legs outstretched and relaxed, on tree branches. One young fox squirrel was collected on August 21, 1942, in the early afternoon, while resting on the second highest rail of a fence. Collection was on a very hot, humid day, an hour or so before a rainstorm. This animal seemed to be seeking relief from the oppressive atmospheric conditions.

Rain seemed to have some reducing effect on squirrel activity. Neither fox nor gray squirrels were as active during heavy rains or high winds as at most other times, although both species were often seen during showers and immediately after heavy rainfall. Misty days are favored by some hunters, no doubt partly because of the quietness with which squirrels may be stalked at such times. Many fox and gray squirrels were collected by gun on drizzly days, during light showers, and before and after heavy rains. Occasionally, animals with wet outer hair were taken, indicating activity either during rain or in wet vegetation.

Both fox and gray squirrels were observed swimming. Two gray squirrels were seen deliberately entering water to reach the opposite shore of a slough, and two fox squirrels were observed swimming to shore after falling from dead, loose-barked soft maple trees. The distance these squirrels were seen swimming was not over 10 yards.

SEASONAL MOVEMENTS

Live trapping and general observation offered considerable opportunity for studying squirrel movements. The information gathered is given under "Local Movements," a subject that involves day-to-day travels of squirrels in feeding and other routine activities; "Migration," which considers mass movements of squirrels in

a well-defined direction; and "Dispersal," which deals with the phenomenon of spread or "shuffle" in squirrel populations, especially in the fall prior to the breeding season.

Local Movements

Both fox and gray squirrels are usually considered sedentary species, although the latter, according to some authors, are subject to irregular migrations, discussed below. As has been reported by Seton (1928), Baumgartner (1938, 1943*a*), Goodrum (1940) and Allen (1942, 1943), local movements in both species of squirrels appear to be caused mainly by food conditions. In the course of a year, fox squirrels, apparently in foraging, may cross woodland or open fields for a distance of 2 or 3 miles. Gray squirrels, where favored by continuity of forest cover, may travel equal if not greater distances. The homing instinct of this species was studied by Hungerford & Wilder (1941), who reported returns in 6 of 15 animals, the greatest distance being 2.8 miles during a period of 4 weeks.

Squirrels shift readily from one local food area to another. On the Chautauqua National Wildlife Refuge, fox squirrels deserted one area after another as specific foods in other areas became available. They frequented the elm lowlands from late February into July, when elm buds and seeds, and later mulberries, supplied staple foods; they raided adjacent cornfields from midsummer until fall; and they used upland oak-hickory areas as main foraging grounds during the fall and winter. These shifts, however, at no time involved travels of more than a few hundred yards, and in no sense did they take on the usual characteristics of migration.

In one wooded area on the Chautauqua Refuge containing mature oaks, pecans and hickories, in addition to elms, maples and other riverbottom species, seasonal shifts in the squirrel population (all fox squirrels) were much less distinct than those mentioned in the foregoing paragraph. Indeed, day-to-day travel here seemed to be confined to a small area, usually not more than a few acres, and often the vicinity of one or a small group of food trees. The annual range of the resident population covered only about 150 acres.

During the young-rearing period particularly, females seemed to confine their movements to the vicinity of their brood sites, which numbered from one to several. In both species local movements were most extensive during the fall.

When not disturbed by overhunting, fire, drought or lumbering, individual squirrels may spend an entire year or more in the vicinity of a given nest tree. Allen (1942) reported an example of a Michigan fox squirrel female that used a red maple as headquarters continuously from October, 1937, at least until observations were terminated in December, 1939.

Seton (1928) stated that a gray squirrel may live its entire life on a 100-acre plot. Goodrum (1940) considered the home range of this species to be 200 yards or less, but he believed that some individuals may cover 4 or 5 miles during the course of a year. Middleton (1930) intimated that gray squirrels in Great Britain seldom travel more than 100 yards from headquarters, but also stated that the species extended its range 35 miles in 5 years.

Migration

No evidence of migration in fox squirrels was observed in this study. Baumgartner (1938) writes: "General and regular migration of the fox squirrel is unknown." Allen (1943) states: "Fox squirrels have seldom been observed in mass movements similar to those of the gray, which was known in early days as the 'migratory squirrel.' " There are numerous reports of mass movements or migrations of gray squirrels covering considerable distances; in these movements the animals were not deterred even by the formidable widths of the Hudson, Ohio or Mississippi rivers. Seton (1928) associated this phenomenon with food shortage, overpopulation and cyclic influences. Chapman (1936) attributed it mainly to the first two reasons. Jackson (1910, 1921) cited two instances in which numbers of the gray squirrel, in one case possibly because of a food shortage, swam the Mississippi River from Wisconsin to enter Minnesota. Goodwin (1934) reported an extensive migration in the New England states in 1931 and 1933. Osgood (1938) reported a

gray squirrel migration of small proportions in Vermont in 1935. According to the reports of numerous authors, the migrations covering the most territory, as well as involving the most individuals, occurred before the twentieth century.

Dispersal

According to Baumgartner (1940), the most extensive and important movement in fox squirrels "is the traveling associated with the annual readjustment of populations. This dispersal movement occurs between August 10 and September 15. The distances traveled at this time average about two or three miles, although two long records of 14 and 8 miles respectively were secured. This movement is responsible for the annual restocking of overhunted areas."

Allen (1943) indicates that a population shuffle occurs in Michigan fox squirrels. He states (1943) that " . . . it appears that increased activity among squirrels begins in late August, rises to a peak in late September, and is over by the middle of December."

Of the reasons for dispersal Baumgartner (1943*a*) writes: "The cause of this movement is controversial. The motivating factor is usually considered to be population pressure correlated with a shortage of food, yet it occurs when the food supply is greatest, almost simultaneously with the maturing of the nut crop. The moving squirrels are more noticeable when the population is high, and the writer believes the movement results from *intra-species intolerance*. This view is partially substantiated by the fact that no record of excessive fox squirrel populations, either in the literature or in the field, could be authenticated. Seven such reports were investigated but none showed more than two squirrels per acre."

Our evidence indicates that in Illinois a dispersal occurs in both fox and gray squirrels during the fall. Continuous and intensive live trapping on the Wade area over a 10-month period prior to August 8, 1942, resulted in the capture and marking of most if not all resident squirrels, since only one unmarked animal, a 1941 summer juvenile (female), was taken either by trapping or hunting during the period between July 12 and October 15, 1942. This individual was trapped on August 5, and it is likely that the squirrel had only recently moved onto the area from a woodland to the east. On August 8, 1942, the writers shot two fox squirrels (Nos. 11 and 26) and seven gray squirrels (Nos. 1, 5, 9, 13, 26, 33 and 50) on the Wade area. No unmarked animals were among these squirrels. In the period October 15 through 17 the senior writer shot 13 additional specimens, 5 fox squirrels and 8 gray squirrels, of which 1 fox and 2 gray individuals were unmarked. They were 1942 spring juveniles, and therefore subject to trapping and marking had they been present during the last 8 to 10 weeks of trapping. It is believed that these three animals had moved onto the area during the period of August 8 through October 17. Other than these three spring juveniles, six unmarked 1942 summer juveniles (one fox, five gray) were collected in mid October, 1942, but these may have been young born on the area and too small to be taken in live traps prior to August 8.

CONDITION

Weight and length measurements were taken of most squirrels collected, and information on diseases, parasites, deformities and pelage development was recorded when observed in the specimens.

Weight

Weights were obtained for a total of 706 fox squirrels and 317 gray squirrels. The data are given in table 9. In adults, weights were recorded by sex, but in juveniles the weights of the two sexes were lumped.

As indicated in table 9, there were no significant differences in weight between male and female adults in either species. Allen (1942, 1943) found female fox squirrels in Michigan to be slightly larger than males. A point of interest in the present study is that of size in juveniles at the time they began to enter hunters' bags in July. Spring juvenile fox and gray squirrels at that time had an average weight of 1.28 pounds and 0.84 pound, respectively. By late October or November, the spring juveniles of both species had reached approximately average adult

Table 9.—Weights, in pounds, of Illinois squirrels collected by the writers, 1940, 1941 and 1942.

Month	Fox Squirrels								Gray Squirrels							
	Adults				Spring Juveniles		Summer Juveniles		Adults				Spring Juveniles		Summer Juveniles	
	Males		Females						Males		Females					
	Number	Average Weight	Number	Average Weight	Number	Average Weight	Number	Average Weight	Number	Average Weight	Number	Average Weight	Number	Average Weight	Number	Average Weight
January	44	1.77	30	1.74	..	..	19	1.42	12	1.17	5	1.13	..	..	6	0.91
February	17	1.62	19	1.71	..	..	17	1.49	12	1.15	7	1.20	..	..	7	0.92
March	21	1.71	11	1.59	..	..	15	1.43	9	1.09	5	1.10	..	..	5	1.04
April	13	1.67	12	1.68	..	..	5	1.47	8	1.13	14	1.14	..	..	4	0.96
May	30	1.65	16	1.63	17	0.84	..	..	16	1.13	19	1.23	9	0.44	..	..
June	7	1.69	14	1.71	21	1.16	..	..	10	1.24	5	1.17	9	0.65	..	..
July	10	1.73	16	1.71	23	1.28	..	..	1	1.27	2	1.02	5	0.84	..	..
August	29	1.66	24	1.67	83	1.37	5	0.98	10	1.16	15	1.19	17	0.99	..	..
September	17	1.64	19	1.70	32	1.52	7	1.02	6	1.24	8	1.16	18	1.02	7	0.64
October	9	1.71	7	1.77	13	1.66	14	1.13	9	1.27	4	1.28	7	1.27	9	0.77
November	8	1.84	5	1.69	4	1.61	4	1.07	5	1.16	3	1.14	..	..	1	0.78
December	19	1.77	16	1.71	..	..	14	1.41	4	1.29	20	1.17	..	..	4	0.98
Total or Average	*224*	*1.70*	*189*	*1.69*	*193*	*1.34*	*100*	*1.26*	*102*	*1.18*	*107*	*1.18*	*65*	*0.89*	*43*	*0.86*

Table 10.—Lengths, in millimeters, of Illinois squirrels collected by the writers, 1940, 1941 and 1942.

Month	Fox Squirrels												Gray Squirrels											
	Adults						Spring Juveniles			Summer Juveniles			Adults						Spring Juveniles			Summer Juveniles		
	Males			Females									Males			Females								
	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length	Number	Average Body Length	Average Total Length
January	44	310	530	30	294	542	..	..	..	19	281	520	12	262	462	5	250	470	..	..	..	6	239	436
February	17	299	535	19	289	534	..	..	..	17	281	531	12	258	459	7	256	479	..	..	..	7	234	437
March	21	298	528	11	291	548	..	..	..	15	281	521	9	267	462	5	256	470	..	..	..	5	239	447
April	13	289	536	12	291	537	..	..	..	5	279	539	8	263	467	14	261	477	..	..	..	4	241	459
May	30	297	523	16	287	530	17	231	461	..	..	..	16	265	464	19	255	477	9	205	389	..	..	..
June	7	299	537	14	293	539	21	265	499	..	..	..	10	263	467	5	245	462	9	225	408	..	..	..
July	10	291	542	16	289	532	23	266	494	..	..	..	1	260	465	2	241	447	5	231	433	..	..	..
August	29	289	526	24	287	537	83	277	514	5	236	470	10	255	463	15	254	469	17	245	454	..	..	..
September	17	282	520	19	288	535	32	275	516	7	240	469	6	260	466	8	257	461	18	247	456	7	209	412
October	9	285	526	7	290	538	13	279	521	14	250	496	9	262	465	4	262	474	7	261	469	9	214	439
November	8	298	529	5	287	536	4	286	534	4	252	513	5	256	464	3	258	471	..	..	..	1	228	443
December	19	294	524	16	291	534	..	..	..	14	267	508	4	268	476	20	258	473	..	..	..	4	245	455
Total or Average	*224*	*296*	*528*	*189*	*290*	*537*	*193*	*270*	*507*	*100*	*268*	*512*	*102*	*263*	*464*	*107*	*256*	*472*	*65*	*238*	*439*	*43*	*245*	*438*

weight, representing gains in weight of about 33 or more per cent since July.

Development of summer or second-litter juveniles approximated that of spring or first-litter young in both species, and, as would be expected, summer-born animals taken the following September and October showed the lowest average weight of any age class in the kill at that time.

Length

Body and total lengths of 706 fox squirrels and 317 gray squirrels were recorded, table 10. All readings were taken in a standard manner (Anderson 1932). Length of the hind foot was taken for a large series, but the differences appeared so insignificant that taking of this measurement was discontinued.

Spring juveniles were first collected in May, at which time the average body length and total length in the fox squirrels were 231 millimeters and 461 millimeters, respectively, and, in the gray squirrels, 205 millimeters and 389 millimeters, respectively, table 10. By mid fall these measurements had increased, respectively, about 17 and 13 per cent in fox squirrels, and about 27 and 21 per cent in gray squirrels. The apparently greater rate of increase in gray squirrels may be accounted for by the 2-week difference in the average breeding dates of the two species, and, consequently, in the proportionally younger age of gray squirrels collected in May.

Summer juvenile fox squirrels, first collected in August, had an average body length of 236 millimeters at the time, and 267 millimeters in December. Summer juvenile gray squirrels were first collected in September. At that time their average body length was 209 millimeters. In December it was 245 millimeters.

Deformities

Only one type of deformity, that of stub tail, was noted in 706 fox squirrels and 317 gray squirrels handled by the writers. Ninety-five, or 13.5 per cent of all fox squirrels, and 39, or 12.3 per cent of all gray squirrels, showed this defect to a greater or less degree. This incidence of stub tail in the two species is considered surprisingly high. The deformity is well known to hunters, who commonly attribute it to fighting between males and the mating chase between males and females. We have no more logical explanation. In no case was the deformity observed to impede travel or any other activity.

Wounds

Six crippled squirrels, four fox and two gray, were collected by the writers.

Fig. 7.—Crippled female fox squirrel collected in Piatt County, February, 1945. The injury was probably caused by a steel trap or a .22 caliber bullet. Despite the injury and a case of mange, this female was pregnant and in good condition as to body fat.

These numbers represented little more than one-half of 1 per cent of the total number of animals collected, but they gave, of course, no true index of crippling loss, which hunters' questionnaires indicate are much higher, table 23. Animals showing imbedded shot but healed wounds, or missing toes probably due to shooting, were not counted among the cripples. In two cases, one in each species, bones of a hind leg were so badly shattered that recovery was improbable. Some seriously wounded squirrels undoubtedly make their way to cavities or nests, from which they probably never emerge. In all except one case, shotgun pellets were the cause of the crippled condition observed. A fox squirrel that recovered from a severe wound is shown in fig. 7.

Molt and Color

Fox and gray squirrels molt once a year, the two species having similar molting characteristics. The molt consists of two phases, the first involving the body and the second the tail. Males molt before females, beginning in the spring and concluding the process during the summer. Females appear to molt at any time between April and September, after their last young of the year have been born. Adult males and spring juveniles ordinarily molt before adult females, especially those producing second-season or summer litters. These adult females usually complete the molt in September.

Molting in both fox and gray squirrels requires 3 to 4 weeks. Progress in the body phase is from nose to tail; on the tail, molting begins at the distal end and progresses anteriorly to the base of the tail. In most individuals there is a definite line of demarkation between the new and old hair. When such a line is not present in molting animals, new hair is being replaced over a relatively wide area, the old and new hair tending to blend.

Few of the color patterns ordinarily found in squirrels were encountered in Illinois during the course of this study. One very reddish female fox squirrel was shot that may have been an example of erythrism. This was a mature animal, taken on August 7, 1942, while "cutting" a hickory nut. She was host to a very large ascarid. No distinct albino or melanistic individuals were taken. However, albino gray squirrels occur in considerable numbers in Olney, where they are said to have increased from an albino pair released some years ago. Melanistic squirrels have been reported from Ogle County and other northern Illinois localities. In an early report, Kennicott (1857) stated that of 50 gray squirrels killed near Rockford, Illinois, all were black. During the pioneer period, black squirrels were common in Michigan (Allen 1943), Indiana (Haymond 1869, Hahn 1909) and in other states. One adult male gray squirrel trapped in Pike County, February 25, 1941, had reddish thoracic hair and black abdominal hair. A juvenile male fox squirrel with blue eyes was trapped in Pike County, February 8, 1942. Baumgartner (1943*b*) reported nine different color patterns in Ohio fox squirrels, including melanistic, near albino, browntail, and variations of black and red or rufus.

PARASITES AND DISEASES

Several papers dealing with the parasites of squirrels, particularly fox squirrels, have been published. Katz (1939) brought most of this information together. Harkema (1936) studied the parasites of 53 gray squirrels in North Carolina, finding one species of tapeworm, one of round worm, three of mites, two of lice and one of flea. Chandler (1942) recently reported on the helminth worms of tree squirrels in southeast Texas; and Graham & Uhrich (1943) published on the external and internal parasites of the fox squirrel in southeastern Kansas. Baumgartner (1940) and Allen (1942, 1943) discussed briefly the parasites and diseases of fox squirrels in Ohio and Michigan, respectively; and Goodrum (1940) reported similarly for gray squirrels in Texas. The most prevalent parasites reported by all these authors were mange mites. No diseases of endemic nature other than mange were reported.

Most squirrels studied during 2 years of field work in this investigation were examined for mange, and for ticks and other external parasites. The same species of parasites were found to occur on both fox and gray squirrels. Mange (caused by *Sarcoptes* sp.) occurred to a

noticeable degree in only 0.03 per cent of the 722 fox squirrels and 0.06 per cent of the 353 gray squirrels examined for this condition. Incidence of mange in all squirrels studied was 0.04 per cent. All zones were represented by the animals examined for parasites.

The degree of infestation was negligible in most woodland populations, but in some urban populations of both species a heavier rate prevailed. Woodland squirrels showing evidence of mange were found on only two localized areas, one the pin oak bottoms near Thomson in Carroll County, involving only fox squirrels, and the other near Griggsville in Pike County, involving both fox and gray squirrels. The first area showed an infestation of 47 per cent in a sample of 15 squirrels; the latter, 15 per cent in a sample of 94. The degree of infestation in Pike County was about the same in the two species. In both localities squirrels were collected during the breeding seasons, and in both infested individuals were apparently normally active. A female shot February 26, 1941, on the Thomson area had bare patches of skin on head, neck and back, yet contained three well-developed embryos. Another collected on February 17, 1945, near Monticello, Piatt County, had the left hind foot missing and was practically devoid of hair, due to mange, on the neck and thoracic regions, but this animal, fig. 7, likewise contained three normal embryos. None of the infested squirrels were in poor physical condition.

Practically every squirrel, fox and gray, was host to fleas; many animals carried the common dog tick; less than 1 per cent carried sucking lice. Dr. H. H. Ross of the Illinois Natural History Survey supplied the following notes on ectoparasites.

The same species of ectoparasites occur on both the gray and fox squirrels in Illinois.

TICKS (Ixodoidea)

Dermacentor variabilis (Say).—Taken very commonly on squirrels throughout Illinois. This is the common dog tick and occurs on many other mammals.

PARASITIC MITES (Parasitoidea)

Several species of this superfamily of mites have been encountered on Illinois squirrels.

FLEAS (Siphonaptera)

Orchopeas howardii (Baker).—Very common and frequently extremely abundant. This species has been found in great numbers in overwintering nests throughout Illinois.

Orchopeas nepos Rothschild.—Taken only rarely in Illinois.

SUCKING LICE (Anoplura)

Hoplopleura sciuricola Ferris.—Taken only rarely in Illinois.

In addition to the above, chiggers undoubtedly occur on Illinois squirrels. Although we have no definite records for this state, Roger Williams, while at the University of North Carolina, found chiggers on squirrels. These chiggers belong to the mite genus *Trombicula* and allied genera.

In a small number of squirrels studied for internal parasites, one-third of the animals contained parasitic worms. Identification of these specimens was made by Dr. Lyell J. Thomas of the University of Illinois. The following remarks are quoted from his report.

No. 1.—Female fox squirrel, Thomson, Illinois, collected May 27, 1941: Eight cestode cysts in visceral cavity, identified as *Taenia pisiformis*. These generally occur in rabbits.

No. 2.—Female fox squirrel, Griggsville, Illinois, collected April 19, 1942: Several nematodes from intestine; all females, and identified as *Impalaia* sp., probably new.

No. 3.—Female fox squirrel, Griggsville, Illinois, collected August 7, 1942: One large male nematode from large intestine identified as *Ascaris* sp. (probably *A. lumbricoides*). Has been recorded from East Indian squirrels, but not, to my knowledge, from North American squirrels. Normal hosts are man and pig. Closely allied species occur in skunks and armadillos.

No. 4.—Female gray squirrel, Griggsville, Illinois, collected April 21, 1942: Three male and five female nematodes from intestinal tract identified as *Impalaia* sp., probably new. Two female nematodes from intestinal tract identified as *Mescistocirrcus* sp., probably new.

The four squirrels yielding the above endoparasites appeared to be in normal vigor, although none contained noticeable fat in the body cavity. The female that was host to the ascarid was reddish to the point of erythrism. The uterus showed five placental scars and the mammae con-

tained milk. This squirrel weighed 1.59 pounds, was 544 millimeters in total length, and had about half completed the molt.

A female fox squirrel, too weak to escape, was captured alive near Urbana, Illinois, on April 11, 1941. Diagnosis in the Animal Pathology Laboratory of the University of Illinois revealed a fractured tibia and the presence of hepatic coccidiosis. On August 5, 1943, Dr. R. E. Yeatter of the Illinois Natural History Survey collected near Urbana a very weak female fox squirrel; diagnosis in the University's Animal Pathology Laboratory " . . . revealed the presence of small, circumscribed white foci in the liver and spleen. In view of these lesions and the history of the squirrel having been found sick, we regard the possibility of tularemia in this animal as being quite good . . . cultures were not made." This female had recently nursed young.

The writers and others of the Illinois Natural History Survey staff sometimes found dead squirrels in wood duck nest boxes. Usually these squirrels were so badly decomposed that cause of death could not be determined. The number of squirrels found dead was not great, and the over-all evidence suggests that no appreciable number of these animals die of diseases or the effects of parasitism.

PREDATION

Predation losses in squirrel populations are unimportant in Illinois. There are numerous published reports of squirrels being taken by hawks, owls, dogs and other predators, but the writers found little evidence that such losses reach serious proportions in this state. Extreme agility and a speed that attains a maximum of 12 miles per hour in the fox squirrel (Cottam 1941), and probably an equal speed in the gray squirrel, enable both species to elude most predators effectively.

In January, 1941, in the examination of 680 wood duck boxes, one weak male fox squirrel was found that showed conclusive evidence of having been attacked by a raptoral bird. Talon punctures on the dorsal surface reached to the body cavity. Mange was present under the forelegs and about the hocks. When released, the squirrel appeared dazed and climbed back to the box with difficulty. Two months later another inspection revealed that he had died in the box. No sign of gunshot or other injury could be found.

A northern Illinois coon hunter reported one instance of weasel predation on fox squirrels. This attack was at night. The hunter first heard a squirrel in a tree, then a crash, followed by a struggle on the ground. With the aid of a flashlight the hunter saw the squirrel and weasel plainly. The squirrel escaped, but it is not known how badly it may have been injured.

The senior writer once flushed a feral cat that was obviously trying to stalk a barking fox squirrel. On snow in northern Illinois he observed a red fox stalk a fox squirrel that was busily engaged in eating an Osage orange fruit, but the fox was frightened before reaching a springing position. On another occasion the senior author saw a red fox leap upon and capture a badly wounded fox squirrel, but shouts caused the fox to drop its victim and dash away.

Fox and gray squirrels caught in steel traps were occasionally attacked by hawks, free-ranging dogs and other predators. The red-shouldered hawk and red-tailed hawk were the only raptors actually flushed from trapped animals. A trapped fox squirrel, caught late in the afternoon, was killed during the night by a weasel. Dogs are known to have eaten three fox squirrels and one gray squirrel caught in traps. It is recognized, of course, that trapped squirrels attract the attention of predators and offer easy prey, making them unreliable criteria for measuring predation losses.

BREEDING

The term *breeding* as usually employed in this study includes pre-mating behavior, mating and such physiological aspects of breeding as oestrus, pregnancy, testes development and changes in the Cowper's glands.

During the period of investigation, data on breeding or young rearing were obtained from a total of 4,790 squirrels, which are listed in table 11 by species and according to time and manner collected.

The 1,075 squirrels shot or steel-trapped by the writers and used for detailed

Table 11.—Squirrels counted or collected for study in Illinois, 1940–1943.

How Collected or Counted	Period of Count or Collection	Number		
		Fox Squirrels	Gray Squirrels	Total
Fetal counts	July 1, 1940, to August 31, 1943	75	12	*87*
Litter counts	July 1, 1940, to April 15, 1942	87	19	*106*
Shot by writers, all zones	July 1, 1940, to October 31, 1943	381	182	*563*
Steel-trapped by Brown, all zones	July 1, 1940, to June 30, 1942	341	171	*512*
Live-trapped by Brown, Pike County	October 16, 1941, to August 7, 1942	64	61	*125*
Killed by hunters throughout Illinois	July 15 to November 15, 1940	955	577	*1,532*
	August 15 to November 15, 1941	1,413	452	*1,865*
Total		*3,316*	*1,474*	*4,790*

laboratory study were taken during every month of the year, table 12.

Breeding Seasons

Numerous workers have reported that both fox and gray squirrels are dioestrus, that is, have two breeding seasons annually. Allen (1942, 1943), whose studies of the fox squirrel exceed in both scope and duration those of any other investigator, found that old females of this species (2 years or more) usually produce two litters per year, but that younger females ordinarily produce only one. Females from spring litters usually breed the following December or January, when about 11 months old, giving birth to their first young in late February or March. These young females usually do not breed

Table 12.—Month of collection, species and sex of squirrels studied in laboratory in Illinois, July, 1940, to October, 1942.*

Month	Fox Squirrel		Gray Squirrel	
	Male	Female	Male	Female
January	53	38	14	9
February	31	22	15	11
March	28	19	11	8
April	18	12	15	11
May	37	26	26	18
June	26	20	13	11
July	26	23	17	15
August	80	56	25	17
September	40	30	17	15
October	31	22	17	13
November	19	16	15	12
December	29	20	15	13
Total	*418*	*304*	*200*	*153*

*Includes 305 fox squirrels and 122 gray squirrels not used in breeding studies, tables 14 and 15.

a second time, that is, during the summer, in their first 18 months after birth. Females from summer litters are usually too immature to breed during the ensuing winter season, at an age of 7 months or less, but they breed during the following summer, at an age of about a year.

The gray squirrel has been found to have breeding dates almost paralleling those of the fox squirrel. Goodrum (1940) in east Texas reported two breeding seasons for the gray species, one beginning about December, with winter pregnancy reaching a peak in January or early February, and the second beginning in late May or early June, with summer pregnancy reaching a peak in August. In Kentucky, Hibbard (1935) also found the gray squirrel to have two breeding seasons.

Data on the two breeding seasons for fox and gray squirrels disclosed by the Illinois investigation, table 13, are in general agreement with the conclusions of Allen for the fox squirrel. In Ohio, Baumgartner (1940) indicates two fox squirrel breeding seasons, one from December to April and another from late May to early October. A logical explanation of the two peaks in the female cycle of Illinois squirrels, fig. 8 and table 15, is found in the fact that most old females, and females born the previous spring, breed during December, January and early February, and that little further breeding ensues until females born the previous summer, and old females producing second-season litters, reach the oestrus condition, usually in May or June.

The annual breeding cycle of males in Illinois was found to coincide approximately with that of females, but the two peaks are less distinct in the males, which appear to be in breeding condition continuously from late fall to midsummer, although a minor decline is apparent in February and March, fig. 9 and table 14. The data indicate that males are in breeding condition earlier than females. Cessation of breeding occurs in midsummer.

Our studies indicate that between the northern and southern limits of Illinois there is a difference of about 3 weeks in the average breeding dates for both fox and gray squirrels, the season being progressively later south to north, as would be expected. The breeding peak for gray squirrels, zone for zone, is about 10 days to 2 weeks later than for fox squirrels. These variations appear to hold roughly, in old squirrels, for both the first and second breeding seasons. In table 13 generalized breeding dates of Illinois squirrels are given.

It should be understood that dates given in table 13 are based on only 2 years of study, and that breeding periods are subject to fluctuation from year to year. Such fluctuation may include dates either earlier or later than the dates given, and, while the extent of fluctuation is not known, it is believed not to exceed one week.

Several criteria were used in arriving at peak breeding dates. As discussed below and illustrated in figs. 10 and 11, these criteria were average testes length, average testes weight, average diameter of Cow-

Table 13.—Generalized peak mating dates of squirrels in three Illinois zones, based mainly on 2 years of study, July 1, 1940, to June 30, 1942.

Species	First Season			Second Season		
	Southern Zone	Central Zone	Northern Zone	Southern Zone	Central Zone	Northern Zone
Fox squirrel	December 15–25	December 25–January 5	January 5–15	May 25–June 5	June 5–15	June 15–25
Gray squirrel . . .	January 1–10	January 10–20	January 20–30	June 15–25	June 25–July 5	July 5–15

per's glands and evidence of oestrus. In the first three characteristics, all peculiar to males, there was close similarity but not exact uniformity in the two species. In both fox and gray squirrels, testes length and weight peaks were reached before or by the time of peak mating. It is evident that none of the criteria based on male organs are fully satisfactory for determining the breeding seasons, and for this reason we have placed greater reliance in the percentage of females showing oestrus, fig. 8, assuming that peak oestrus and mating occur simultaneously, or nearly so. Dates given in table 13 are in general agreement with findings reported by other workers.

The chronology of squirrel breeding data in Illinois, including the earliest, latest and peak dates for various reproductive activities or conditions, are given in table 16. Peak dates are applicable

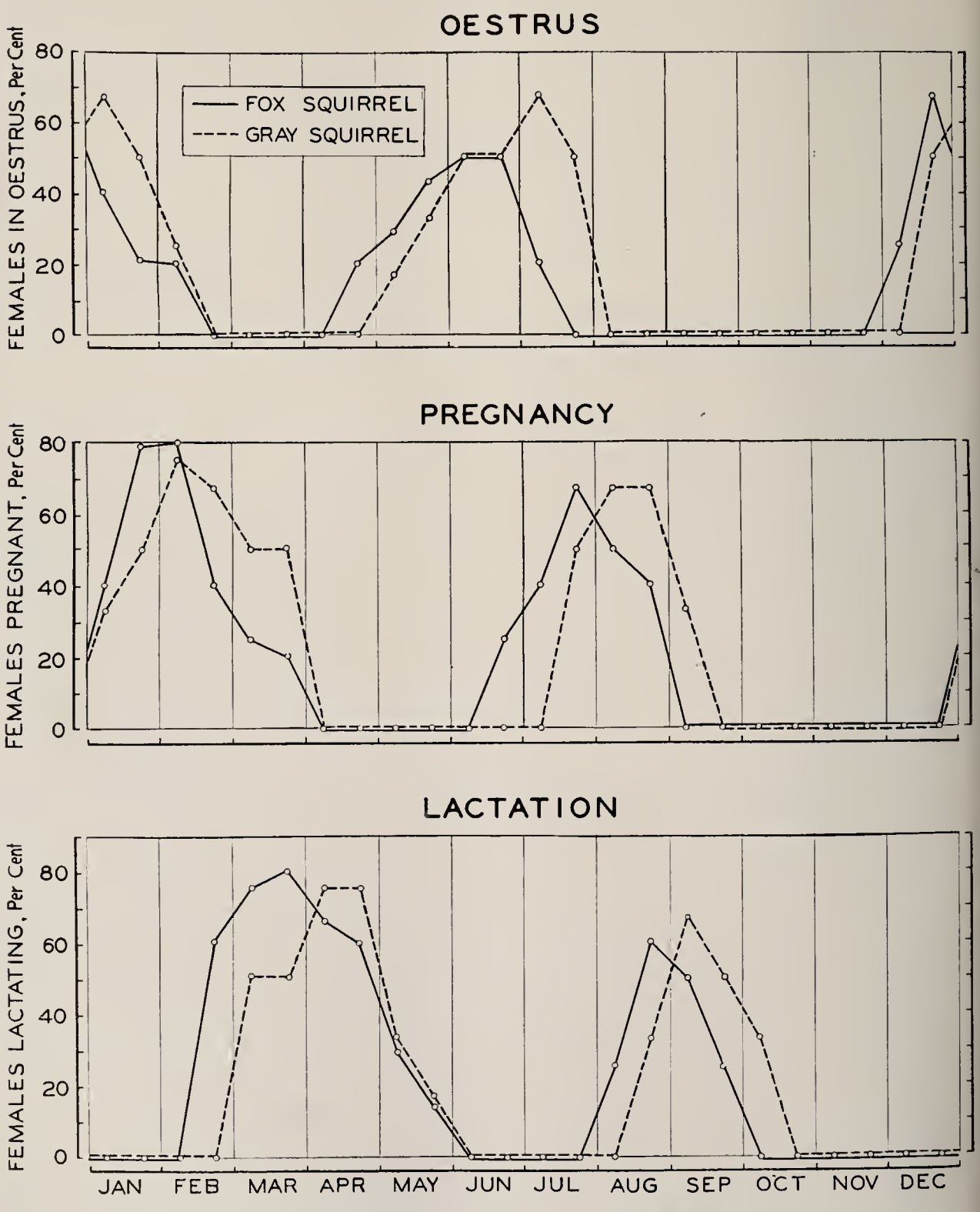

Fig. 8.—Breeding seasons in female squirrels in Illinois, 1940—1942.

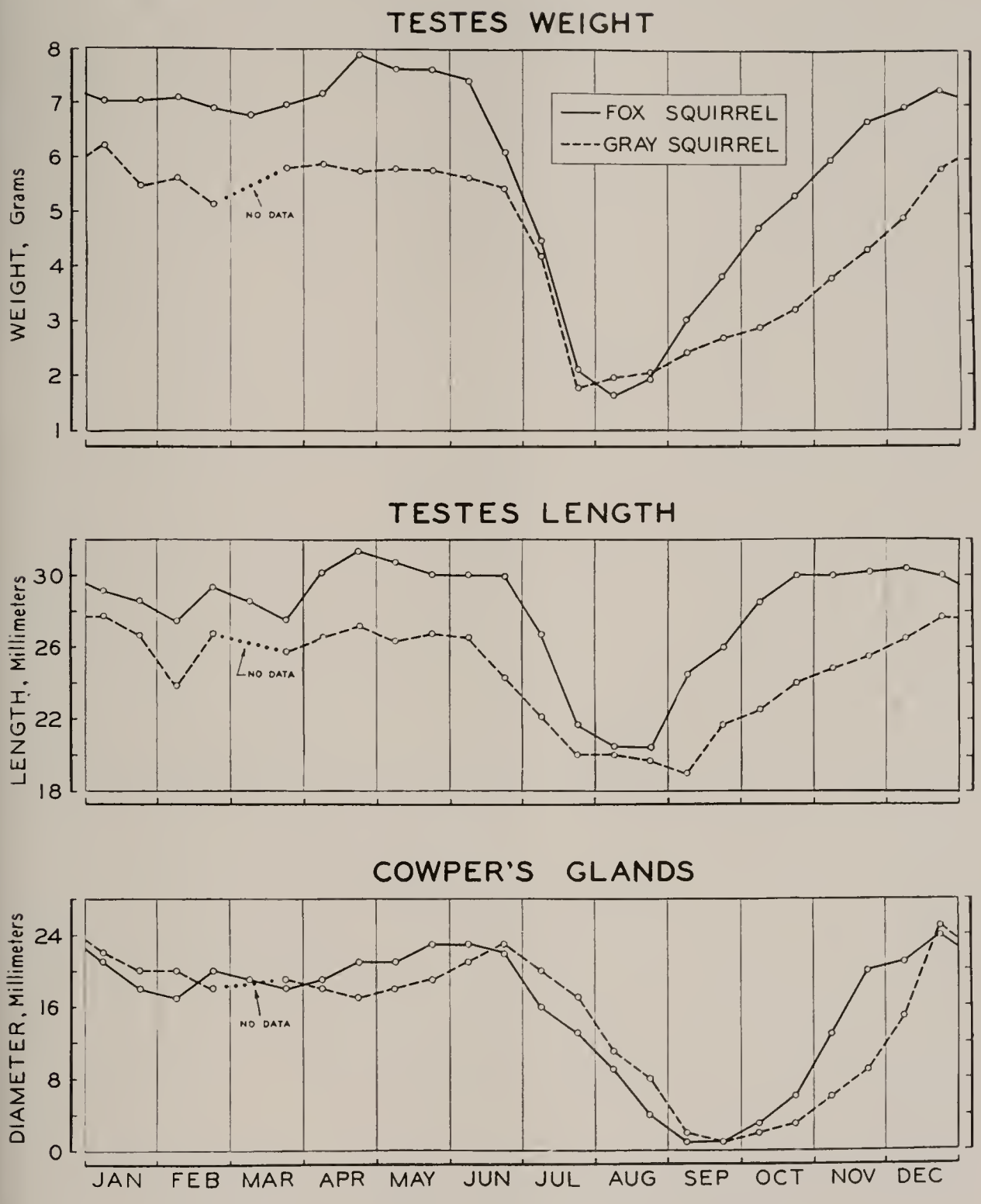

Fig. 9.—Breeding seasons in male squirrels in Illinois, 1940–1942.

particularly to the central zone; in the northern and southern zones, the time of corresponding peaks may, in general, be expected about 6 or 7 days later and earlier, respectively.

Duration of the oestrual period, on the basis of evidence at hand, is approximately 10 days. Peak dates for pregnancy and lactation are less easily established, since gestation requires about 45 days and nursing continues for 8 to 10 weeks. Averages of all data, tables 15 and 16, indicate that pregnancy peaks in fox squirrels were reached about February 1–15 and July 16–31; in gray squirrels, February 10–25 and August 5–20. Lactation peaks in fox squirrels occurred during the months of March and August; in gray squirrels April and September.

Considerable overlap was found in the two breeding and young-rearing seasons. Ending the first season was a lactation

Table 14.—Breeding activity in adult male squirrels in Illinois; data obtained mainly July 1, 1940, to June 30, 1942.*

Breeding Characteristic	January		February		March		April		May		June		July		August		September		October		November		December	
	1–15	16–31	1–15	16–29	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–30	1–15	16–31
Fox Squirrel																								
Males	27	15	9	12	10	9	10	5	12	15	6	8	6	6	12	19	12	7	5	4	5	4	10	11
Adult males	21	12	6	8	7	6	8	4	10	11	2	5	4	2	5	7	6	3	1	2	2	2	7	8
Weight of both testes (adults), average in grams	7.07	7.07	7.19	6.82	6.69	6.88	7.31	7.84	7.68	7.68	7.36	6.21	4.49	2.09	1.64	1.94	3.08	3.78	4.74	5.41	5.92	6.66	6.88	7.38
Length of testes (adults), average in mm.	29.1	28.5	27.4	29.3	28.5	27.5	30.1	31.3	30.7	30.0	30.0	29.9	26.7	21.7	20.5	20.4	24.5	26.0	28.5	30.0	30.0	30.2	30.4	30.0
Diameter of Cowper's glands (adults), average in mm.	21.0	18.0	17.0	20.0	19.0	18.0	19.0	21.0	21.0	23.0	23.0	22.0	16.0	13.0	9.0	4.0	1.0	1.0	3.0	6.0	13.0	20.0	21.0	24.0
Gray Squirrel																								
Males	2	8	7	4	2	6	5	8	5	16	3	4	3	5	7	8	4	2	2	5	5	4	6	7
Adult males	2	5	5	2	0	6	4	6	4	13	2	2	2	1	4	5	2	1	2	1	3	2	4	7
Weight of both testes (adults), average in grams	6.16	5.43	5.56	5.10	.....	5.73	5.80	5.66	5.73	5.73	5.60	5.40	4.20	1.77	1.94	2.10	2.42	2.68	2.86	3.18	3.78	4.42	4.88	5.80
Length of testes (adults), average in mm.	27.7	26.6	23.8	26.7	.....	25.7	26.5	27.1	26.3	26.7	26.5	24.3	22.1	20.0	20.0	19.7	19.0	21.7	22.5	24.0	24.8	25.5	26.5	27.7
Diameter of Cowper's glands (adults), average in mm.	22.0	20.0	20.0	18.0	.....	19.0	18.0	17.0	18.0	19.0	21.0	23.0	20.0	17.0	11.0	8.0	2.0	1.0	2.0	3.0	6.0	9.0	15.0	25.0

*Measurements of testes length to nearest 0.1 millimeter; diameter of Cowper's glands to nearest millimeter; weight of testes (pair) to nearest 0.01 gram.

Table 15.—Breeding activity in adult female squirrels in Illinois; data obtained mainly July 1, 1940, to June 30, 1942.

Breeding Activity	January		February		March		April		May		June		July		August		September		October		November		December	
	1–15	16–31	1–15	16–29	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–31	1–15	16–30	1–15	16–31	1–15	16–30	1–15	16–31
Fox Squirrel																								
Females	12	18	7	8	5	8	4	6	8	11	5	6	8	6	10	12	9	6	3	4	4	4	7	7
Adult females	10	14	5	5	4	5	3	5	7	7	2	4	5	3	4	5	2	4	2	1	1	2	4	6
Adult females in oestrus, number	4	3	1	0	0	0	0	1	2	3	1	2	1	0	0	0	0	0	0	0	0	0	1	4
Adult females in oestrus, per cent	40	21	20	0	0	0	0	20	29	43	50	50	20	0	0	0	0	0	0	0	0	0	25	67
Adult females pregnant, number	4	11	4	2	1	1	0	0	0	0	0	1	2	2	2	2	0	0	0	0	0	0	0	0
Adult females pregnant, per cent	40	79	80	40	25	20	0	0	0	0	0	25	40	67	50	40	0	0	0	0	0	0	0	0
Adult females lactating, number	0	0	0	3	3	4	2	3	2	1	0	0	0	0	1	3	1	1	0	0	0	0	0	0
Adult females lactating, per cent	0	0	0	60	75	80	67	60	29	14	0	0	0	0	25	60	50	25	0	0	0	0	0	0
Gray Squirrel																								
Females	5	2	4	4	4	2	4	5	6	8	4	4	4	5	4	6	4	4	4	2	2	5	5	6
Adult females	3	2	4	3	2	2	4	4	6	6	2	2	3	2	3	3	3	2	3	0	0	2	2	4
Adult females in oestrus, number	2	1	1	0	0	0	0	0	1	2	1	1	2	1	0	0	0	0	0	0	0	0	0	2
Adult females in oestrus, per cent	67	50	25	0	0	0	0	0	17	33	50	50	67	50	0	0	0	0	0	0	0	0	0	50
Adult females pregnant, number	1	1	3	2	1	1	0	0	0	0	0	0	0	1	2	2	1	0	0	0	0	0	0	0
Adult females pregnant, per cent	33	50	75	67	50	50	0	0	0	0	0	0	0	50	67	67	33	0	0	0	0	0	0	0
Adult females lactating, number	0	0	0	0	1	1	3	3	2	1	0	0	0	0	0	1	2	1	1	0	0	0	0	0
Adult females lactating, per cent	0	0	0	0	50	50	75	75	33	17	0	0	0	0	0	33	67	50	33	0	0	0	0	0

Table 16.—Chronology of breeding in female squirrels in Illinois; data obtained mainly July 1, 1940, to June 30, 1942. Peak dates are applicable particularly to central zone.

Species	Reproductive Activity*								
	Oestrus			Pregnancy			Lactation		
	Earliest	Peak	Latest	Earliest	Peak	Latest	Earliest	Peak	Latest
First Season									
Fox squirrel	December 11	December 30	January 27	January 1	February 1–15	March 22	February 20	March	May 27
Gray squirrel	December 16	January 15	February 11	January 13	February 16–29	March 29	March 1	April	May 31
Second Season									
Fox squirrel	April 20	June 10	July 11	June 19	July 16–31	August 29	August 4	August	September 22
Gray squirrel	May 5	June 30	July 27	July 5	August 5–20	September 9	August 18	September	October 8

*Peak dates determined by averaging data from first and second breeding seasons in the first 2 years of study. Pregnancy peaks are given for a 2-week, and lactation peaks for a 4-week, period.

record for May 27 in fox squirrels, and for May 31 in gray squirrels. These dates marked the latest that first season lactation was observed in the two species, and came after the earliest observed dates of second-season oestrus, which were April 20 in fox squirrels and May 5 in gray squirrels. Since it is probable that neither the latest nursing nor the earliest oestrus was observed, overlap in the two seasons may be greater than indicated in table 15. This table indicates that completion of summer mating in July was distinct; pregnancy extended into late August in fox squirrels and into September in gray squirrels; lactation continued into September in fox squirrels and into October in gray squirrels.

Table 17.—Dates of first and last reproductive activity and duration of squirrel breeding seasons (all zones) in Illinois; data obtained mainly July 1, 1940, to June 30, 1942.

Species	First Season			Second Season		
	Dates of First and Last Reproductive Activity		Days	Dates of First and Last Reproductive Activity		Days
	Oestrus	Lactation		Oestrus	Lactation	
Fox squirrel	December 11	May 27	168	April 20	September 22	155
Gray squirrel	December 16	May 31	167	May 5	October 8	155

The writers believe that most of the females not breeding during the first or winter season fail to do so because of immaturity or senility. Of the two causes, immaturity is probably the more common. Probably poor physical condition is the most important cause of the failure of some old females to produce the second-season litter.

The first and last dates of reproductive condition or activity observed in Illinois during this study and the apparent season duration are given in table 17. Season length appears to be about the same in the two species.

Mating Chase

The most obvious indication of breeding seasons in squirrels is the mating chase. Fox squirrels appear to be shier than gray squirrels in their mating activities. During the present study, the number of mating chases observed, in proportion to populations, was less in fox squirrels; likewise, the average number of fox squirrels per chase was less. Seldom were more than three fox squirrels observed in a single chase, whereas, in gray squirrels, observations were made on chases of nine and of six animals, and many of five or less. The average mating group, however, even in gray squirrels, involved only three or four animals. Chases were enacted indiscriminately in trees, on logs and on the ground.

In the chase in which nine gray squirrels participated, two of the animals were females, and it is believed that the remaining seven were males, one a juvenile. The two females barked continuously. One female, despite her calling, turned and fought the nearest male when pursued too closely; the other, when chased into isolated positions, such as the smaller branches of a tree, was mounted by several males, but copulation was not observed. One of the females was mounted as she raced up a tree, but she fell upon reaching the top, whereupon the male lost his position. The nearest pursuing male often turned to drive back his rivals. This chase covered an acre of dense undergrowth, lasted about 20 minutes, and was well advertised by continuous barking and noisy quarreling. Chases involving a large number of squirrels sometimes split into two or more separate chases. The chases involving nine and six gray squirrels, respectively, occurred late in the forenoon. Observations similar to the foregoing were made by Baker (1944) in Texas.

In both species, barking or "chatting" was noticed more in December than in any other month, but it was more or less common throughout the summer, fall and early winter. Intermittent barking may occur during any month. Although barking is characteristic of mating behavior, it may, of course, denote alarm, surprise, anger and probably other reactions.

Physiological Aspects

In studying the physiological aspects of breeding, it was necessary, due to limitations of personnel and to field conditions, to rely upon gross laboratory examination rather than the more precise technique of vaginal smears and gonad sectioning with microscopical study.

Mossman, Lawlah & Bradley (1932), who studied the male squirrel reproductive tract, including the Cowper's glands, reported the male reproductive organs in fox and gray squirrels to be similar.

Testes.—In both species the testes, fig. 10 and table 14, began to enlarge in September. In mature males, enlargement was from a flaccid to a turgid condition. For the first breeding season the maximum average testis length, December 1–15, was 30.4 millimeters in fox squirrels, and, December 16–January 15, 27.7 millimeters in gray squirrels. Testis length during the second breeding season was slightly greater than in the first or winter season in fox squirrels, but slightly less in gray squirrels. Following the second season, the testes became much smaller and apparently inactive; the minimum average length in mature males for any 15-day period was 20.4 millimeters in fox squirrels and 19.0 millimeters in gray squirrels. These measurements were reached in late August and early September, respectively. At this time, the testes may have been drawn into the abdominal cavity, and the dormant-like condition have continued until some time in September, when the organs began an increase in size that continued until the winter maximum was reached. Testes measurements for juve-

nile males were, of course, much smaller than for adults, the difference being greater in the fall than in the spring.

Weight of testes, which may be a somewhat more accurate indication of breeding stage than testes length, showed greater fluctuation during the breeding seasons than the length measurement. In fox squirrels, peak average weights of 7.38 grams and 7.84 grams for the testes were reached in late December and late April, respectively. In gray squirrels, corresponding data, less reliable due to fewer samples, averaged 6.16 grams for the testes early in January and 5.73 in May; the average of a small number of samples in early April was 5.80 grams. Adult and juvenile testes are illustrated in fig. 10.

Fig. 10.—Testes of adult and juvenile squirrels. *A*, adult fox squirrel; *B*, adult gray squirrel; *C*, juvenile fox squirrel; *D*, juvenile gray squirrel. Epididymis removed in right example of each pair. Coles and Piatt counties, late January, 1944.

Cowper's Glands.—The location, large size and relationship to breeding activity of the Cowper's glands make them a good criterion by which to judge the sexual condition of males. These glands, fig. 11, are paired, discoid bodies, the function of which is production of sperm-carrying fluid. The glands, coiled like a Polygyra snail shell, are situated one on each side of the rectum. Connection with the penis is by duct. When turgid, these glands extend posteriorly, distending the anal orifice and increasing the average body length by about 10 millimeters.

Enlargement in the Cowper's glands in both species was first observed in October, after which development was rapid. The maximum diameter of the glands in each species was about 25 millimeters, reached during the latter half of December. The spring maximum observed was about 23 millimeters, attained about the end of May in fox squirrels and the last 2 weeks of June in gray squirrels. The number of gray squirrels examined was so small that the data for them may not be representative; comparable data for the fox squirrel indicate that the peak diameter of Cowper's glands in the gray squirrel was reached earlier in June than is shown in table 14. Following cessation of breeding in the summer, these glands became dormant and decreased so greatly in size that, in August, September and October, they were difficult to find, even by dissection of the animals.

Scrotum.—Field observations showed that, as the breeding season progressed, the scrotum became comparatively smooth, and both skin and hair assumed an oily, brown-stained appearance, fig. 5. Following the mating season, in June or later, the scrotum lost this rubbed, blackened appearance through sloughing of the skin and replacement of hair and underfur in the molting process. The new skin of the sac was of lighter pigmentation, as in juvenile males, fig. 5. In old squirrels, the loose saclike condition of the scrotum prevailed, whereas in juveniles, because of

the more abdominal position of the testes, the scrotum was less pendent.

Oestrus.—The earliest evidence of first-season or winter oestrus observed in fox squirrel females was December 11 in Alexander County (southern zone), tables 15, 16 and 17. The latest oestrus records for the first season in the southern and central zones were January 27; the two observations were a year apart. In gray squirrels the earliest evidence of winter oestrus was December 16, and the latest was February 11, both observations in the southern zone.

The external indication of oestrus, commonly called "heat," is a swollen, protruding condition of the vulva. During oestrus the uterus is enlarged and congested with blood, by which the vulva is commonly discolored. This condition is easily observed in external examination. Following copulation the congested condition of the uterus clears. The uterus becomes spongy and thick-walled, and fetal nodes, 3 millimeters in length, appear about 10 days after successful coitus.

Pregnancy.—An attempt was made early in the survey to distinguish oestrus and early pregnancy by the use of vaginal smears, but this proved impractical under conditions prevailing in the field. The oestrual period thus was probably not distinguished as precisely as is desirable, and perhaps an unknown number of very early pregnancies were listed under the heading of oestrus. Pregnancy could be determined with some certainty by noting the relaxed and perforated state of the vulva and development of the mammae. Somewhat advanced stages of pregnancy (15 millimeter fetuses) could be detected by palpating the lower abdomen.

The earliest and latest first-season pregnancy records for fox squirrels were January 1 (one animal with 3 fetuses averaging 6 millimeters in length) and March 22 (one animal with 3 fetuses averaging 19 millimeters in length), table 16. The first-season peak of fox squirrel pregnancy, based on 43 adult females, 23 of them pregnant, table 15, came during the first half of February. In gray squir-

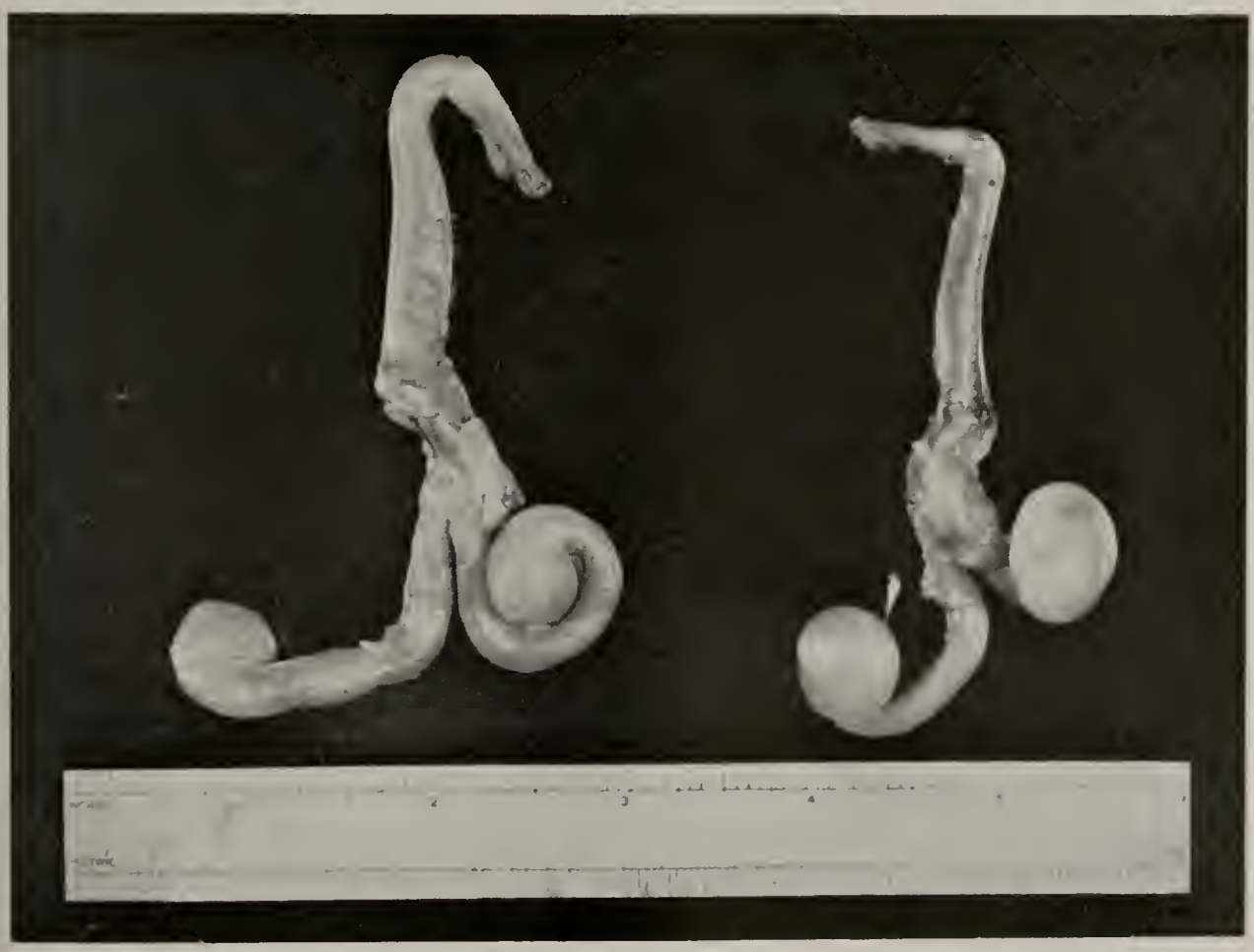

Fig. 11.—Glans penis and urethra of adult male squirrel, with Cowper's glands attached in an uncoiled and in a nearly natural position in each case. Left, fox squirrel; right, gray squirrel. Coles County, late January, 1944.

rels, the earliest and latest pregnancy records were January 13 (one animal with 2 fetuses averaging 4 millimeters in length) and March 29 (one animal with 3 fetuses averaging 15 millimeters in length), table 16. Peak gray squirrel pregnancy for the first season, based on 16 adult females, 9 of them pregnant, came about the middle of February, table 15. The earliest and latest second-season pregnancy records were June 19 and August 29 for fox squirrels, and July 5 and September 9 for gray squirrels, table 16. Fox squirrel females taken on August 15 and 29 each contained 2 fetuses; those of the first averaged 20 millimeters in length and those of the second 48 millimeters. Fig. 12 shows embryos at the age of about 15 days in the uterus of a fox squirrel.

Gestation.—Previous writers have reported difficulty in determining exactly the

Fig. 12.—Uterus of pregnant fox squirrel. Right horn contains two normal fetuses and one apparently in process of being resorbed.

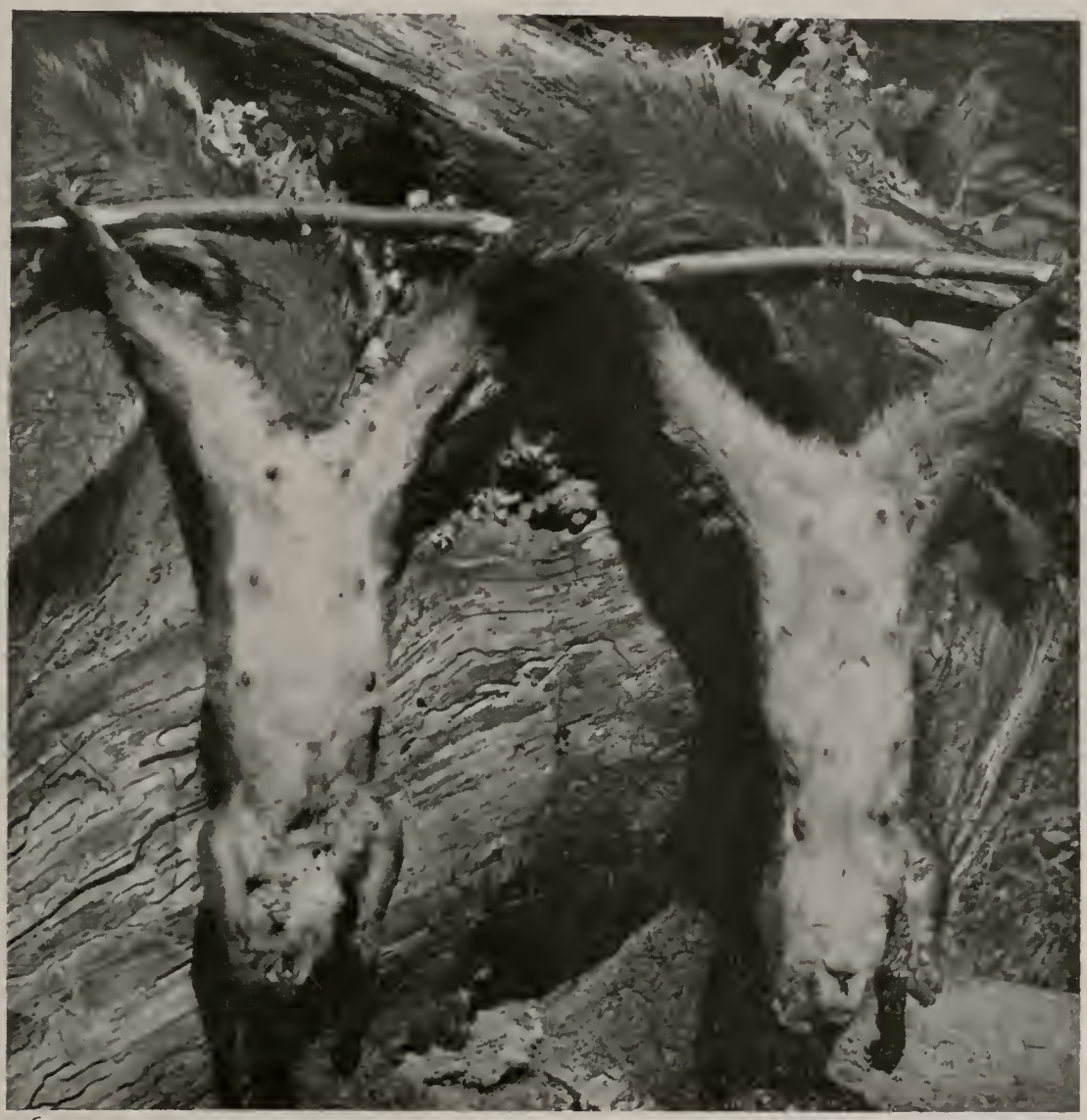

Fig. 13.—Lactating gray squirrels, Coles County, September 15, 1944. Note distended appearance of mammary glands and nipples.

gestation period in squirrels. Allen (1942, 1943) and Lyon (1936) indicated that gestation in fox squirrels is probably about 45 days. Since the oestrual peak in this species in Illinois, as determined by the present study, was late in December and early in January, a 45-day term would place the birth peak in February. The oestrus records in table 15 and the birth records in table 18 indicate that the gestation period in Illinois fox squirrels is about 45 days. Seton (1928, 4: 44), quoting Powers, gives the gestation period in gray squirrels as 44 days. Goodrum (1940) and Baumgartner (1940) also considered that 44 days was the probable term. The oestrus-mating peak in the small number of gray squirrels observed in the Illinois study was early or mid January, table 15, and the birth peak was early March, table 18, indicating an average gestation period of about that suggested by Goodrum, Baumgartner and other authors mentioned above.

Mammae.—In both fox and gray squirrels, the mammae are eight in number and are arranged in four pairs, occupying the ventral body surface behind the forelegs, fig. 13. Allen (1942) designated the mammae positions as pectoral 1, pectoral 2, abdominal and inguinal. He stated that, in the fox squirrel, the abdominal pair develops first following insemination, and that the usual order of development is abdominal, inguinal, pectoral 2 and pectoral 1. In some cases, however, Allen found that the pectoral 2 and abdominal pairs developed equally, or the former preceded the latter in development. The pectoral 1 pair may not be functional in some cases. Milk can be squeezed from the nipples a few days before the young are born and, in some cases at least, for 2 or 3 weeks after the young are

weaned. Thus the glands may contain milk for 3 months or more subsequent to parturition.

The teats and mammary glands of squirrels develop rapidly after pregnancy begins. In both species, the teats swell and become black pigmented. The glandular tissue becomes thickened and spreads to cover the ventral body surface. Hair on the mammae of nursing females becomes worn and matted, and the nipples show an obviously distended and stretched condition, fig. 13. On cessation of lactation the teats become greatly reduced and, in fox squirrels at least, the black pigmented condition of the nipples remains apparent, fig. 6.

YOUNG REARING

In the term *young rearing,* as it is usually employed in this paper, are included the biological phenomena associated with young squirrels.

Birth Dates

In the spring of 1941 birth dates were estimated for 35 litters of fox squirrels and 4 litters of gray squirrels. Most of

Table 18.—Birth dates by 2-week periods for 35 fox squirrel litters and 4 gray squirrel litters in Illinois, all zones, spring, 1941.

Species	February		March		April
	1–15	16–28	1–15	16–31	1–15
Fox squirrel	0	20	11	4	0
Gray squirrel	0	1	2	1	0

Table 19.—Aging criteria for juvenile fox squirrels in Illinois. Data obtained principally from caged animals, which were weaned at the age of about 10 weeks.

Age in Weeks	Condition of Eyes	Condition of Ears	Condition of Incisors		Average Weight in Pounds*	Pelage
			Lower	Upper		
1	Closed	Closed	Not erupted	Not erupted	0.05	Naked, except for bristles on chin and nose; claws well developed; body dark pinkish.
2	Closed	Closed	Not erupted	Not erupted	0.12	Black bristles prominent.
3	Closed	Closed	Showing	Not erupted	0.15	Grayish-brown hair on dorsal surface.
4	Open (milky)	Closed	1 mm.	Not erupted	0.23	Short brownish hair covering body.
5	Open (clear)	Closed	2 mm.	Showing	0.31	Guard hairs on tail ¼ inch or longer.
6	Open	Closed or open	3 mm.	1 mm.	0.36	Brownish hair turning rufus.
7	Open	Open	4 mm.	2 mm.	0.41	Tail beginning to bush out.
8†	Open	Open	5 mm.	3 mm.	0.45	Hair well developed, tail bushed out.

*Average of 7 individuals weighed at weekly intervals.
†Squirrels 9 and 10 weeks old similar in appearance to these in eighth week but larger.

the litters had been born in wood duck nest boxes, but a few of the fox squirrels in leaf nests. The distribution of estimated birth dates by 2-week periods is shown in table 18.

In addition to the fox squirrel births included in table 18 were those involving two nursing females taken on February 20 and another on February 21. In these animals the uterus had returned to approximately normal size and all showed placental scars. Scars do not appear until the uterus has cleared, several days following birth of the young.

The earliest first-season birth date estimated for Illinois gray squirrels (only four litters observed) was February 20 and the latest March 18. One pregnant gray squirrel female, almost to term, was taken March 29, indicating first-season young are born at least through March.

No birth records were obtained for the second season in 1941, or for either the first or second season in 1942. From the numerous records of oestrus, pregnancy and lactation in both species, however, the birth peaks can be approximated.

Birth Sites

Because squirrel dens and leaf nests are discussed later in this report, no details on birth sites are given here. Although young are born in both cavity and leaf nests, it appears that the cavity type is preferred. More litters were found in natural cavities than in leaf nests, and many litters were found in boxes constructed and erected for wood ducks. The senior author checked, on the Mason County State Forest, a total of 89 leaf nests during the first half of April and found only 2 litters of partly grown fox squirrels. Only fox squirrels inhabited this area. Goodrum (1940) states that in east Texas gray squirrels are usually born in hollows of trees, but that they may be transferred to leaf nests. Both species move their young from nest to nest when disturbed. On such occasions the mother grasps the young in her mouth, in the manner of a cat moving her kittens.

Lactation

The young of both fox and gray squirrels nurse for 8 weeks or more. The earliest and latest records of lactation during the first season are for fox squirrels, February 20 and May 27; for gray squirrels, March 1 and May 31, table 16. Most fox squirrel females had finished nursing by May 1; most gray squirrel females by May 15. Lactation data for both species and for both breeding seasons are given by 2-week periods in table 15.

As indicated in table 15, lactation in the Illinois fox squirrels studied was most prevalent in March and August, when 78 and 44 per cent, respectively, of the adult females handled showed this condition. In gray squirrels, lactation was most prevalent in April and September, when 75 and 60 per cent, respectively, of the adult females handled were nursing. In some females the cessation of lactation was found to be delayed. In both species, females showing second-season oestrus still carried first-season milk, which could readily be exuded by pinching the nipples. The young observed during the study were weaned when about 8 or 10 weeks old.

Development of Young

Fox squirrels handled shortly after birth were 50 to 60 millimeters in length and weighed 14 to 18 grams (about one-half ounce). They were dark pinkish, naked, except for vibrissae about the nose and chin, and virtually helpless. The claws were well developed. Both the eyes and ears were closed, and neither the upper nor lower incisors had erupted. The vibrissae grew rapidly, and hair first appeared on the upper dorsal surface at an age of 8 or 10 days. Further growth characteristics are detailed in table 19, data for which were obtained principally from caged animals.

Because of a growth differential between caged and wild specimens, the data in table 19 may vary from corresponding data for wild squirrels by 2 or 3 days. Information relating to pelage is probably subject to wider variation than that pertaining to eyes, ears, teeth or weight.

There was no opportunity during the study to weigh or measure gray squirrels at birth. These animals are smaller and somewhat lighter in color than fox squirrels.

At weaning age, or during late April and May and late August and September

Table 20.—Litter size in Illinois squirrels (all zones) as indicated by nest, fetus and placental scar counts, 1941 and 1942.

Year	Litters*		Fetuses				Placental Scars				Litter Averages					
	First Season		First Season		Second Season		First Season		Second Season		First Season		Second Season		First and Second Seasons	
	Number Litters	Average	Number Litters	Average	Number Litters	Average	Number Litters	Average	Number Litters	Average	Number Litters	Average	Number Litters	Average	Number Litters	Average
Fox Squirrel																
1941	26	2.65	10	2.50	4	2.75	3	2.66	1	3.00	39	2.61	5	2.80	44	2.63
1942	7	2.71	10	2.30	7	2.28	15	2.20	2	3.00	32	2.34	9	2.44	41	2.36
1941–1942	*33*	*2.66*	*20*	*2.40*	*11*	*2.45*	*18*	*2.27*	*3*	*3.00*	*71*	*2.49*	*14*	*2.57*	*85*	*2.51*
Gray Squirrel																
1941	5	3.00	2	2.00	1	3.00	2	2.50	5	2.40	9	2.66	6	2.50	15	2.60
1942	1	4.00	1	3.00	1	2.00	16	2.68	0	....	18	2.77	1	2.00	19	2.73
1941–1942	*6*	*3.16*	*3*	*2.33*	*2*	*2.50*	*18*	*2.66*	*5*	*2.40*	*27*	*2.74*	*7*	*2.43*	*34*	*2.68*

*No second-season records were obtained for post-birth litters; most first-season records were obtained from litters born in nest boxes erected for wood ducks.

for most individuals, fox squirrels were found to average about one-half pound in weight; gray squirrels, on the basis of a very few samples, about one-third pound or somewhat less. By mid June, young fox squirrels handled averaged slightly more than 1 pound, and young gray squirrels about 0.6 pound.

At the time of weaning the pelage in both species, including that of the tail, was well developed. The young animals were active, being able to leave the nest and, with some awkwardness, to forage for buds and other food. Manual dexterity in gray squirrels seemed to develop somewhat more rapidly than in fox squirrels. At or near weaning age the young of both species began to join the adults in travels, and were often observed in litter groups feeding on elm seeds and buds in the spring, and acorns and hickory nuts in the late summer and early fall. It is doubtful, however, if 8- to 10-week old squirrels are fully self-sustaining. Allen (1942, 1943) considers that fox squirrels are not self-sustaining until they are between 3 and 4 months old, a belief shared by the present writers. Development in first- and second-season squirrels appears to be at about the same rate.

Litter Size

The average size of litters in Illinois squirrels was determined by counts of young in nests, of fetuses and placental scars, table 20. As found from study of 85 litters of fox squirrels and 34 litters of gray squirrels, the average size of litters in grays was somewhat larger than that in fox squirrels, but the difference was not significant. Neither was there a great difference in the size of the first- and second-season litters in either species. Gray squirrels showed the larger average in the first season; fox squirrels the larger in the second season.

During the course of this study, interesting data were gathered on the possible effect of food quality on fecundity. The investigation was conducted mainly on the rougher, wooded parts of Illinois, where soil fertility is comparatively low, and where the staple squirrel foods consist principally of nuts, acorns, fruits, berries and buds. Other investigators in Illinois, working on the more fertile agricultural areas where corn is the main staple, found that litter size in fox squirrels there was larger than was found by the writers on wooded range, table 21.

The nutritional value of corn is probably greater than that of the combination of nuts, acorns, buds and fruits of wooded localities, and since, on most Illinois farms, corn is abundant at all seasons, either at cribs or in fields, farmland fox squirrels in this state are well nourished. Most woods-inhabiting squirrels in Illinois appear to suffer no serious food shortages,

Table 21.—Litter size in fox squirrels in two types of Illinois habitat, 1941 and 1942.

YEAR	FARMLAND				OAK-HICKORY UPLAND	
	Urbana Township, Champaign County*		Bright Land Farm, Cook County†			
	Number Litters	Average Number Young	Number Litters	Average Number Young	Number Litters	Average Number Young
1941	6	3.66	....	....	44	2.63
1942	4	3.75	15	3.20	41	2.36
1941–1942	*10*	*3.70*	*15*	*3.20*	*85*	*2.51*

*Litter counts by R. E. Hesselschwerdt, leader of Illinois Federal Aid Project 4-R. In March, 1945, the inspection of den boxes in Urbana Township by Dr. Ralph E. Yeatter revealed four litters totaling 14 young, an average of 3.50 per litter.

†Litter counts by Dr. William H. Elder, Assistant Game Technician, Illinois Natural History Survey.

but midwinter supplies are often less abundant in the woodlands than in farm regions. The difference in average litter size in the two habitats, as shown in table 21, is significant. The writers believe that the superior quality and quantity of food characteristic of many farmland habitats may be the main reason for the differential in litter size. No comparative data are available for gray squirrels, but it is of interest that 34 litters found in woodland types averaged 2.68 young, table 20, a number smaller than the average for farmland fox squirrels.

ILLINOIS HABITATS

Forest cover is the basic requirement of fox and gray squirrel habitats, and the kinds, combinations and sizes of the trees, shrubs and brambles they contain, and the density of the stand, to a large extent determine their quality. Since the occurrence and growth of woody vegetation vary with soil, climate and the activities of man and other animals, the types of squirrel habitats in Illinois are many. Although the variations in squirrel habitats are not readily classified, it is possible to include them under two main headings: black prairie and woodlands.

Black Prairie Habitats

The black prairie region of Illinois is overwhelmingly agricultural and is dominated by the production of corn, soybeans and wheat. It contains very little wooded area, and therefore has an acute shortage of den trees. Subtypes making up the squirrel range in this region are woodlots, wooded stream bottoms, hedgerows, and fields and farmyards with scattered trees or groves. The woodlots are predominantly oak-hickory. Walnut plantations are widely scattered and aggregate only a very small acreage. In the bottoms, the main trees are elms, maples, sycamore, white ash and other wet-site species; and on the bluffs, oaks and hickories are the principal trees. The only important hedgerow species is the Osage orange, the older and larger hedges of which are now steadily being pulled. Practically all wooded areas on the black prairie are grazed.

Fig. 14.—Typical farm habitat of fox squirrels on Illinois black prairie type, Champaign County, February, 1941.

Staple squirrel foods in this region, in probable order of importance, are corn,

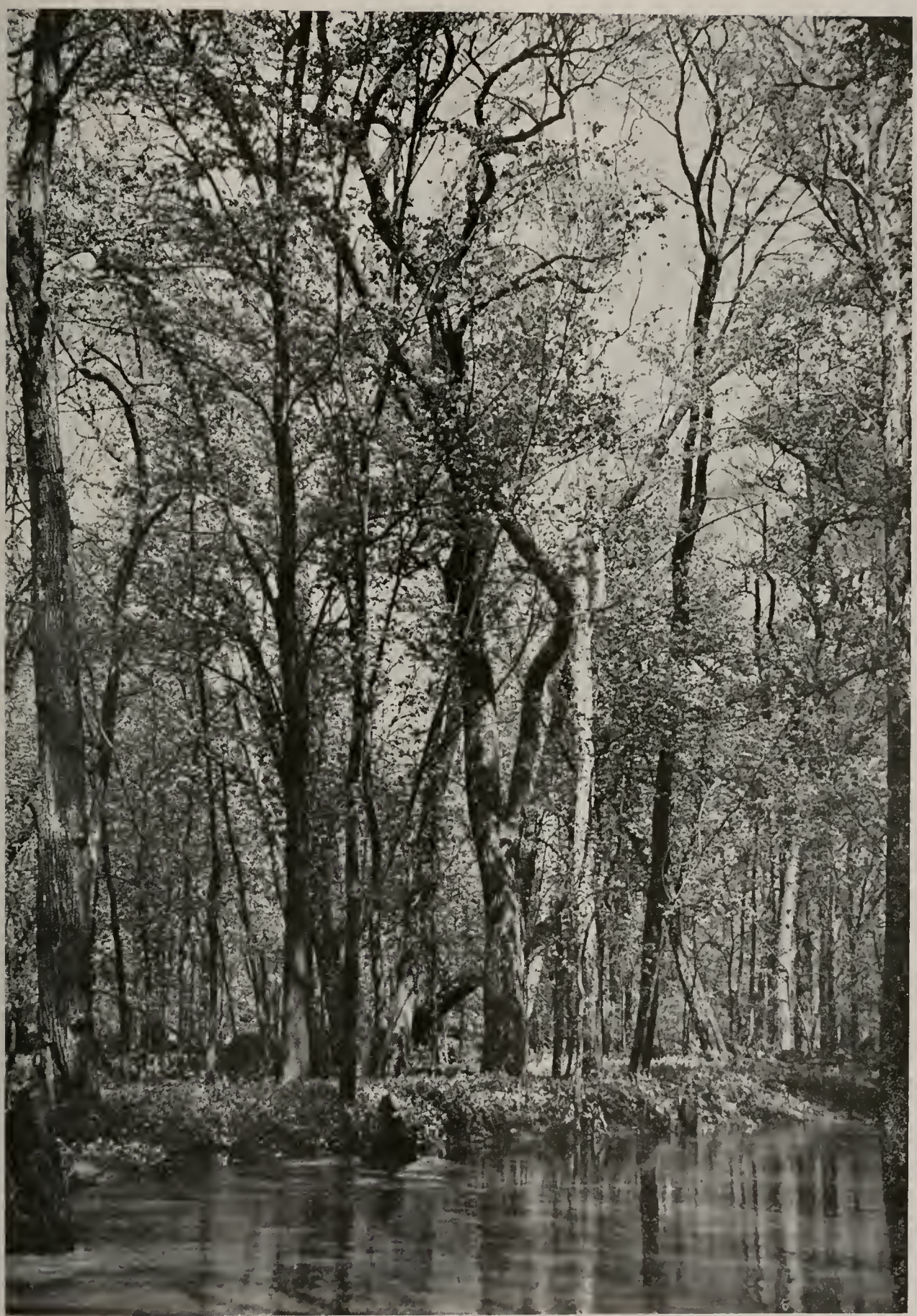

Fig. 15.—Mature elm-maple river-bottom type, Piatt County. Pin oak through the northern two-thirds of Illinois, and pecan and other hickories in the southern half of the state, add to the quality of many river-bottom squirrel habitats by helping to insure a year around food supply. The pure elm-maple type is rich in squirrel foods during the spring, but low in this respect during other seasons of the year.

acorns, nuts, buds and seeds, especially of elms and maples, and Osage orange fruits. Water is supplied by streams and ditches and probably by such succulent foods as berries and green corn. The fox squirrel exclusively is found in the black prairie, except in towns and in a few heavily wooded and ungrazed bottoms. Fig. 14 illustrates this type.

Fig. 16.—The cypress or cypress-tupelo gum type in the extreme southern tip of Illinois is fair squirrel range. Foods offered by this type are cypress seeds and tupelo gum drupes. Shown here is a tupelo gum bottom, Massac County.

Woodland Habitats

The term woodland, as used here, denotes squirrel habitats other than the woodlot types found on the black prairie. The Illinois woodland habitats contain a vastly larger total wooded area, as well as much larger wooded tracts, than the black prairie. A rough distinction between the two types of squirrel habitat is that black prairie woodlots are surrounded by fields, while woodland range is only irregularly broken by cultivated fields or other open land. Woodland habitats, for convenience, may be divided into two main subtypes: the river bluffs and bottoms and the wooded upland.

River Bluffs and Bottoms.—Constituting this type are the bottoms and contiguous bluffs of the various river systems bordering and within Illinois. The most important wooded areas of this type are along the Mississippi, Illinois, Ohio, Wabash, Rock, Kaskaskia, Embarrass, Big Muddy and Cache rivers and aggregate more than 2,250,000 acres (Case & Myers 1934). The variety of trees and shrubs on this extensive area is great. The principal bottomland trees in the northern half of the state are elms and maples, and in the southern half these species plus oak, hickory and pecan; cypress and tupelo gum swamps are found in a few wet bottoms in extreme southern Illinois. The bluffs in all cases support oaks and hickories, with walnut occurring in many localities. Shrubs are of wide variety and may be considered an important part of the cover.

A bottomland habitat in central Illinois is illustrated in fig. 15. A southern Illinois habitat, principally tupelo gum, is shown in fig. 16.

The river bluffs and bottoms type is found in Illinois in varying densities and stages of maturity. Grazing is the rule, as in black prairie woodlots, but not many of the bottomland areas are seriously injured as squirrel range by this practice. Den trees are generally ample, but extensive lumbering is now seriously reducing both the number of den trees and the number of areas containing such trees.

Staple foods, in probable order of importance, are acorns, nuts, buds and seeds (especially of elms and maples), and corn. Water is amply supplied by streams, lakes and springs. Both fox and gray squirrels are common in this habitat, but the latter are much more restricted than the former in distribution.

Wooded Upland.—The wooded upland possesses many of the qualities of the river bluffs and bottoms type, but contains a larger percentage of oak, hickory, and, in northwestern, central and southwestern localities, of walnut. Fruit-bearing shrubs, wild grapes, bittersweet and brambles supplement the basic food supply of nuts and acorns. Many of the wooded areas border fields of corn, which thus becomes available as staple food, fig. 17. From the standpoint of food, the wooded upland type affords a habitat of higher quality than does the river bluffs and bottoms type, except perhaps in those bottomland situations in which pecans are plentiful. Den trees are not so abundant on the wooded uplands as on the bottoms and bluffs, due both to the presence of large numbers of hickories and other species not given to formation of cavities and to the fact that upland stands have been more continuously and selectively logged, especially of oaks. The residual upland stands, as a result, are younger and more vigorous. Despite this condition there is no pressing

Fig. 17.—Good squirrel country in Effingham County. Oak-hickory woods adjacent to cornfields constitute a habitat with a dependable year around food supply for fox and gray squirrels.

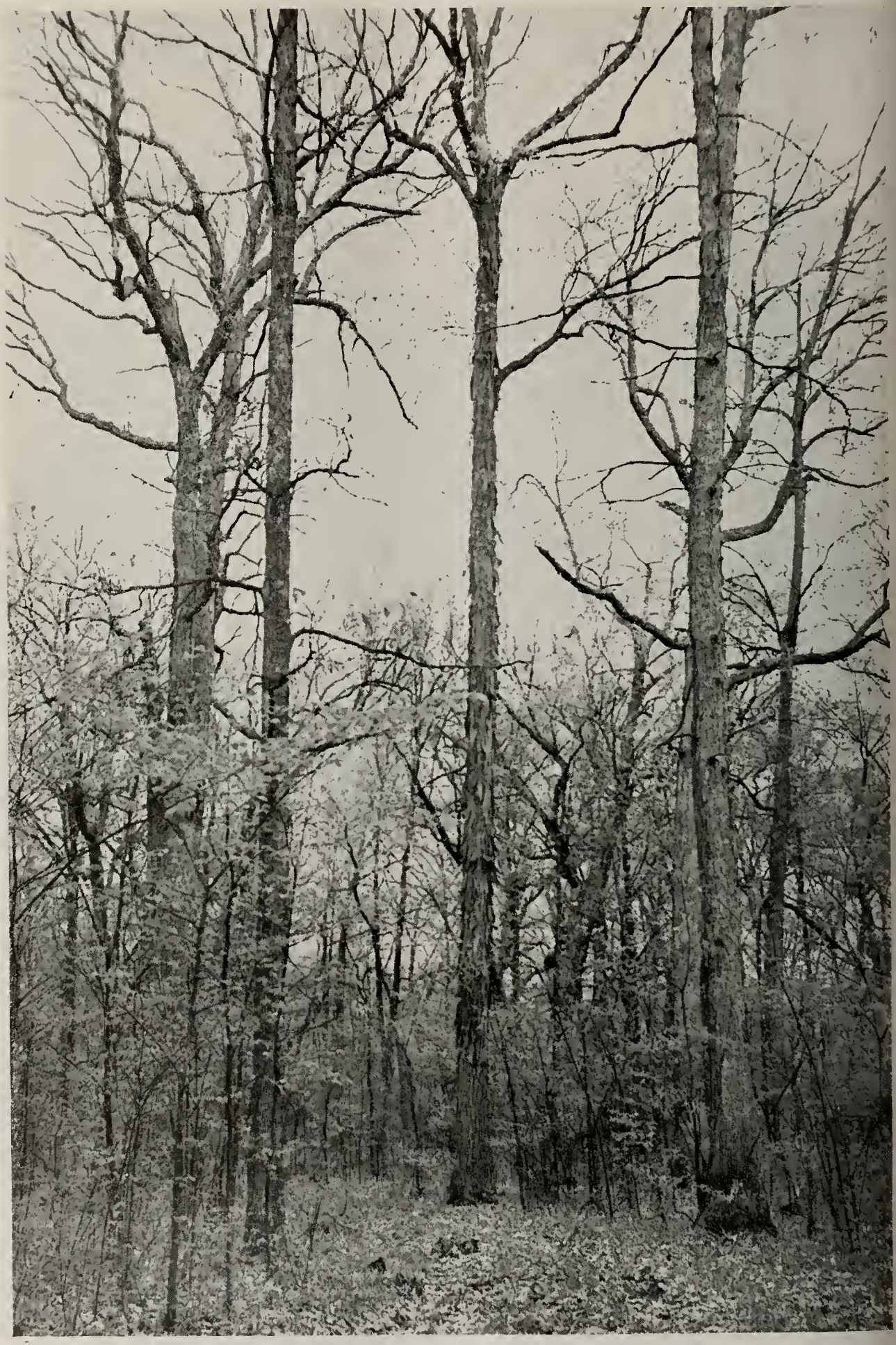

Fig. 18.—Oak-hickory type in Piatt County, a high quality fox squirrel habitat. Here various tree species provide food through most of the year.

den shortage on the wooded uplands. Water is not so plentiful, but in most upland areas is amply supplied by small runs and springs. Grazing is heavier than on the more rugged bluffs. Fire offers a somewhat greater hazard. The cutting of walnut for military use has been more widespread and intensive on the wooded uplands than in any other squirrel habitat in Illinois.

The wooded upland type reaches its best development in several southern and southwestern counties, but there is an appreciable acreage of it in Jo Daviess, Carroll and other northwestern counties. The extensive black oak stands in Mason and Cass counties may be considered a part of the wooded upland type. The aggregate wooded upland acreage is roughly twice that of the river bluffs and bottoms, or about 4,500,000 acres. Both fox and gray squirrels inhabit the upland type, the former occurring throughout, and the latter, as in the case of the river bottoms and bluffs, being restricted generally to areas having heavy forest cover. Wooded upland habitats are shown in figs. 18 and 19.

Miscellaneous Habitats

Throughout Illinois there are habitat types other than those described where squirrels occur in varying numbers. The most common are residence districts of cities and villages, parks, estates, cemeteries and college campuses. There may be some question as to whether urban-dwelling animals are comparable to wild or non-urban populations. Observations by the writers indicate that wild and urban squirrels have identical breeding periods and great similarity in feeding and nesting habits. It is estimated that the adjoining cities of Champaign and Urbana, with a total human population of about 40,000, have 1,000 squirrels, all of which are gray. It is probable that no Illinois municipality is without a squirrel population, and that

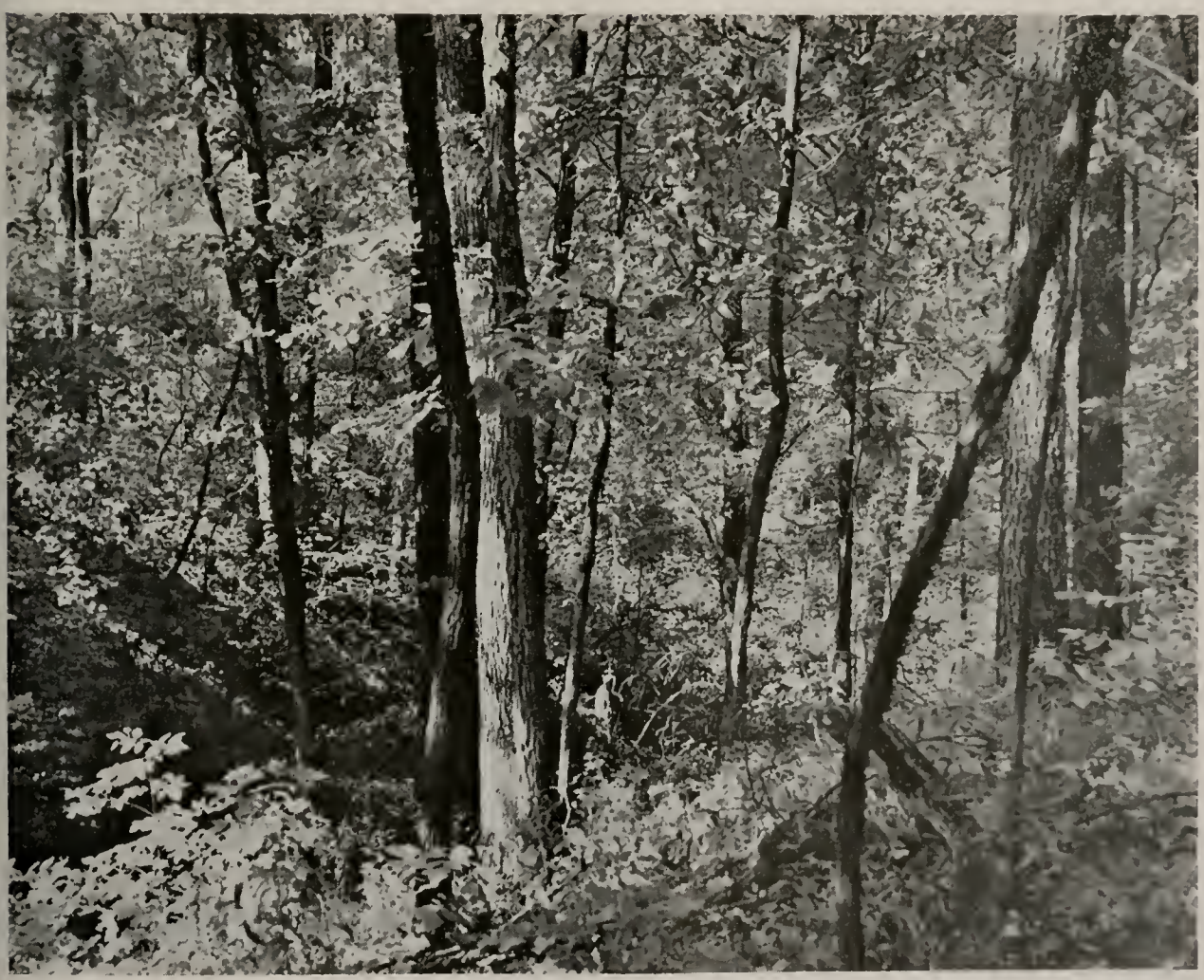

Fig. 19.—Dense oak-hickory-hard maple type, Coles County, unpastured and undamaged by fire. A typical and high quality range for both fox and gray squirrels.

200,000 or more squirrels are resident in municipal areas in the state.

Stripmines, which provide an unimportant habitat in the state, are best represented in Vermilion, Perry, Saline and Fulton counties (Yeager 1942), fig. 20. Only in Vermilion County has forest succession in this type of habitat advanced far enough to attract gray squirrels. The cover usually found in stripmine areas is an early stage of river-bottom forest, consisting mainly of cottonwood, sycamore, willows, elms and maples, a combination low in quality as all-year range. Buds, flowers and seeds of trees, and fruits of brambles and wild strawberries offer an appreciable amount of spring and summer forage. Hickory nuts and acorns are seldom represented in these stands. Probably not more than a few hundred squirrels, most of which are fox squirrels, are resident on Illinois stripped lands.

FOODS AND FEEDING

In this investigation no study of squirrel foods based on detailed laboratory analysis of stomach contents was attempted. Through 2 years of field work, however, every opportunity to observe and record squirrel feeding was utilized. Many aspects of the study—particularly those associated with collecting specimens, trapping live animals and making inspections of den boxes—were well adapted to the making of reliable observations. In 716 hours devoted to hunting, several hundred records on squirrel feeding were gathered. Although the nature of the data precludes quantitative evaluation, the writers believe that a good general picture of feeding, based on frequency of observation, was obtained.

In the following discussion, as well as in table 22, no food is listed unless squirrels were observed eating it, or unless other positive evidence of its having been eaten was obtained. Food remains of squirrels were easily distinguished from those of other rodents by the location of "cuttings" as well as by incisor marks on them (Pearce 1938). Only fresh material was used in these determinations. It was impractical to distinguish between fox and gray squirrel food remains, and for this reason, as well as because of great similarity in food habitats, this section of our report is, in general, applicable to both spe-

Fig. 20.—Stripmines, lacking in trees bearing acorns and nuts, are poor year around squirrel habitats. Vermilion County.

Fig. 21.—This Piatt County woodlot of mixed hardwoods, including hickory, black oak, white oak, walnut, elm and soft maple, offers staple foods at all seasons. A nearby cornfield and an Osage orange hedge supplement this food supply. The mature trees contain an ample number of cavities. These characteristics probably represent the optimum in fox squirrel habitat.

cies. Information peculiar to either species is detailed separately.

Food Sources

In table 22, 76 species or groups of squirrel food plants are tabulated. Included are 56 trees and shrubs, 2 groups of vines, 4 brambles, 6 wild herbs, 7 cultivated crops and various fungi. The list is, of course, incomplete; the writers are certain that other plants, particularly herbs, are taken in small amounts. The unlisted foods, however, are of little significance in the squirrel dietary.

Although many items are listed in table 22, the important staple food sources of Illinois squirrels comprise only a half dozen plant groups. There are the hickories, including pecan, and the oaks, walnuts, elms, mulberry and field corn. An imposing list of other foods may be important locally or seasonally. Examples are Osage orange and wild grapes. Boulware (1941) reported local use of eucalyptus by fox squirrels in California, and Dambach (1942) similar use of hawthorn (*Crataegus mollis*) by gray squirrels in Ohio. Woods (1941) reported that a blackberry patch, wild plum thicket or cultivated orchard may furnish the bulk of the food for one or a few squirrels during the few weeks when fruits of such plantings are available. However, no matter how varied and abundant auxiliary seasonal foods may be, most wild squirrels are forced to rely for much of the year on one or more of the staples listed. An environment without a variety of staples may be of little value, and may actually be uninhabitable, except when auxiliary foods prevail. Common examples of such a deficient environment are river-bottom forests of pure elm-maple or extensive cottonwood-willow flats, even those bordering cornfields.

From the standpoint of food, the importance of mixed stands in squirrel habitats is clearly apparent, fig. 21. This factor is discussed by Goodrum (1938). Most of the original forests were of suitable composition, especially those of hardwoods or mixtures of hardwoods and conifers. Most of the larger natural stands now present in Illinois meet the staple food

Table 22.—Plant food sources of Illinois squirrels as observed in field, 1940, 1941 and 1942.

SPECIES	PARTS UTILIZED	PERIOD OF UTILIZATION	STORED	RATING* S –Staple SS–Substaple A –Auxiliary E –Emergency
TREES AND SHRUBS				
Pecan, *Carya pecan*	Nuts	September 1 until exhausted; sometimes all year	x	S
Shagbark, *Carya ovata*	Nuts	August 15 until exhausted; sometimes all year	x	S
Mockernut, *Carya alba*	Nuts	August 15 until exhausted; sometimes all year	x	SS
Pignut, *Carya glabra*	Nuts	September 1 until exhausted; sometimes all year	x	SS
Small pignut, *Carya ovalis*	Nuts	August 25 until exhausted; sometimes all year	x	S
Big shellbark, *Carya laciniosa*	Nuts	September 1 until exhausted; sometimes all year	x	SS
Bitternut, *Carya cordiformis*	Nuts	September 1 until exhausted; sometimes all year	x	SS
Black walnut, *Juglans nigra*	Nuts	September 1 until exhausted; sometimes all year	x	S
Butternut, *Juglans cinerea*	Nuts	September–November	x	A
Red oak, *Quercus borealis maxima*	Buds and acorns	Late April and May; September 1 into winter or later	x	SS
Black oak, *Quercus velutina*	Buds and acorns	Late April and May; July 15 into winter or later	x	S
Pin oak, *Quercus palustris*	Buds and acorns	Late April and May; July 15 into winter or later	x	S
White oak, *Quercus alba*	Buds and acorns	Late April and May; August 1 into winter or later	x	S
Swamp white oak, *Quercus bicolor*	Buds and acorns	Late April and May; August 1 into winter or later	x	A
Bur oak, *Quercus macrocarpa*	Buds and acorns	Late April and May; August 1 into winter or later	x	SS
Chinquapin oak, *Quercus Muhlenbergii*	Buds and acorns	Late April and May; August 1 into winter or later	x	A
Shingle oak, *Quercus imbricaria*	Buds and acorns	Late April and May; September and October or later	?	A
American elm, *Ulmus americana*	Buds and seeds	February and March; April and May	...	S
Slippery elm, *Ulmus fulva*	Buds and seeds	February and March; April and May	...	A
Winged elm, *Ulmus alata*	Buds and seeds	February and March; April and May	...	A
Silver maple, *Acer saccharinum*	Buds and seeds	March and April; late April and May	...	A
Red maple, *Acer rubrum*	Buds and seeds	March and April; late April and May	...	A
Sugar maple, *Acer saccharum*	Buds and seeds	March and April; September and October	...	A

*See footnote, page 501.

Table 22—Continued

SPECIES	PARTS UTILIZED	PERIOD OF UTILIZATION	STORED	RATING* S –Staple SS–Substaple A –Auxiliary E –Emergency
TREES AND SHRUBS—Continued				
Box elder, *Acer negundo*	Seeds	September into winter	...	A
Hackberry, *Celtis* spp.	Berries	July–October	...	A
Beech, *Fagus grandifolia*	Nutlets	Late August into October or later	?	SS
Buckeye, *Aesculus glabra*	Nuts	Sampled in September but not eaten in quantity	...	A
Basswood, *Tilia glabra*	Berries	July 15 to September	...	A
Ironwood, *Ostrya virginiana*	Nutlets	Late August to November	...	A
Red mulberry, *Morus rubra*	Fruit	Mid May to August	...	S
Osage orange, *Toxylon pomiferum*	Fruit	August into the winter	...	SS
Tulip poplar, *Liriodendron tulipifera*	Buds; seeds (in cones)	May; September–December	...	A
Red gum, *Liquidambar styraciflua*	Buds; seeds (in capsules)	May; October–February	...	A
Black locust, *Robinia pseudoacacia*	Seeds	October–December	...	E
Honey locust, *Gleditsia triacanthos*	Pulp of pods; seeds	September–November	...	A
Kentucky coffee tree, *Gymnocladus dioicus*	Pulp of pods	Fall into winter	...	A
Redbud, *Cercis canadensis*	Seeds	Fall into winter	...	E
White ash, *Fraxinus americana*	Seeds	June (so far as observed)	...	A
Pumpkin ash, *Fraxinus profunda*	Seeds	June (so far as observed)	...	A
Cucumber tree, *Magnolia acuminata*	Seeds (in cones)	Fall into winter	...	A
Tupelo gum, *Nyssa aquatica*	Seeds (kernels)	October–February	...	A
Black gum, *Nyssa sylvatica*	Fruit	September and October	...	A
Black cherry, *Prunus serotina*	Fruit	August and early September	...	A
Cypress, *Taxodium distichum*	Seeds (in cones)	October–March	...	SS
Red cedar, *Juniperus virginiana*	Berries	November–March	...	E

*See footnote, page 501.

Table 22—Continued

Species	Parts Utilized	Period of Utilization	Stored	Rating* S –Staple SS–Substaple A –Auxiliary E –Emergency
Trees and Shrubs—Continued				
Persimmon, *Diospyros virginiana*	Fruit	Late September into December	...	A
Pawpaw, *Asimina triloba*	Fruit	August–October	...	A
Hawthorn, *Crataegus* spp.	Fruit	October and November	...	A
Apple, *Malus* spp.	Fruits and seeds	September–December	...	A
Sassafras, *Sassafras officinale*	Fruit	August 15 through September	...	A
Flowering dogwood, *Cornus florida*	Fruit	September and October	...	A
Gray dogwood, *Cornus paniculata*	Fruit	August–October	...	A
Wild plum, *Prunus americana*	Fruit	August and September	...	A
Hazelnut, *Corylus americana*	Nuts	September–January	x	SS
Sumach, *Rhus* spp.	Seeds	December and January	...	E
Serviceberry, *Amelanchier canadensis*	Fruit	Late June and July	...	A
Vines				
Wild grapes, *Vitis* spp.	Berries	September–February	...	A and E
Bittersweet, *Celastrus scandens*	Berries	September–February	...	E
Brambles				
Dewberry, *Rubus* spp.	Fruit	June and July	...	A
Blackberry, *Rubus* spp.	Fruit	July and August	...	A
Raspberry, *Rubus* spp.	Fruit	June and July	...	A
Gooseberry, *Ribes* spp.	Fruit	July and August	...	A

*See footnote, page 501.

Table 22—Continued

SPECIES	PARTS UTILIZED	PERIOD OF UTILIZATION	STORED	RATING* S –Staple SS–Substaple A –Auxiliary E –Emergency
HERBS				
Corn, *Zea mays*	Kernels dry and in milk	July and August; September through winter	...	S
Wheat, *Triticum* sp.	Kernels	July and August	...	A
Rye, *Secale* sp.	Kernels	June and July	...	A
Soy bean, *Soja max*	Beans	September–December	...	A
Bluegrass, *Poa pratensis*	Seeds	July and August	...	A
Squash, *Cucurbita* sp.	Seeds	August–October	...	A
Pumpkin, *Cucurbita*, sp.	Seeds	September and October	...	A
Watermelon, *Citrullus* sp.	Seeds	July–October	...	A
Pokeweed, *Phytolacca decandra*	Berries	September–November	...	A
Burdock, *Arctium lappa*	Seeds	October	...	E
Climbing buckwheat, *Polygonum scandens*	Seeds	September and October	...	A?
Smartweeds, *Polygonum* spp.	Seeds	October–December	...	E
Lotus, *Nelumbo pentapetala*†	Seeds	October–January	...	E
FUNGI				
Agaricaceae and others	Fruiting body	Late spring through summer	?	A

**Staple* foods are those of most importance, having statewide distribution; *Substaple* foods are preferred foods, important locally, or are thinly distributed over a large part or all of the state; *Auxiliary* foods may be of seasonal importance, use of which is limited by abundance of other foods or other factors; *Emergency* foods are mainly those used during periods of food shortage.

†*Nelumbo lutea* of some manuals.

requirements of both fox and gray squirrels, and many woodlots, supplemented by agricultural crops, particularly corn, meet these requirements for fox squirrels.

The writers found during 2 years of field work only one extensive squirrel habitat showing definite evidence of food shortage. This was the Mississippi River bottoms in Carroll County, where pin oaks furnished the main squirrel fare over a large area. Only fox squirrels occurred there, and they were somewhat underweight, mangy and otherwise in subnormal condition during the late winter of 1940-41. The near failure of pin oak acorns on the area in 1940 is believed to have been the main reason for this situation.

At least one other area was found where serious food deficiency would likely result from mast failure. This was the sand region of Cass and Mason counties, where extensive and nearly pure stands of black

Fig. 22.—Nearly pure black oak stand in Mason County, Illinois. During years of mast failure, pronounced squirrel food shortage may exist in this type due to lack of variety in staple food species. Den boxes, erected for wood ducks, are readily used by fox squirrels.

Fig. 23.—Elm (left) and maple buds and flowers offer the first squirrel food produced each year.

oak occurred, fig. 22. Only fox squirrels inhabited this locality, and during years of poor acorn crops they would be forced to depend mainly on residues of corn, rye and other grains, and such natural foods as wild grapes, bittersweet and miscellaneous seeds and herbage.

In practically every section of Illinois, a general failure of oak mast, and in some sections, especially in southern and southwestern localities, failure of wild pecans in the bottoms and hickories and black walnuts on the uplands might create unfortunate food contingencies during the late winter and early spring. That serious food shortages did not prevail in many instances in 1940–1942 is indicated by the good to excellent condition of the several hundred squirrels examined, some of which were collected during every month of the first 2 years of study.

The nature of the food studies made in this investigation did not permit determination of either the number or importance of animal foods taken by squirrels in Illinois. Numerous writers, however, have called attention to the inclusion of insects and other animal forms in the dietary. Davis (1907, 1924) reported the destruction of acorn weevil larvae (*Balaninus*) and oak apple galls (*Amphibolips confluens*) by gray squirrels. These animals were observed by Hamilton (1943) to feed on caterpillars of the halfwing geometer (*Phigalia titea*). Goodrum (1940) found that in Texas over 3.5 per cent of the food of gray squirrels consisted of insects, mainly lepidopterous larvae. He also presented limited evidence to show that animal food is necessary to successful breeding. Both fox and gray squirrels are said by Seton (1928) to use insects and other animal matter. The evidence is general that animal life, particularly insects, constitutes a small but more or less important food source for tree squirrels.

Brooks (1922) reported the use of chestnut bark and other tree bark by gray squirrels in West Virginia, and Allen (1943) reported use of maple bark by fox squirrels in Michigan. The use of bark by fox squirrels was observed by the junior author in Coles County, Illinois.

The effect of lumbering, fire and grazing on squirrel food sources is discussed in other sections.

Food Succession

Succession in the use of foods by squirrels is somewhat distinct, the Illinois study showed, and the order of succession in this state is approximately the same in both species. The first foods of the late winter or spring season are the buds and flowers

of several hardwoods, particularly of elms, maples and oaks, and the buds of sweet gum, ash and other tree species, fig. 23. "Budding," well described in gray squirrels by Nichols (1927), Deuber (1934) and Terres (1939), begins in February in southern Illinois and extends into April. During late April and May, the winged seeds of the American elm are an important item in the diet of Illinois squirrels. From mid May until late July mulberries are utilized in all regions where they occur. Various bramble fruits, as well as wild cherries, wild grapes, wild strawberries and wild plums, are eaten during the summer and early fall as they become available. Corn, in the milk stage, is eagerly sought by both species during July and August, but is much more important to fox squirrels than to gray squirrels because of the wide occurrence of the former in open, agricultural range. Fungi and herbage are taken probably in maximum quantities during the spring and summer; ground feeding, in which fungi and herbage are mainly found, is most prevalent in July and August. It is during this period of extensive ground feeding that squirrels are most difficult to see in the woods.

In Illinois, July and August usher in the principal mast season, the period of greatest food abundance for tree squirrels throughout the northern hemisphere. Although initial use of black oak and probably other acorns may be as early as July 15 in Illinois, most mast species are not used extensively until about mid August. Fruits of oaks, sugar maple and honey locust are commonly eaten in August and later, and are followed by nuts of the hickories and walnuts. Pecans, beechnuts, hazelnuts, fall grapes, Osage orange fruits, pokeberries, ripe corn and numerous other foods are generally used in late August or September and later. In the extreme southern tip of the state, the seeds of cypress and tupelo gum are appreciable food items in late October. Although rare in Illinois, the seeds of various pines are a staple fox squirrel food wherever the range of the trees and the animal coincide.

Fig. 24.—Corn cribs or corn shocks or fields adjacent to squirrel range offer the best feeding stations, and may carry normal squirrel populations through severe food shortages. Pike County.

Following the flush of mast availability in September and October, acorns and nuts supply the bulk of squirrel food during the winter and early spring. Such food is taken both from residues on the ground and from cached supplies. It is after these sources are largely used up, and before the availability of buds, that the food problem of squirrels most often becomes acute. In many farm localities, corn, whether residue, shocked or cribbed, is of great value during this period of deficiency, fig. 24; other emergency foods consist of Osage orange fruits, often dug out of snow, still clinging box-elder seeds, dried grapes, frozen, half-decayed apples and such miscellaneous items as smartweed,

climbing buckwheat, burdock and American lotus seeds. In several instances it was found that acorns that had fallen in water were eaten 3 or 4 months later, after the winter drawdown, on areas affected by navigation dams on the Mississippi River, fig. 25. Many other seeds are undoubtedly eaten during the period of scarcity; and various writers have reported greater use of animal foods, particularly insects, during the late winter and spring than at any other time.

Food Preferences

The acorns of every species of oak occurring in Illinois appear to be used by squirrels, but because of their abundance and wide distribution those of pin oak (*Quercus palustris*), white oak (*Q. alba*) and black oak (*Q. velutina*) are the most important food sources. The acorns of bur oak (*Q. macrocarpa*), shingle oak (*Q. imbricaria*), chinquapin oak (*Q. Muhlenbergii*), swamp white oak (*Q. bicolor*) and others are taken where they occur. According to Allen (1943) red oak (*Q. borealis maxima*) acorns are bitter and, in Michigan at least, appear to be used less than the fruit of most oaks. Of the hickories, the shagbark (*Carya ovata*), both because of its statewide distribution and tendency to fruit, is easily first in use among Illinois squirrels. Nuts of the small pignut (*C. ovalis*), occurring most commonly in east-central and southern Illinois, were found to be eaten avidly by both fox and gray squirrels, fig. 26. The mockernut (*C. alba*), pignut (*C. glabra*), big shellbark (*C. laciniosa*) and most other Illinois hickories are of only secondary importance, partly because they are less common than the shagbark and also, perhaps, because they are thicker shelled and therefore more difficult for squirrels to open than are the thin-shelled species. The bitternut (*C. cordiformis*), although thin-shelled, is both bitter in taste and small in size, but appears to be utilized. Pecan (*C. pecan*) is eagerly taken wherever it occurs and represents the most important mast species in the central and lower Illinois River bottomlands and in some southern Illinois localities.

Squirrels show definite preferences when several foods are abundant at one time. During "mast years," when a dozen or more staple or substaple foods, including hickory nuts, walnuts, pecans, acorns, beechnuts, hazelnuts and corn, may be available in quantity from late August through September, hickory nuts (shagbark and the small pignut) seem to rank first in preference with both fox and gray

Fig. 25.—After winter drawdown on area affected by Mississippi River navigation dam, squirrels foraged under ice for pin oak acorns that had lain in water since the previous fall. Carroll County, January, 1941.

squirrels. While these nuts are available, squirrels travel greater distances for them than for any other food and lose to a greater degree their altertness to danger when feeding on them. Pecans and black walnuts also rank high. Among fox squirrels living in farm habitats where nuts are absent, the fruit of the Osage orange seems to rank next to corn as a preferred food, and in numerous instances was taken in winter, even when acorns were available, fig. 27. In the early spring, elm buds and seeds are the most used foods of both squirrel species; in May

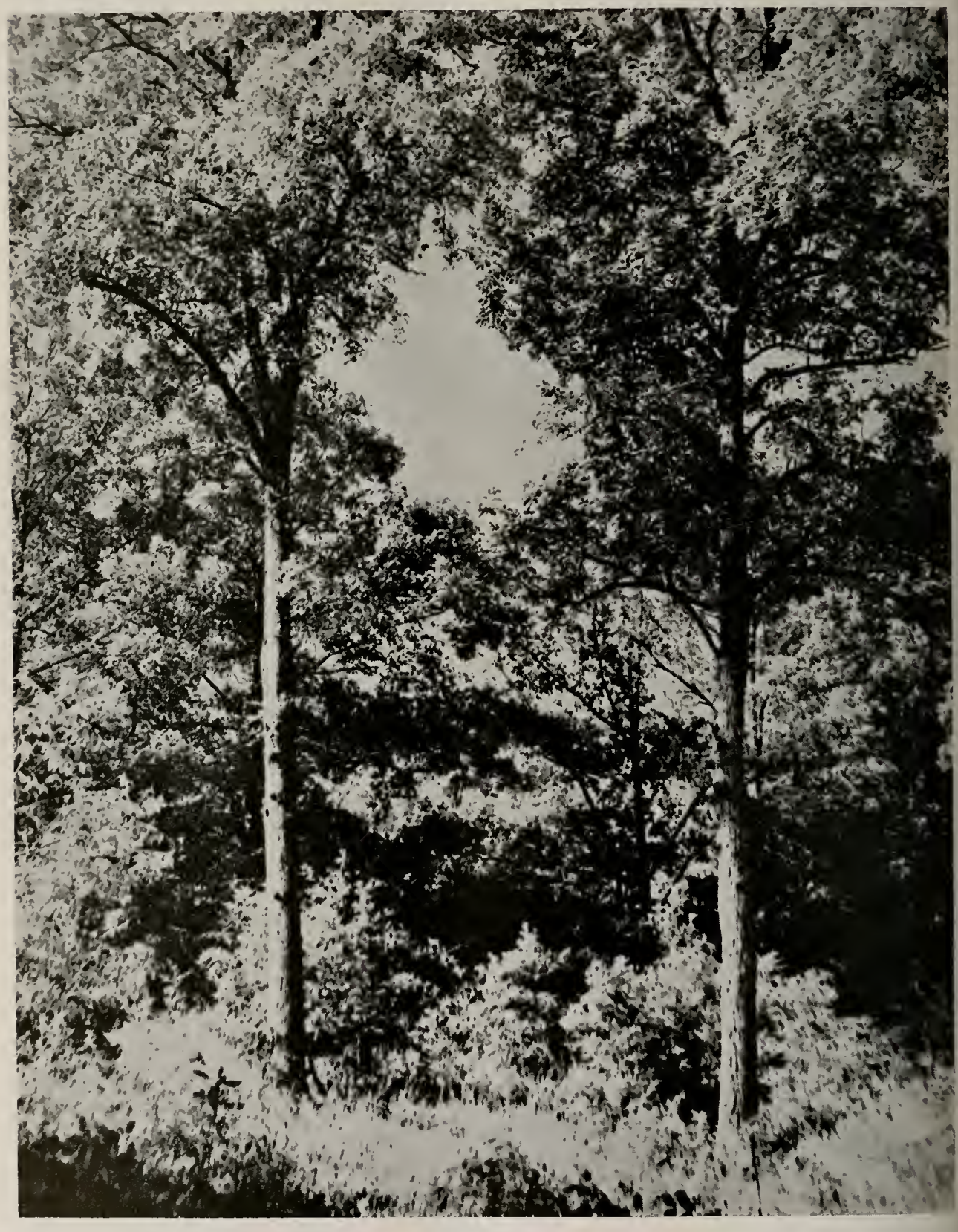

Fig. 26.—Two hickory trees, heavily fruited, known to have supplied much of the food of 20 or more Coles County squirrels (both fox and gray) from late August until late September in 1943.

Fig. 27.—Osage orange fruits provide food for fox squirrels from late summer through the winter. Cobs under the tree indicate extensive use of corn from an adjoining field.

and June, mulberries apparently rank first; and, during the early summer, corn in the milk stage is probably highest in palatability rating, at least for fox squirrels.

Because of the well-known adaptability of fox squirrels to open timber and agricultural habitats, this species makes greater use of farm crops than gray squirrels. Of farm-crop foods, corn is of outstanding importance, but wheat, soybeans, oats, apples and other crops are popular. Field crops adjoining woodlots or other timbered areas are used more than those in fields some distance from such areas. Corn is the only cultivated crop used to any considerable extent by gray squirrels in Illinois, and this only where fields adjoin woodland suitable to their requirements. Isolated nut trees, hazel clumps or bramble patches are ordinarily monopolized by fox squirrels.

Failure of any important mast species tends to hasten and increase the use of the species that produce. In 1941, the hickory nut crop was heavy over much of Illinois. Squirrels in the central zone began to use the nuts by mid August, and black walnuts were left untouched until early September. In 1942, hickory mast was scarce in many localities. The small supply was soon exhausted, and in August the squirrels shifted to walnuts, which were still green. Squirrels inhabiting areas short of summer foods, of which heavily grazed woodland is probably the best Illinois example, are often driven to use immature acorns. In the black oak stands in Mason and Cass counties, where the ground cover is mainly grasses, seedlings and second-growth sprouts, immature acorns were taken by the fox squirrels resident there as early as July 15.

Fox squirrels were found to be more tolerant of limited variety in diet than gray squirrels, and on many areas having only one or a very few staple foods it was

Fig. 28.—Sweetgum "balls" stored by a gray squirrel, Horse Shoe Lake Game Refuge, Alexander County, Illinois, December, 1940. This is the only instance of cavity storage noted in tree squirrels in 4 years of field work.

noted that the squirrel population was limited to the former species. This situation was encountered on certain Mississippi River bottoms where pin oaks supply the main food resource; in the sand region of Mason and Cass counties, where black oak supplies the main food staple; and on farm regions throughout the state, where corn is the basis of subsistence. Food, however, is only one criterion for defining the preferred range of the two species. The range appears to be determined by the combination of food, cover, water and possibly space.

In the course of field work it was noted many times that both species of squirrels, even in regions abundantly supplied with food, made limited use of acorns, walnuts, hickory nuts, Osage orange fruits and similar items while they were still quite green. What this use represented—merely a sampling, the activity of juvenile squirrels, an attempt to obtain water—was not ascertained.

Storing and Feeding Habits

Storing or caching appears to be instinctive in squirrels; juveniles are among the first to begin this activity in the fall.

Fig. 29.—Fox squirrel feeding in characteristic manner—sitting on hind legs with nut grasped between forepaws. (Photo by Gordon S. Pearsall.)

Caching in Michigan fox squirrels was well described by Cahalane (1942). The stored foods observed in the present Illinois study were mainly hickory nuts, walnuts, pecans and acorns, which were commonly buried in the ground. Only one instance of cavity storage was found: a gallon or more of sweet gum (*Liquidambar styraciflua*) capsules in the hollow base of a tree of this species, fig. 28. The cache, on the Horse Shoe Lake Game Refuge, Alexander County, was the work of a gray squirrel. In storing, squirrels usually bury only one nut or acorn in a place, carrying each to a point 50 to 100 feet from the food tree by the most direct route.

Storing begins about September 1, and in both 1940 and 1941 it was noticed first in gray squirrels. It seems to be an extension of the forenoon and afternoon feeding periods, and is conducted with fewer-than-usual alerts for danger. Harvesting is rather thorough; once cleaned, the trees are visited only infrequently. In trees nearly stripped, squirrels were observed to go to the uppermost branches and descend in spiral fashion until a nut was found. Acorns and nuts are gleaned later from the ground, but apparently the storing of fallen fruits does not awaken in squirrels the intensity of purpose comparable to that shown early in the season when stores are gathered directly from the trees.

Squirrels seem to have the ability to detect unsound nuts and acorns, usually fruits undeveloped or worm eaten. By what means they make this distinction is not known, but we have many observations of squirrels dropping unsound nuts almost instantly after picking them up. The unhulled nuts they dropped that were examined by us usually showed only one set of incisor marks; the hulled nuts showed little if any "cutting."

Fig. 30.—"Cuttings" on the ground under a hickory tree, Coles County, September, 1943.

In feeding, squirrels ordinarily sit upright on their hind legs, whether on a branch, stump, log or the ground. They possess great skill in handling food with their front paws while eating, fig. 29. Gray squirrels often eat on the spot where they find food, but sometimes, as with fox squirrels usually, they carry the food to a favorite eating place, such as a horizontal branch, a log or stump. Animals of both species leave abundant signs in the form of "cuttings," figs. 30 and 31, and hunters habitually locate them by looking under hickory, walnut, pecan or oak trees to determine the extent and recency of feeding activity. The animals dislodge from trees more fruits than they eat but they usually eat cleanly the nuts and acorns they open.

Neither fox nor gray squirrels take a large number of foods in making any one meal. The writers opened scores of stomachs, but seldom found more than four or five foods in any one stomach, and often only one or two. Items present in

stomachs could often be identified by odor or appearance.

Minerals

The mineral requirements of squirrels are not well known. Little information on the subject was gathered in this investigation. As reported previously (Carlson 1940, Coventry 1940), bones are eaten by

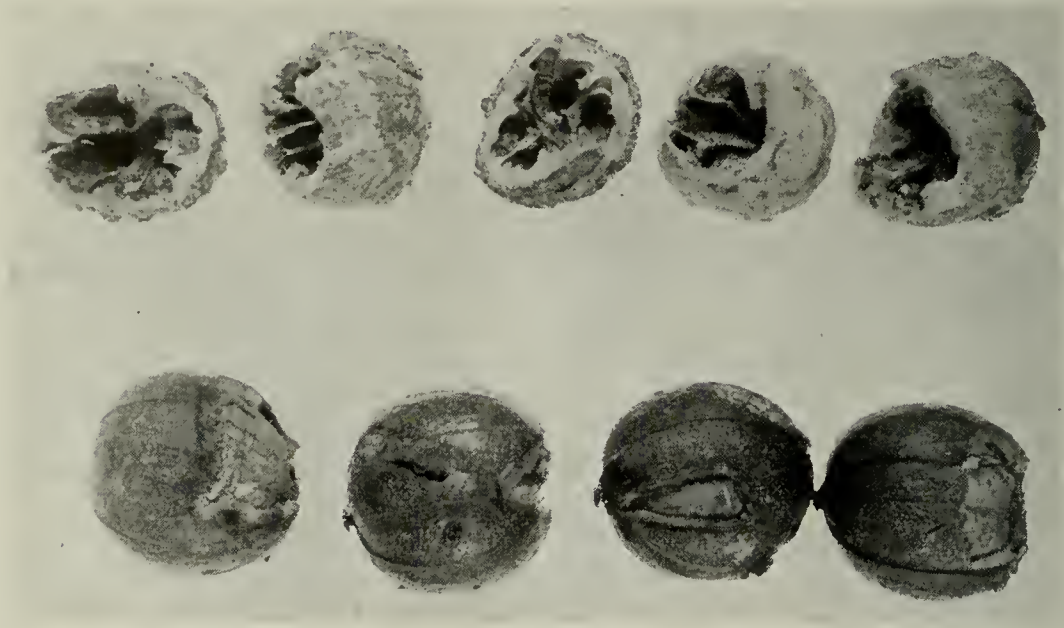

Fig. 31.—Examples of squirrel "cutting" on nuts of the small pignut, *Carya ovalis*. The thin hull and shell of this species, in addition to the sweet-flavored meat, make it highly attractive to both fox and gray squirrels.

both species of squirrels, perhaps for the purpose of obtaining minerals. Baumgartner (1939*a*) reported that fox squirrels eat soil to obtain mineral salts. Soil was found in small quantities in some of the stomachs opened by the present writers.

Water

Water apparently is not a requirement of the fox squirrel habitat, but it seems to be a necessity in the habitat of gray squirrels. The tracks of both species are often found in the mud or sand at the edge of streams, ponds and lakes. It was not determined in the present study how often squirrels drink, but observations on animals and study of tracks indicated that during the warmer months gray squirrels, at least, take water daily. A comparison of typical habitats of the two Illinois species leads to the conclusion that the gray squirrel is more exacting in its water requirements than its larger cousin. Gray squirrels were never found at any appreciable distance from open water.

Some evidence is available that mulberries, plums and other succulent fruits serve as water sources for Illinois fox squirrels. Robert E. Hesselschwerdt of the Illinois Natural History Survey did not find that fox squirrels on the Urbana Township Wildlife Area showed a tendency to migrate during the extremely dry summer and early fall of 1940, when all open water within 2 or 3 miles had disappeared. During this period the squirrels made free use of Osage orange fruits and of green corn and apples, from which sufficient moisture may have been obtained. On the Mason County area, wild grapes, blackberries and wild plums probably supplied needed moisture during periods of drought. Other observers, including Allen (1943), have noted the ability of fox squirrels to survive on uplands far from open water. Terrill (1941), working in Missouri, found that extreme drought, resulting in the withering of succulent foods, tended to concentrate both fox and gray squirrels around ponds or other open water sources.

NESTING

As has been reported by many writers, fox and gray squirrels throughout their range utilize both leaf and cavity nests.

The degree to which they use each type is determined, at least partly, by the kind and age of the trees in an area. Squirrels were sometimes found by the present writers in young stands, in some cases where cavities were very scarce; but the animals were more common in older, cavity-containing timber. There is no doubt of the superiority of the mature forest range, but the fact that both fox and gray squirrels built leaf nests even where cavities were present suggests that the highest quality habitat must possess the possibility of both types of nest. The writers believe that either type of nest may supply the essential year around nesting requirements of either species.

Dens

On the large expanse of Illinois black prairie, where only the fox squirrel is important, there is an acute shortage of tree cavities suitable for denning purposes. In this region, a few bottoms, occasional woodlots and Osage orange hedgerows supply the main tree cover. The hedges contain very few cavities, and Osage orange leaves are not well suited to nest construction. Although both bottoms and woodlots of the black prairie region contain numerous trees with cavities, the total acreage of such units is so small and their distribution so poor that great inadequacy of dens prevails in the region. In one Illinois study, Hesselschwerdt (1942) demonstrated that boxes made of lumber serve very usefully in meeting the den shortage in the fox squirrel habitat of the black prairie, fig. 32. Use of these boxes is discussed further in the section on "Management."

Many river bottoms and wooded upland areas, particularly in southern parts of the state, are well supplied with den trees. Most cutover areas, as a result of the destructive practice of cutting to smaller diameter limits, have been stripped of

Fig. 32.—Nest box suitable for squirrels in an Osage orange hedge, Champaign County, 1940. A screech owl is sitting in the entrance of the box. An acute shortage of tree cavities suitable for denning purposes exists on the Illinois black prairie.

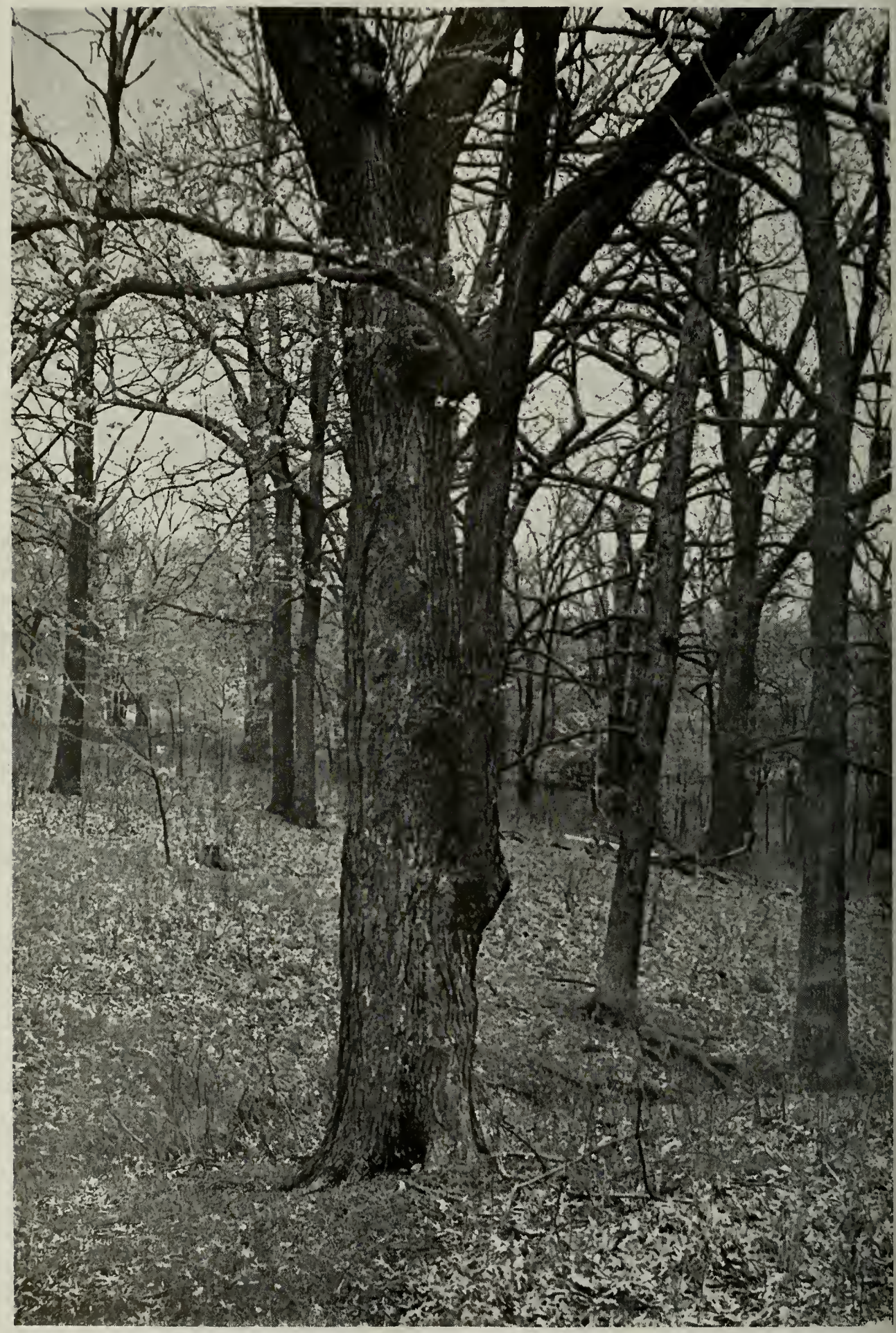

Fig. 33.—Den tree used by fox squirrels, Piatt County. Cavities are usually higher in trees than the cavity shown here. This den tree is included in the habitat illustrated in fig. 21.

trees with cavities. Selective cutting, especially if light, results in little harm to squirrel range, either temporary or permanent.

The best den trees in Illinois are the oaks, maples, American elm, white ash, beech, sweet gum and, in extreme southern Illinois, cypress and tupelo gum. The inherent soundness of such trees as Osage orange, cottonwood and the hickories, even when mature, eliminates them as important den producers. The oaks, partly because of their abundance and state-wide range, are easily the most important den-tree group, fig. 33.

The physical characteristics of cavities in relation to squirrel denning requirements were not studied by the present writers. Baumgartner (1939*b*) and Allen (1942, 1943) reported in some detail on this subject. Both writers found that squirrels maintain den entrances at a suitable size in growing trees by gnawing the green cambium each year. Allen (1943) found that fox squirrels used almost any size or depth of hollow, sometimes stuffing with leaves those too large for comfort. He also found that certain individuals may establish and use specific dens for long periods, occasionally for the entire life of the animal. Four or five usable cavities per acre are probably ample for any permanent squirrel population. The present writers found considerable evidence that one squirrel, male or female, may use concurrently two or more cavities or nest boxes.

Of the protective value of cavity nests, Allen (1942) aptly states: "From the management standpoint, hollow trees are doubtless desirable even though squirrels can live without them. They protect the animals from hunters, natural enemies, such as raccoons and owls, and severe weather." The present writers, in agreement with Allen, have observed that good tree cavities afford, during storms and extreme cold, a protection that may be

Fig. 34.—Typical fox squirrel leaf nest in oak, Cook County. (Photo by Gordon S. Pearsall.)

Fig. 35.—Fox squirrel nest in white oak tree, Piatt County. Leaf nests may be located in almost any position or height in trees, but most commonly they are situated in branch crotches near the central stem and at heights lower than shown here.

largely responsible for high survival rates of juveniles and of adults in winter.

Leaf Nests

Late summer is the period of greatest nest-building activity in Illinois for both fox and gray squirrels. Stoddard (1920) indicated that the fox squirrel in Indiana and Wisconsin constructs two types of leaf nests, a compact one used for young-rearing, and a larger, more loosely constructed nest used as a summer retreat. Wide variability in the size and shape of nests, in construction materials, and position in trees was observed in the present study. This variability rendered classifying and aging of nests so difficult that the writers were unable to use them as a satisfactory means for censusing squirrels, although a general correlation seemed to exist between the number of nests and the size of the population.

Squirrels in Illinois were found by the writers to exhibit no clearly defined choice of tree species for nest building. Perhaps because they were the most abundant and widely distributed tree group, oaks con-

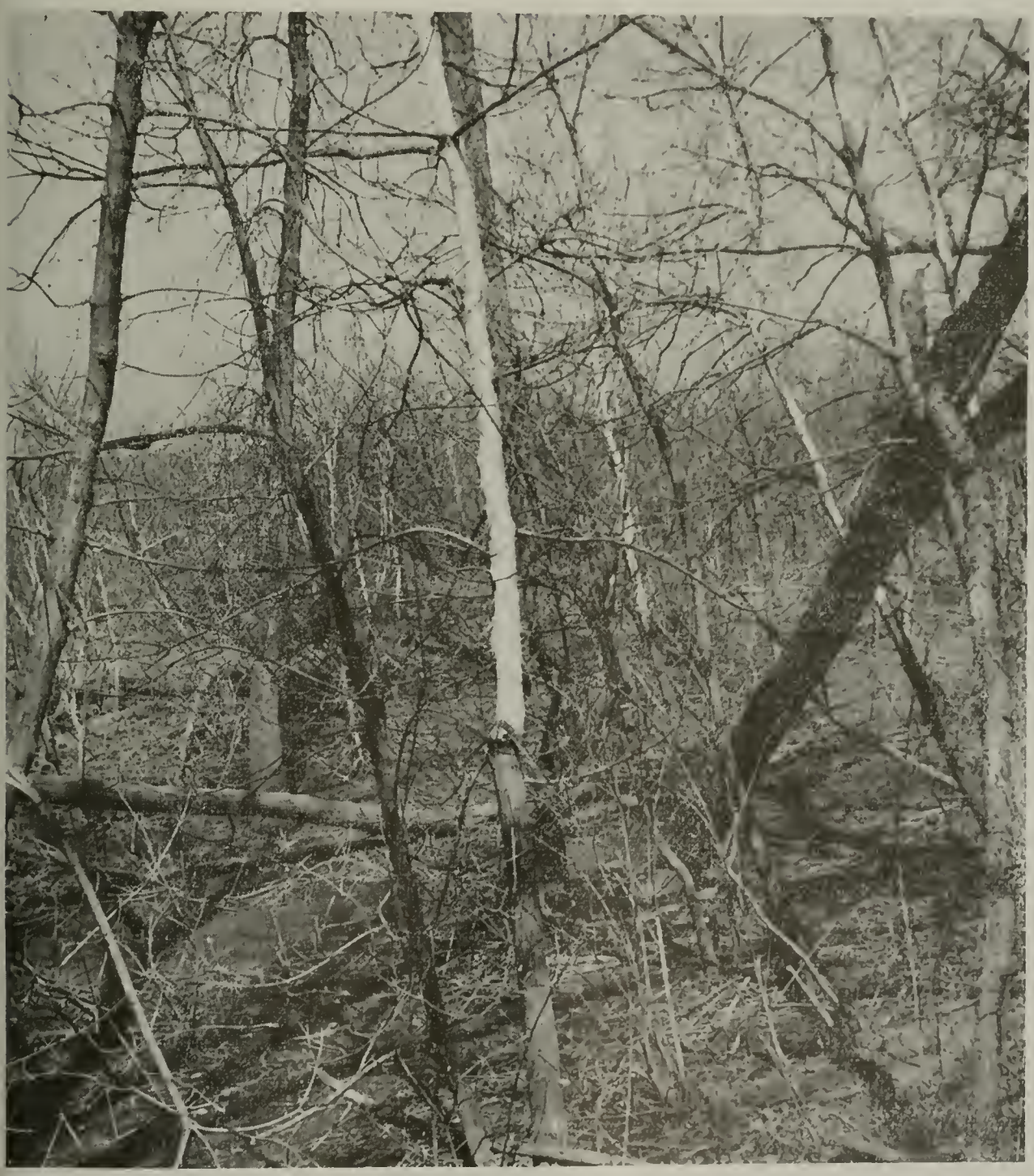

Fig. 36.—Box elder barked by fox squirrel, Ogle County. (Photo by C. S. Walters.)

tained the largest number of nests. Oak leaves were the most widely used nest material, partly because of abundance, but also, the writers believe, because oak leaves and twigs are highly suited to the type of construction found in squirrel nests, fig. 34. Nests were found in every common Illinois tree species, including cypress and Osage orange. In most cases they were made from leaves of the host tree, but other material also was used. Thus, nests of tupelo gum leaves were found in cypress trees. Crotches of larger limbs were the most common construction sites observed, but there were many sites in forks, between slender branches and, not uncommonly, in the topmost branches of tall trees, fig. 35. Unlike the Bryant fox squirrel, as reported by Dozier & Hall (1940), neither Illinois species was found to choose a characteristic nest position in trees.

Ordinarily, the nests observed by the writers were not lined, but the inner leaves had become frayed and served as lining. Finely shredded bark was at times used for this purpose, and occasionally grass, fine roots, and even rags and paper had been utilized. Some individuals, particularly female fox squirrels, seemed to be addicted to the barking of trees, fig. 36, for the purpose of obtaining nest material, and no doubt for other reasons. The use of bark in tree-cavity nests has been reported previously (Yeager 1936).

HUNTING

Material gathered during the course of the present investigation included information on the method of hunting squirrels in Illinois, on the annual kill and on crippling losses.

Hunters and Hunting Methods

In Illinois, no field sport except rabbit hunting is confined more to rural and small-town populations than that of squirrel hunting. Whereas waterfowl and upland bird shooting draws its devotees largely from urban and professional groups, squirrel hunting is mainly the diversion of farmers, laborers and local business men. This is true particularly in the important southern zone. The sport is highly prized by those who participate in it, both for its recreational value and because it means "meat on the table." To thousands of Illinois citizens, a "mess of young squirrels" is a delicacy annually looked forward to; and to some the resource represents an important and often needed food during the late summer and early fall, fig. 37.

Squirrel hunting tactics are very simple. With experienced hunters, no form of hunting is more likely to result in game bagged, because an understanding of squirrel habits practically insures success. If persistently hunted, however, both fox and gray squirrels become wary, and under such conditions stalking them requires a considerable degree of skill.

Squirrel hunting, except when a dog is used, is primarily a stalking and waiting game. During the mast season, one of the most successful methods is for the hunter to sit or stand quietly near hickory, walnut or oak trees currently being "worked" by squirrels. Often hunters reach such feeding sites by daybreak and shoot the animals as or soon after they emerge from nests in the vicinity, or approach from outlying territory. Under such conditions the killing of one squirrel does not result in cessation of feeding by other squirrels for more than a short time, often only a few minutes. Indeed, limits of five squirrels are often killed at a single site, and sometimes from a single tree. The writers have several records of five squirrels killed from one tree in the space of a few minutes. In such cases, the hunters shot the feeding animals before they could escape into surrounding cover. It is not uncommon for bags made under such conditions to be composed of both fox and gray squirrels.

Stalking is a favorite method of hunting when conditions permit. During dry periods, leaves and twigs are noisy when walked upon, making stalking difficult or impossible. When such conditions prevail, hunters advance from point to point, remaining quietly for a time at each. Points that offer a good view of the surrounding territory are usually selected. Thus, the end of a ridge, especially when bordered by a narrow valley and with timbered slopes beyond, offers a favorable waiting site. When quiet stalking is possible, such as after a rain or early in the morning, hunters walk slowly through the woods, either overland or along trails, pasture fences or dry creek beds, taking

advantage of all cover en route. This method permits maximum coverage of hunting territory. A summary of hunting success of 236 Illinois hunters in 1940 and 1941 is given in table 23.

Dogs, which are not widely used in squirrel hunting in Illinois, are perhaps most common in the southern zone; they are most effective after the leaf fall, when squirrels can be easily seen. The 1944 season, closing November 15, October 30 and October 15, in the northern, central and southern zones, respectively, when leaves were still on the trees, virtually eliminated the use of dogs in the southern zone, and permitted only limited use in the

Fig. 37.—A limit typical for central or southern Illinois—three gray and two fox squirrels. Shotguns are used by many Illinois squirrel hunters.

central and northern zones. It is said that squirrel dogs were more widely used in Illinois when the season closed later than in 1944.

The writers believe that the data presented in table 23 are too few and selective to be accepted at their face value. There is reason to suspect that they are based on returns made by the more successful hunters. The strikingly uniform bag of slightly more than one squirrel per hour in all zones and for both years represents a very high index of hunting success. The writers suspect that the true index of success falls between 0.5 and 1.0 squirrel bagged per hour.

The uniformity in success per unit of effort in the three zones may be explained by the relationship that exists between the number of hunters and the number of squirrels in each zone. Just as there is a progressive decline in the acreage of squirrel range, and consequently in squirrel numbers, south to north, there is likewise a decline in the number of squirrel hunters. This circumstance would make for more or less equal hunting pressure and consequently success, as is indicated by the data.

It is not known how accurately crippling losses are indicated in table 23. On the basis of the writers' observations and the opinions of many experienced hunters, the figures are conservative. The greatest source of error probably lies in the number of animals hit but giving no indication to hunters of having been wounded. Such cases are not listed in the tabulations. There is evidence based on skulls and bones found in tree cavities that an appreciable number of wounded squirrels reach their dens and die there.

The habit of shooting into leaf nests is more or less common in Illinois. Allen (1940, 1943) in Michigan has shown this to be a wasteful and altogether undesirable

Table 23.—Average number of squirrels bagged, hours of hunting, squirrels bagged per hour and crippling losses, as reported by 236 Illinois hunters, 1940 and 1941.

Zone	Number of Hunters Reporting	Average Number			Cripples Not Bagged* (Per Cent of Total Known to Have Been Hit)	
		Squirrels Bagged per Hunter per Year	Hours of Hunting per Hunter per Year	Squirrels Bagged per Hour	Fox Squirrel	Gray Squirrel
			1940			
Northern	13	14.8	13.2	1.2	8.1	10.5
Central	30	18.4	16.7	1.1	12.6	12.8
Southern	110	19.7	17.9	1.1	12.6	15.7
Total or Average	*158*	*18.9*	*17.1*	*1.1*	*12.0*	*15.4*
			1941			
Northern	15	19.0	17.0	1.1	12.8	
Central	33	25.9	22.1	1.2	15.8	
Southern	30	23.3	24.2	1.0	16.1	
Total or Average	*78*	*23.6*	*21.9*	*1.1*	*14.4*	

*Crippling loss in 1941 not tabulated by species on hunters' return forms.

practice. He found that the majority of leaf nests shot into did not harbor squirrels, and in instances where animals were present they usually did not jump from the nests if hit; if they were killed, he believed they usually were not recovered.

The types of guns used by Illinois squirrel hunters are indicated in table 24, which is based on 158 returned questionnaires.

A carving, fig. 38, by an unknown individual is indicative of public interest in squirrels.

Kill

Through the cooperation of the Illinois Department of Conservation, a good estimate of the 1942 squirrel kill in Illinois, based on hunters' kill return cards, is available. The total was 1,463,305 squirrels. A breakdown of the 1942 kill, as disclosed by the present investigation, is presented in table 25. We have no comparable data for 1940 and 1941, the hunting seasons principally represented in this study.

Table 24.—Types of firearms used by 158 Illinois squirrel hunters reporting in 1940.

TYPE OF FIREARM	NUMBER	PER CENT
12-gauge shotgun	68	43
.22-caliber rifle	55	35
16-gauge shotgun	16	10
.410 bore shotgun	13	8
20-gauge shotgun	6	4
Total	*158*	*100*

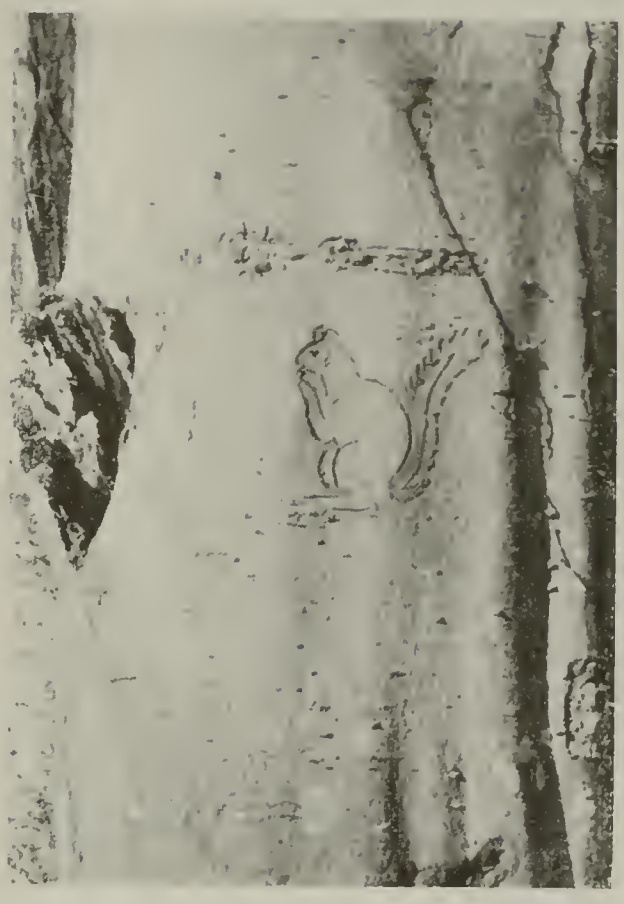

Fig. 38.—Carving found on a beech tree, Alexander County, 1941.

The dressed weights of squirrels, heads off, based on a small series handled by the writers, averaged about 0.98 pound for fox squirrels and about 0.60 pound for gray squirrels. These weights applied to the figure of 1,463,305 animals, approximately 65 per cent of them fox squirrels, indicate that the 1942 squirrel kill in Illinois represented about 1,240,000 pounds of high-quality meat, practically all of which was used for human food. The annual squirrel kill in Illinois is thus believed to repre-

Table 25.—Calculated squirrel kill in Illinois in 1942 based on hunters' kill return cards of the Illinois Department of Conservation.

ZONE	PER CENT OF HUNTERS	FOX SQUIRREL		GRAY SQUIRREL		TOTAL	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
Northern	14 0	144,046	86.1	23,255	13 9	167,301	11 4
Central	26.7	372,399	87.4	53,687	12 6	426,086	29 1
Southern	59.3	430,609	49.5	439,309	50.5	869,918	50 5
Illinois	*100 0*	*947,054*	*64.7*	*516,251*	*35 3*	*1,463,305*	*100 0*

sent between 1 million and 1¼ million pounds of edible game.

MANAGEMENT

Management of wildlife resources is basically the maintenance of various species at any desired population level. To accomplish this objective, use is made of what is known of the life requirements of each species in question. Thus, in the field, pheasants may be provided with more adequate winter cover, or quails with brush-bramble thickets adjacent to food areas. If such changes plug the most serious environmental gaps confronting the species, the habitat is improved; and, in the broad sense, further improvement is attained only when the next most serious gap has been mended. It can be said that game habitats are no better than their weakest environmental factor, and that they usually may be improved up to the point where all conditions are optimum, after which intraspecific tolerance, or lack of it, becomes the important factor in population density.

Our present knowledge of squirrel ecology, admittedly inadequate, permits some general suggestions for managing fox and gray squirrels in Illinois.

Habitat Improvement

Among the more effective means of improving squirrel habitats are maintaining favorable food and den tree combinations through selective cutting and planting, maintaining hedgerows, providing den boxes, protecting against fire and grazing, and supplying feed in winter.

Forestry Practices.—In that fox and gray squirrels are dependent on woodland, no factor can be more important in their husbandry than the woodland management policy. Fortunately, good forest practices generally lend themselves to good squirrel management, especially in the case of fox squirrels. In fact, a small amount of cutting improves large, unbroken stands as squirrel range, because the openings so made promote the growth of food-producing brambles and shrubs, and hence greater variety in both cover and food resources. Fox squirrels may respond to improvements effected by selective cutting within a year or two; gray squirrels only after appreciable shrub growth has appeared. Shrub-bordered woodlots or stands provide variety in food resources, and the shrubs are of value in site protection. Logs and down treetops, or piled brush, have a certain, but unmeasured, attractiveness for squirrels, and their presence in the habitat adds to its quality.

Slashing, wherein all commercial timber is ruthlessly cut and logged, may—and indeed often does—destroy completely a woodland as a squirrel range. Such cutting, followed by fire, may eliminate occupancy even by fox squirrels for 10 to 25 years. Likewise, the cutting of all defective trees, to which cavity dens are largely confined, greatly reduces habitat quality, not only for squirrels but for other cavity-denning wildlife. Many defective trees are good mast producers. Release and improvement cuttings that result in taking out all or most individuals of such species as mulberry, black cherry, wild plum, hawthorn and wild grape make for food shortage during the spring and summer. It has been observed that one elm and one mulberry per acre in oak-hickory or beech-maple types may represent the difference between good, permanent habitat and that which is deficient for squirrels during the spring and early summer months. The usefulness of mulberry is noted by Goodrum (1938).

Naturalness in forest stands, involving a reasonable variety of species, the presence of all age classes, including some defective, cavity-containing trees, and an understory of shrubs and young trees, insures a satisfactory squirrel habitat in almost any part of Illinois, fig. 39.

Forest practices that result in leaving at least a few oaks, hickories and walnuts in the stand are of the greatest importance in maintaining the squirrel range. Of these three tree groups, the hickories, including the pecan, are, tree for tree, of the greatest value to squirrels. Hickories are generally considered of secondary commercial value for lumber, and a policy of favoring them in forest practices creates a conflict of interests. However, where hickory constitutes an appreciable part of the stand, as it does throughout much of the oak-hickory type, it is not necessary to save every hickory in maintaining good squirrel range. Under such circumstances, release and improvement cuttings may well favor the commercially more valuable

oaks, walnuts and yellow poplar, reserving only a few hickories per acre.

Stand composition in high quality squirrel range must, however, consist of more than acorn and nut species, notwithstanding the essential function of these groups in producing food staples. Spring and summer food species are needed, since mast is not available until midsummer or later. Highly important are buds and seeds of elms and maples, the first green food of the year; mulberries, which tend to replace buds and seeds in the diet in May and which supply a staple food throughout July; and black cherries, wild plums, serviceberries and similar fruits, all of which become available in summer.

The mulberry is especially useful because it not only offers an attractive food during a food-deficient period, but is shade tolerant and grows and produces well under a variety of site conditions. It appears to do best on moist, fertile, riverbottom soils.

Osage orange trees in woodlots or other forested areas provide a good food resource. Cattle may eat Osage orange fruits during the winter and thus scatter viable seeds in droppings over woodlots and timbered areas. Many of the scattered Osage orange trees occurring in Illinois pastures and woodlots are believed to have originated in this manner. Squirrels are probably responsible for others.

Fig. 39.—Mixed hardwood stand, Piatt County. This forest type, common in Illinois, offers one of the best year around habitats for squirrels.

Brambles, particularly blackberries and raspberries, improve the food resources of any squirrel habitat, as does adjacent corn.

Hedgerows and Fencerows.—In farm localities, or in any region where woodland occupies only a small acreage, hedgerows and fencerows may constitute a very appreciable part of the squirrel habitat (Whitaker 1939). Even in more heavily wooded localities, hedgerows connecting two woodlots or stands, or offering shelter along cornfields or bramble patches, represent a valuable feature of the range. The most common black prairie squirrel habitat is the Osage orange-corn-soybean combination, supplemented in some cases by food- and cavity-bearing walnuts, oaks and maples, usually near a farmstead.

Although of very low carrying capacity for the total acreage involved, this type of habitat is in some respects satisfactory for fox squirrels, as is attested by the generally excellent condition of animals collected in

it. Removal of hedgerows, which has been extensive during recent years, has measurably reduced the acreage of habitable fox squirrel range in the state.

Undoubtedly the best hedgerow cover for squirrels is offered by very large, untrimmed Osage orange trees, but a hedge of this size lowers the crop yield for a distance of 20 or 30 feet on each side and therefore is resented, with some justification, by many landowners. Smaller hedgerows are of material value to fox squirrels, and trimming, although it impairs, does not destroy their usefulness to squirrels. Fencerows of oaks, elms, maples, hickories or red cedars are commonly used by fox squirrels to the limit of food and cover offered.

The value, to fox squirrels particularly, of one or a few good food trees in hedgerows, corners or in open stands is appreciable. The most desirable species for such situations are hickories, including pecans, walnuts and most oaks. They are well adapted to hedgerow planting, as they produce well when isolated and thus favored by full light.

Den Boxes.—Den boxes, fig. 40, suitable for squirrels and other cavity nesting species have been tested extensively in Illinois (Hawkins & Bellrose 1941, Hesselschwerdt 1942, Yeager 1942, Brown & Bellrose 1943) and in Michigan (Allen 1942, 1943). The outcome of these studies leaves little doubt of the possibility of substituting artificial for natural cavities in regions where the latter are scarce or lacking. Den boxes appear to be especially useful on the black prairie, where the shortage of natural cavities is acute, and in food-producing forest stands too immature for cavity formation.

Almost any covered box or keg having an entrance hole and room for a nest will be used by squirrels if placed in a tree on their range. The box recommended here is 2 feet deep, 8 by 8 inches inside cross section, and with an entrance hole 3 inches in diameter. It should have a removable top to facilitate cleaning, which is occasionally necessary because squirrels fill boxes with leaves and other materials. Small cracks in the boxes do not seem to interfere with use of the box by squirrels, and a perch will be used if present but is not necessary. Boxes constructed from nail kegs or sound old lumber will last

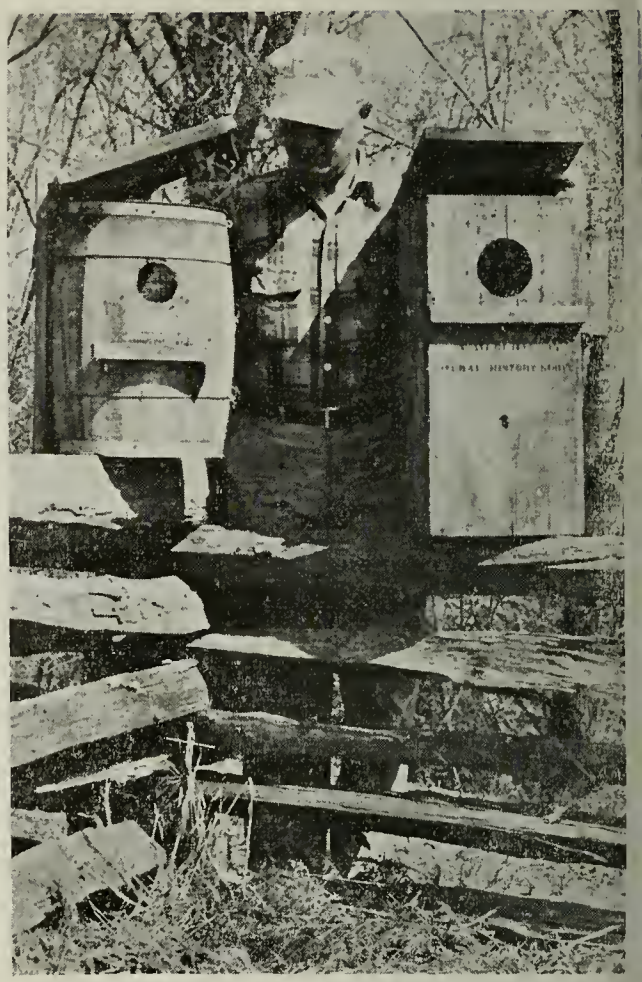

Fig. 40.—Two types of artificial den boxes suitable for squirrels. A box having a minimum cross section of 8×8 inches, at least 2 feet deep and with an entrance 3 inches in diameter, is recommended.

for 2 or 3 years or longer. Such boxes can be built and erected for a small sum each; if made of cypress or cedar lumber that must be purchased as new, the cost will be higher. However, nests made of the better material will give, with some repair, at least 10 years of service. Two or three boxes per acre are ample, and they should be placed in the larger trees, 20 feet or more above ground. In order to insure the most effective utilization, they should not be placed in den trees, but instead in sound trees some distance away from den trees. On large tracts, boxes placed on or near the timber edge are more attractive, at least to fox squirrels, than those 100 yards or more inside the stand. Where ample tree cavities already exist, it is a waste of time and materials to install artificial dens, and for this reason their use in most all-age stands is unnecessary.

Control of Fire and Grazing.—The burning and grazing of woodlands in Illi-

nois is a common practice. About 10 years ago, approximately 75 per cent of all timbered area in the state was grazed (U. S. Department of Commerce 1935), and an unknown, but appreciable, percentage is burned annually, especially in the south-central and southern counties. Both burning and grazing are injurious to timber growth as well as to the site, as has been pointed out many times.

Due to the arboreal nature of squirrels, fire and grazing are not so injurious to them as to ground-frequenting birds and certain other wildlife. In woodlots having very heavy ground cover, light grazing may be of some benefit both to fox squirrels (Allen 1941, 1943) and gray squirrels (Goodrum 1940). However, grazing of wooded land gives neither a good pasture nor a good woodlot, and sound land use decrees that stock be kept off forested range. Very heavy grazing undoubtedly depletes the quality of squirrel habitats wherever it occurs, since it results in decreased food supply through the destruction of shrubs and brambles. This practice, therefore, may easily result in food shortage, or at least a shortage of certain attractive foods, during the months prior to the ripening of mast.

Fire is actually and potentially so destructive to Illinois woodlands that its suppression in these areas is considered desirable at all times. There is no evidence pertaining to this state that fire is ever of benefit in squirrel management.

Winter Feeding.—It is only during periods of heavy ice or actual food shortage that winter feeding of squirrels in Illinois is recommended. Snow is of little hindrance to successful foraging, since both fox and gray squirrels dig readily through a foot or more of snow to reach food, fig. 41. On the better oak-hickory range in the state it is rare indeed that feeding is necessary; and, due to availability of waste corn left by mechanical pickers, it is needed on the extensive black prairie type only during periods of heavy ice.

If conditions warrant feeding, it is recommended that ear corn, hickory nuts, walnuts or unroasted peanuts be used. Corn, because of its abundance, availability and attractiveness to squirrels, is by far the most practical emergency food. Ears may be impaled on spikes driven upright through small poles or boards; nuts may be placed in trays or hoppers in such a manner as to prevent excessive scattering. A corn shock near the woods border makes a simple and effective feeder. Feeding operations should be centered on the best squirrel range, to take advantage of maximum cavity and natural food availability. Chapman & Baumgartner (1939) recommended one feeding station per 25

Fig. 41.—Squirrels are capable of digging through a foot or more of snow in finding Osage orange fruits or stored nuts or acorns.

acres of woodland. Hawkins (1937) estimated that individual squirrels consumed about 2 pounds of shelled corn per week. A practical feeding station is shown in fig. 42.

Winter feeding projects are relatively easy to organize among sportsmen and conservationists, but such activities are also easy to neglect during severe weather. A feeding program, if it is neglected during a critical period, especially after squirrels or other game have been concentrated by feeding during mild weather, may do more harm than good to the animals.

Fig. 42.—A practical winter feeding station—standing corn adjacent to a woodlot and hedgerow, Champaign County.

Hunting Seasons

The regulations under which squirrels are hunted are among the most important factors in their management. One of the ultimate objectives of this study was the determination of dates for biologically sound open seasons on fox and gray squirrels in Illinois.

The Illinois squirrel season has always begun early and lasted long, and the bag limit has been liberal. Despite heavy hunting and extensive habitat depletion in the state, squirrels, particularly fox squirrels, have maintained appreciable populations. This circumstance attests eloquently to high quality in much of the Illinois squirrel range. A comparison of the 1944 season in Illinois with seasons in other central states is given in table 26.

Of the midwest states, only Missouri and Kentucky, with 153-day and 84-day seasons, respectively, had longer open seasons than the central and northern zones in Illinois. Only Missouri had an earlier season than the southern zone. The daily bag limit in the midwest states was rather uniform, table 26, and apparently satisfactory. Only Michigan had a

season limit on the kill, the total being 25.

It is interesting to note that long seasons are, for the most part, in those states where the oak-hickory forest type is most extensive. These forests, in the central states, probably reach their best development in Missouri and Illinois. That this correlation of season with habitat should occur is perhaps significant; it appears to be an instance in which the law of supply and demand exerts a dominating influence on legislation governing the utilization of a wildlife resource.

Effect of Early Seasons.—The basic effects of early-season hunting may be summarized as follows: (1) Approximately 50 per cent of the kill is of first-litter young; (2) the kill includes a considerable portion of the pregnant and lactating females; and (3) many young squirrels too immature to be self-sustaining die of starvation.

From a biological standpoint, there is no real objection to a high percentage of young squirrels in early-season bags. Mature animals appear to be the more certain winter-season breeders. From the standpoint of the hunter, young squirrels rank higher than old, as they are of maximum tenderness and palatability, whereas breeding squirrels, particularly spent males and lactating females, are relatively low in these qualities.

The chief objection to early-season hunting is that it results in the destruction of pregnant and lactating females; the pregnant animals involve unborn young, and many of the lactating females involve

Table 26.—Squirrel hunting seasons in midwest states, 1944.

State	Season Dates	Days in Season	Bag Limits			Resident License Cost
			Daily	Possession	Season	
Illinois	September 1–November 16—Northern Zone August 15–October 30—Central Zone July 15–October 15—Southern Zone	76 77 93	5	10	None	$1.50
Indiana	August 10–October 8	60	5	5	None	$1.50
Iowa	September 15–November 15	62	6	12	None	$1.00
Kentucky	August 1–September 15 November 24–December 31	84	6	12	None	$1.00 (county) $3.00 (state)
Michigan	October 15–November 5—Lower Peninsula	22	5	10	25	$1.00
Minnesota	October 15–December 31	77	7	14	None	$1.00
Missouri	June 1–October 31	153	6	9	None	$1.00 (county) $2.50 (state)
Ohio	September 15–September 30	16	4	8	None	$1.25
Wisconsin	October 16–November 12	28	5	10	None	$1.00

young too immature to be self-providing. Cross (1942) found 100 per cent pregnancy during the period September 1–15 in a sample of 39 adult squirrel females in Virginia.

The calculated degree of loss in unborn and immature squirrels resulting from an early hunting season in Illinois is given in table 27. The calculations in this table are from data given in tables 2, 3, 15 and 20. The dates of the period included in table 27 (July 16–October 31) were chosen because they are a compromise between the 1944 hunting seasons in the central and southern zones, where most of the squirrel kill was made and where most of the data in tables 15 and 20 were gathered in the years of this study. Table 3 indicates that of each 100 squirrels bagged during the period July 16–October 31 (the kill during the period of November 1–15 in the northern zone is negligible, while the kill during the period July 15–31 in the southern zone is appreciable), approximately 70 per cent were fox squirrels and 30 per cent were gray squirrels. In each 100 animals, there was an average of 12.8 mature and therefore potentially breeding fox squirrel females and 7.7 potentially breeding gray squirrel females (figures derived from table 15). Pregnant among these mature females was an average of 3.7 fox squirrels and 2.9 gray squirrels, and lactating among them was an average of 3.7 fox squirrels and 2.4 gray squirrels.

The average number of young per litter during the second season, as determined in the Illinois study, was 2.57 in fox squirrels and 2.43 in gray squirrels, table 20. Calculations based on these data give, for each bag of 100 squirrels, a loss of 9.5 unborn young and 9.5 suckling young of the fox squirrel, and 7.0 unborn young and 5.8 suckling young of the gray squirrel. Only females showing unmistakable evidence of lactation were classified as lactating; additional losses in young may have resulted through killing of mothers in the last stages of lactation or those still exercising parental care over young. The losses in unborn and suckling young were in addition to squirrels bagged and fatally hit by hunters in the period beginning July 16 and ending October 31, table 23.

For each 100 squirrels bagged, 31.8 unborn and suckling animals, table 27, as well as the squirrels fatally wounded and not recovered, must be added to the kill in order to obtain the total theoretical loss. The net loss might be somewhat less due to the fact that squirrels suffer some mortality during the post-natal and juvenile periods. This loss, although not known, is probably low, since the young are relatively free from predation and usually are well protected against the elements.

A calculation of the total loss of unborn and suckling young may be made by applying the findings in table 27 to the total kill, which, as discussed under the heading "Kill," was calculated for 1942 at 1,463,305 animals. The ratio of 31.8 young lost for every 100 squirrels bagged applied to this kill figure gives 465,331 as the calculated number of young lost in an Illinois season that begins early, July 16, and continues through October.

Recommended Seasons.—The one change needed in current Illinois laws to provide a biologically sound squirrel hunting season is a later opening date in each zone. In recommending this change, however, the writers have not forgotten that early seasons are traditional in the state, and that there are thousands of hunters who sincerely believe in summer squirrel hunting. That these hunters argue with some logic is indicated by the fact that, despite early hunting seasons in the past, in many parts of the state there is still good squirrel hunting. However, abundance of squirrels in certain areas may be the result of one or more of a number of conditions, some of them local, that favor squirrel survival. In some parts of the state hunting is comparatively rare early in the season and is intensive only through the peak of the mast season, roughly August 15 to September 15. In many places, late in the season, when squirrels are scarcer and the population becomes scattered, interest in squirrel hunting decreases. In some agricultural communities the fall farm harvest requires the attention of a large number of potential hunters. In many counties, the advent of the dove, waterfowl and upland game seasons further reduces the number of squirrel hunters. It is probable that the 76- to 93-day season in Illinois results in only a slightly larger kill than would a 45-day season coming during the main mast season. However, a season be-

Table 27.—Calculated loss in unborn and suckling young per 100 squirrels bagged in Illinois, July 16—October 31, inclusive, 1940—1943. A kill ratio of approximately 70 fox squirrels to 30 gray squirrels was obtained from Illinois kill figures, table 3.

TYPES OF LOSS BY SPECIES	NUMBER PER 100 SQUIRRELS (70 FOX SQUIRRELS, 30 GRAY SQUIRRELS)
Mature, potentially breeding, females (table 15)	
Fox squirrels, 21 of 115 animals (tables 14 and 15; 18.3% of 70 animals)	12.8
Gray squirrels, 16 of 62 animals (25.8% of 30 animals)	7.7
Pregnant (table 15)	
Fox squirrels, 6 of 21 mature females (28.6% of 12.8 mature females)	3.7
Gray squirrels, 6 of 16 mature females (37.5% of 7.7 mature females)	2.9
Lactating (table 15)	
Fox squirrels, 6 of 21 mature females (28.6% of 12.8 mature females)	3.7
Gray squirrels, 5 of 16 mature females (31.3% of 7.7 mature females)	2.4
Unborn young*	
Fox squirrels (3.7 x 2.57) 9.5	
Gray squirrels (2.9 x 2.43) 7.0	
Total unborn young	16.5
Suckling young*	
Fox squirrels (3.7 x 2.57) 9.5	
Gray squirrels (2.4 x 2.43) 5.8	
Total suckling young	15.3
Total loss	*31.8*

*Average size of second-season litters: fox squirrels, 2.57; gray squirrels, 2.43; table 20.

ginning later than the present one would result in the survival of a much greater number of unborn and suckling squirrels that now are lost through destruction of pregnant and lactating females.

In the face of the considerations listed above, we feel that it would be unwise to enact a squirrel season beginning so late that it would prevent all losses attributable to the killing of pregnant and lactating females. Such a season could hardly begin earlier than October 1, and it would certainly be opposed by a large number of hunters. On the other hand, it is clear that the 1944 season, opening July 15 in the southern zone and August 15 in the central and northern zones, is too early, and that such a season results in the death of many thousands of squirrels that are not bagged. We suggest as a reasonable compromise the seasons given in table 28, which takes into consideration the precedent for early hunting in the state, the minimum requirements for adequate reproduction, and the high productive capacity of much of the Illinois squirrel range.

It goes without saying that, although the seasons proposed here will result in appreciable loss due to starvation of young, this loss will be materially less than at present. In time it may be practical to enact laws establishing seasons that give squirrels greater protection in order still further to reduce juvenile losses. It is not out of place to point out that seasons

Table 28.—Recommended squirrel hunting seasons in Illinois.

ZONE	DATES	LIMITS		
		Daily	Possession	Season
Northern	September 15–November 15	5	10	None
Central	September 15–November 15	5	10	None
Southern	September 1–October 31	5	10	None

making for minimum losses due to starvation of immature squirrels are desirable from the humane standpoint.

The proposed seasons are further justified by the current reduction and depletion of Illinois squirrel habitats, especially in the southern zone, by very extensive lumbering. Military requirements for walnut, oak and other hardwood timber, in addition to domestic requirements, are unavoidably resulting in grave acreage and quality losses in the range. Intelligent laws require that these conditions be taken into consideration.

Our recommendations are based in part on Illinois hunters' opinions, table 29.

Opinions as indicated in table 29 reflect no marked preference for either of the two seasons, the second of which began 14 to 31 days later than the first. This is not surprising when it is known that both the 1940 and 1941 dates made possible hunting during the mast season. Most of the hunters desiring an earlier season, somewhat less than one-fourth of the total, like to hunt during the mulberry season, when squirrels are concentrated in the vicinity of mulberry trees. More than 75 per cent of the hunters were satisfied with the present season or desired a later one.

Illinois hunters were so obviously satisfied with kill limits, which were the same in all years of the present study, that this item was not included in the 1941 ques-

Table 29.—Opinions of 236 hunters on the 1940 and 1941 squirrel hunting seasons in Illinois.*

ZONE	NUMBER OF HUNTERS REPORTING†	1940						NUMBER OF HUNTERS REPORTING	1941		
		Season Should Be			Bag Limit Should Be				Season Should Be		
		Earlier	Same	Later	More	Same	Less		Earlier	Same	Later
Northern	18	0	5	13	7	7	3	15	3	6	6
Central	30	12	13	5	3	16	1	33	9	14	10
Southern	110	27	46	37	8	73	0	30	5	15	10
Total	*158*	*39*	*64*	*55*	*18*	*96*	*4*	*78*	*17*	*35*	*26*
Per cent	...	*24.7*	*40.5*	*34.8*	*15.2*	*81.4*	*3.4*	..	*21.8*	*44.9*	*33.3*

*Seasons: 1940—northern and central zones, August 1—October 15, southern zone, July 15—September 10; 1941—northern zone, September 1—November 15, central zone, August 15—October 30, southern zone, August 1—October 15; limits—both years, all zones, 5 daily, 10 in possession; no season limit.

†All hunters reporting did not express an opinion on all items of questionnaire.

tionnaire. The writers endorse the limit of five squirrels per hunter per day.

SUMMARY

1. This investigation (Illinois Federal Aid Project 14-R) was initiated in furtherance of biologically sound squirrel hunting seasons and progressive squirrel management in Illinois.

2. Field work covered a 4-year period; the first 2 years, beginning July 1, 1940, were given to a full-time study and the last 2 years to part-time study. During the first year, 10 days per month were spent by the senior author in each of the three zones into which the state is divided for administration of hunting laws; during the second year, intensive local study was pursued by the same author in Pike County, in the central zone, and in other representative areas inhabited by both fox and gray squirrels. Part-time field work, by the junior author, was carried on mainly in the central zone.

3. No completely satisfactory census technique was developed. The need for such is obvious. Time-area counts of animals and nest counts probably give a rough census. Exhaustive live trapping supplies reliable population numbers, but is too slow and time-consuming for wide-scale use.

4. The western fox squirrel (*Sciurus niger rufiventer*) inhabits most wooded areas, including small woodlots and hedgerows, in every Illinois county. The gray squirrel (*S. carolinensis leucotis* and/or *S. c. carolinensis*) occurs in all Illinois counties except some on the black prairie. It is confined to dense forest stands and is most numerous in those with brushy understory in the river bluffs and bottoms areas. The red squirrel (*Tamiasciurus hudsonicus loquax*) was not found in Illinois by the writers.

5. Fox squirrel density in the areas studied varied from 0.02 to 2.23 animals per acre. Gray squirrel density, on one representative area, was 1.49 per acre; the combined density of both species in this area was 2.34 per acre. An average of about one squirrel per acre on good Illinois habitat appears likely.

6. Species ratio (based on hunters' kill in the 1940 and 1941 seasons) was 69.7 fox squirrels and 30.3 gray squirrels. The ratio varied by zones; being 86.1 fox squirrels to 13.9 gray squirrels in the northern zone, 87.4 to 12.6 in the central zone and 49.5 to 50.5 in the southern zone. Species ratios based on other source data and for other years differ somewhat, and indicate that gray squirrels may constitute as much as 35 per cent of the squirrel population of this state.

7. Sex ratios (based mainly on hunters' kill in 1940 and 1941 and to a small extent on litters and live- and steel-trapped animals) showed a preponderance of males in both species. The ratio was 143 males to 100 females in fox squirrels and 144 males to 100 females in gray squirrels. The actual sex ratios are believed to be more nearly equal than these figures indicate.

8. The best criteria of maturity in males (November–July) are Cowper's glands of one-half inch or more in diameter and enlarged testes with scrotum devoid of hair (or nearly so) on entire ventral surface; for females, large, dark and protruding nipples. Immature males have undeveloped Cowper's glands even during the mating season and only the posterior end of the scrotum devoid of hair; immature females have mammae with small nipples nearly hidden by hair.

9. Age class figures for Illinois fox squirrels, as indicated by several hundred animals shot and trapped by the writers, were as follows: 57.8 per cent adults, 26.7 per cent spring juveniles and 15.5 per cent summer juveniles; for gray squirrels the figures were, respectively, 65.4, 22.4 and 12.2 per cent. The comparatively low kill of summer juveniles is undoubtedly an important factor in maintaining squirrel populations.

10. Little or no competition between fox and gray squirrels was observed.

11. Both species were most active early in the morning, the hour of greatest activity being from 6:00 to 7:00. The greatest activity hour for the afternoon was, in fox squirrels, between 4:00 and 5:00; in gray squirrels, between 5:00 and 6:00. The fox squirrel showed the greater tendency to be active during midday hours; the gray was active later in the evening. Individuals of both species were seen to be active during showers, or soon after, and in deep snow; in both species, high winds, heavy rains, snow-

storms, very high temperatures and also very low temperatures appeared to reduce activity.

12. The two types of movements noted in squirrel populations were daily activity, mainly associated with feeding, and seasonal dispersal, perhaps associated with the annual readjustment of populations, in the late summer and fall. The former usually involved only a few acres; the latter, probably up to several miles. Mass migration was not observed in either species although it has been reported often in the gray squirrel.

13. Neither weight nor length of squirrels proved to be a reliable indicator of age at all seasons of the year. Adult fox squirrels taken in a 2-year period averaged about 1.70 pounds; adult grays, 1.18 pounds. Spring-born juvenile fox squirrels weighed 1.61 pounds by November; spring-born juvenile gray squirrels, 1.27 pounds by October. Length was found to be probably an even less reliable age indicator than weight.

14. Stub tail was the only deformity observed; 13.5 per cent of all fox squirrels and 12.3 per cent of all gray squirrels examined were affected. This deformity, probably due to fighting and mating chases, in no way impeded travel or other activity.

15. Only six of the squirrels collected showed wounds of serious nature. Most badly wounded animals that escape hunters are believed to die in dens, nests or other retreats.

16. Fox and gray squirrels molt once annually, both species undergoing a body and then a tail phase. Males and spring juveniles molt before females, usually before midsummer. Females that produce second-season litters molt last, beginning after lactation is under way. Few color types were found in Illinois squirrels.

17. Neither parasites nor diseases appeared to be of importance in Illinois squirrel populations. Mange, the most prevalent disorder, was observed in only two localities (cities excepted), neither serious. Predators likewise appeared to cause little loss; adult squirrels are too active and alert, and the young are too well protected to be captured easily.

18. Breeding studies were based mainly on 722 fox squirrels and 353 gray squirrels handled in the laboratory. Specimens of both species were available each month from July, 1940, to October, 1942. Other biological and all ecological studies were based on these animals, an additional 2,594 fox squirrels and 1,121 gray squirrels taken mainly by hunters, and more than 2 years of field observations.

19. Both fox and gray squirrels have two breeding seasons per year, the first in winter and spring and the second in spring and summer. Second-season litters appear to be confined largely to vigorous females over 18 months old. Both spring-born and summer-born animals attain sexual maturity at the age of about 10 to 12 months, and the females produce their first young when approximately a year old.

20. In Illinois the breeding season of fox squirrels precedes that of gray squirrels by about 10 days or 2 weeks. Between the northern and southern limits of Illinois there is a difference of about 3 weeks in the average breeding dates for both species. In the central zone, the peak of winter breeding determined for fox squirrels was in late December; in gray squirrels in early January; summer breeding peaks, for fox squirrels, the first 2 or 3 weeks in June; for gray squirrels, the last half of June or a little later. Corresponding peaks may be expected approximately a week earlier and later, respectively, in the southern and northern zones.

21. Mating chases, often involving several squirrels, are characteristic of both species. In males, enlarged testes and Cowper's glands are obvious indications of breeding condition, and the scrotal sac becomes smooth and stained as the breeding season advances. In females, oestrus is indicated by the swollen and discolored vulva.

22. In both species gestation appears to require about 44 or 45 days. In the fox squirrel, pregnancy peaks occurred in early February and late July; lactation peaks in March and August. In the gray squirrel, corresponding peaks were about 10 days to 2 weeks later. Lactation in the gray squirrel extended into October.

23. Squirrels are born both in tree cavities and in leaf nests, more commonly in the former. The average number of young in the litters counted was, in fox squirrels, 2.49 in spring and 2.57 in summer; in gray squirrels, 2.74 in spring

and 2.43 in summer. The eyes of juvenile squirrels open at about 4 weeks; weaning occurs at about 8 to 10 weeks, at which time the hair is well developed. Young squirrels become fully self-sustaining when between 3 and 4 months old.

24. Illinois squirrel habitats are of two types, agricultural and woodland. The former consist mainly of farm woodlots, hedgerows and wooded stream valleys; the latter, the more extensive wooded areas, both upland and bottomland in character. The upland and bottomland types combined provide roughly 6,750,000 acres of squirrel range in the state; agricultural types provide a much smaller acreage of habitable range. Minor habitat types consist of reforested stripmines, estates, parks, college campuses, and many towns and cities.

25. During this investigation, a total of 76 kinds of food plants for Illinois squirrels were recorded; these included 56 trees and shrubs, 2 vines, 4 brambles, 6 wild herbs, 7 cultivated crops and various fungi. Six groups provided most of the staple foods—hickories (including pecan), oaks, walnuts, elms, mulberry and field corn. In Illinois almost any fruit may be important seasonally or locally. Mixed stands produce the greatest variety and abundance of food. Cultivated crops, mainly corn, are of far greater importance to fox squirrels than to gray squirrels. No study of the animal food of squirrels was made. Squirrel food shortage appeared to be rare on Illinois range.

26. Illinois squirrels follow a somewhat distinct order of succession in the utilization of foods. In late winter or spring they feed on the buds and then the flowers and seeds of elms, maples and other hardwoods. Later they make use of mulberries and bramble fruits. The mast season, from July or August through October, is the period of greatest food abundance.

27. Squirrels show definite preferences when several foods are abundant at one time. Hickory nuts seem to rank first with both fox and gray squirrels.

28. Storing or caching, which seems to be instinctive in squirrels, is apparently an extension of the morning and afternoon feeding periods during the mast season. The stored foods observed in the present study were mainly nuts and acorns.

29. The gnawing of bones, observed in both squirrel species, may be for the purpose of obtaining minerals.

30. Fox squirrels apparently are able to inhabit range lacking open water, provided succulent foods such as green corn, blackberries or Osage orange fruits are available. Gray squirrels were never found on areas entirely devoid of open water.

31. Both fox and gray squirrels use cavity and leaf nests, and in both species cavities are important as young-rearing sites. Either type of nest appears to meet the essential requirements of either species, but both types of nests are found in the habitats of highest quality. Squirrels utilize practically any kind of tree for nest location, but, because of abundance and statewide distribution, the oaks are by far the most important group. The oaks, maples, American elm, white ash, beech, sweet gum, and, in extreme southern counties, cypress and tupelo gum are the chief sources of nest cavities for Illinois squirrels.

32. Squirrel hunters are mainly farmers, laborers and small-town businessmen. Slightly more than one squirrel killed per hour was reported by a group of 236 Illinois hunters in 1940 and 1941. A bag figure believed to be more nearly representative for Illinois is between 0.5 and 1.0 squirrel per hour. Crippling loss, calculated from hunters' reports, was about 15 per cent of all squirrels known to have been hit; this figure does not take into account the loss in squirrels not known to have been hit. The 12-gauge shotgun was the most popular arm of Illinois hunters, followed by the .22-caliber rifle and the 16-gauge shotgun.

33. The calculated squirrel kill in Illinois in 1942 was 1,463,305 animals, of which 64.7 per cent were fox squirrels and 35.3 per cent were gray squirrels. The northern zone produced 11.4 per cent, the central zone 29.1 per cent and the southern zone 50.5 per cent of this kill. A total of about 1,240,000 pounds of high quality meat was produced, practically all of which was used for human food.

34. In general, good forest practices, especially the maintenance of mixed, all-age stands and protection from fire and grazing, lend themselves to good squirrel management. Selective cutting, except

when a large percentage of the food trees are removed, may improve the range as squirrel habitat by breaking up solid stands and promoting shrub, vine and bramble growth in the openings. Only a few hickories, elms or mulberries, in addition to oaks, beech or maples, are needed in a stand to provide all necessary squirrel food. Development of fencerows and hedgerows greatly improves fox squirrel range on the prairie. Den boxes are needed only where cavity shortage actually exists. Winter feeding is unnecessary except during periods of crusted snow, heavy ice or actual food shortage.

35. The Illinois squirrel hunting season is traditionally long and is early in starting; in the past it has usually opened in midsummer and continued 75 days or more. Such a season may result in a calculated loss of 31.8 unborn and suckling squirrels for each 100 squirrels bagged, or a total yearly loss of approximately 465,000 unborn and suckling squirrels (hunters' kill, 1942, used as a basis).

36. The squirrel hunting season recommended for Illinois is September 15 to November 15 in the northern and central zones, and September 1 to October 31 in the southern zone. This season will not prevent all loss in unborn and nursing squirrels, but will materially reduce the losses now occurring. Recent severe depletion of the habitat, due to heavy cutting to meet war needs, is an added reason for a hunting season based upon serious consideration of the life history of the animals.

LITERATURE CITED

Allen, Durward L.

1940. A point on fox squirrel management: Shooting into nests is wasteful hunting. Mich. Cons. 9(12) : 11. 1 fig.

1941. Rose Lake Wildlife Experiment Station; Second annual report. Mich. Dept. Cons. Game Div. 365 pp. (Mimeographed.)

1942. Populations and habits of the fox squirrel in Allegan County, Michigan. Am. Midland Nat. 27(2) : 338—79. 19 figs.

1943. Michigan fox squirrel management. Mich. Dept. Cons. Game Div. Pub. 100. 404 pp., 152 figs., index.

Anderson, R. M.

1932. Methods of collecting and preserving vertebrate animals. Can. Natl. Mus. Bul. 69. 141 pp., 46 figs.

Baker, Rollin H.

1944. An ecological study of tree squirrels in eastern Texas. Jour. Mammal. 25(1) : 8—24. 5 figs.

Baumgartner, Luther L.

1938. Population studies of the fox squirrel in Ohio. N. Am. Wildlife Conf. Trans. 3, 1937 : 685—9.

1939*a*. Foods of the fox squirrel in Ohio. N. Am. Wildlife Conf. Trans. 4, 1938: 579—84.

1939*b*. Fox squirrel dens. Jour. Mammal. 20(4) : 456—65. 3 pls.

1940. Trapping, handling, and marking fox squirrels. Jour. Wildlife Mgt. 4(4) : 444—50. 1 pl., 16 figs.

1943*a*. Fox squirrels in Ohio. Jour. Wildlife Mgt. 7(2) : 193—202. 1 pl.

1943*b*. Pelage studies of fox squirrel (*Sciurus niger rufiventer*). Am. Midland Nat. 29(3) : 588—90.

Boulware, Jean T.

1941. Eucalyptus tree utilized by fox squirrel in California. Am. Midland Nat. 26(3) : 696—7. 1 fig.

Brooks, Fred E.

1922. Note on a feeding habit of the gray squirrel. Jour. Mammal. 4(4) : 257—8.

Brown, Louis G., and Frank C. Bellrose, Jr.

1943. Use of nesting boxes for wood ducks by other wildlife. Jour. Wildlife Mgt. 7(3) : 298—306. 1 pl.

Cahalane, Victor H.

1942. Caching and recovery of food by the western fox squirrel. Jour. Wildlife Mgt. 6(4) : 338—52.

Carlson, A. J.

1940. Eating of bone by the pregnant and lactating gray squirrel. Sci. n. s. 91(2372) : 573.

Case, H. C. M., and K. H. Myers

1934. Types of farming in Illinois. Ill. Ag. Exp. Sta. Bul. 403. 226 pp., 40 figs.

Chandler, Asa C.

1942. Helminths of tree squirrels in southeast Texas. Jour. Parasitol. 28(2) : 135—40. 3 figs.

Chapman, Floyd B.

1936. Fox squirrels and gray squirrels. Ohio Div. Cons. Bul. 127. 4 pp. (Mimeographed.)

1937. Controlled squirrel and rabbit hunting on state hunting preserves, 1936. Ohio Wildlife Res. Sta. Release 37. 11 pp. (Mimeographed.)

1938*a*. Controlled squirrel hunting on Ohio hunting preserves, 1937. Ohio Wildlife. Res. Sta. Release 68. 8 pp. (Mimeographed.)

1938*b*. Summary of the Ohio gray squirrel investigation. N. Am. Wildlife Conf. Trans. 3, 1937: 677—84.

1939. A summary of the gray squirrel investigation in southeastern Ohio. U. S. Dept. Ag. Wildlife Res. and Mgt. Leaf. BS-134. 9 pp. (Mimeographed.)

Chapman, Floyd B., and Luther L. Baumgartner
[1939.] Winter feeding of squirrels. Ohio Div. Cons. Bul. 150. 7 pp., 1 pl.

Cottam, Clarence
1941. How fast can a fox squirrel run? Jour. Mammal. 22(3) : 323.

Coventry, A. F.
1940. The eating of bone by squirrels. Sci. n. s. 92(2380) : 128.

Cross, R. H., Jr.
[1942.] Breeding habits and management of the gray squirrel in Virginia. Va. Comm. Game and Inland Fish. 5 pp. (Mimeographed.)

Dambach, Charles A.
1942. Gray squirrel feeding on *Crataegus*. Jour. Mammal. 23(3) : 337.

Davis, Wm. T.
1907. Insects as the food of squirrels. Can. Ent. 39(1) : 16.
1924. Oak apple galls destroyed by gray squirrels. Brooklyn Ent. Soc. Bul. 19(3) : 91—3. 1 fig.

Deuber, Carl G.
1934. Defoliation activities of gray squirrels in American elm trees. Sci. Monthly 38: 60—3. Illus.

Dice, Lee R.
1931. Methods of indicating abundance of mammals. Jour. Mammal. 12(4) : 376—81.
1941. Methods for estimating populations of animals. Jour. Wildlife Mgt. 5(4) : 398—407.

Dozier, Herbert L., and Harrold E. Hall
1944. Observations on the Bryant fox squirrel. Md. Cons. 21(1) : 2—6. Illus.

Edminster, Frank C.
1937. An analysis of the value of refuges for cyclic game species. Jour. Wildlife Mgt. 1(1—2) : 37—41.

Goodrum, Phil D.
1938. Squirrel management in east Texas. N. Am. Wildlife Conf. Trans. 3, 1937: 670—6.
1940. A population study of the gray squirrel in eastern Texas. Tex. Ag. Exp. Sta. Bul. 591. 34 pp., 5 figs.

Goodwin, George G.
1934. The gray squirrel migration. Nat. Mag. 23(5) : 221—2, 255—6. 2 photos.

Graham, Edward, and Jacob Uhrich
1943. Animal parasites of the fox squirrel, *Sciurus niger rufiventer,* in southeastern Kansas. Jour. Parasitol. 29(2) : 159—60.

Hahn, W. L.
1909. The mammals of Indiana. Ind. Dept. Geol. and Nat. Res. Ann. Rep. 33: 417—654.

Hamilton, W. J., Jr.
1943. Caterpillars as food of the gray squirrel. Jour. Mammal. 24(1) : 104.

Harkema, Reinard
1936. The parasites of some North Carolina rodents. Ecol. Mono. 6(2) : 153—232.

Hawkins, Arthur S.
1937. Winter feeding at Faville Grove, 1935—36. Am. Midland Nat. 18(3) : 417—25.

Hawkins, Arthur S., and Frank C. Bellrose, Jr.
1941. Wood duck habitat management in Illinois. N. Am. Wildlife Conf. Trans. 5, 1940: 392—95.

Haymond, Rufus
1869. Mammals found in Franklin County, Indiana. Ind. Ag. and Geol. Rep. 1869: 203–8.

Hesselschwerdt, Robert E.
1942. Use of den boxes in wildlife restoration in intensively farmed areas. Jour. Wildlife Mgt. 6(1): 31–7. 4 pls.

Hibbard, Claude W.
1935. Breeding seasons of gray squirrel and flying squirrel. Jour. Mammal. 16(4): 325–6.

Hicks, Ellis A.
1942. Some major factors affecting the use of two inventory methods applicable to the western fox squirrel, *Sciurus niger rufiventer* (Geoffroy). Iowa State Col. Jour. Sci. 16(2): 299–305.

Hungerford, K. E., and N. G. Wilder
1941. Observations on the homing behavior of the gray squirrel (*Sciurus carolinensis*). Jour. Wildlife Mgt. 5(4): 558–60.

Jackson, H. H. T.
1910. The distribution of certain Wisconsin mammals. Wis. Nat. Hist. Soc. Bul. 8(2): 86–90.
1921. A recent migration of the gray squirrel in Wisconsin. Jour. Mammal. 2(2): 113–4.

Katz, Julius S.
1939. An annotated bibliography of references concerning parasites of squirrels (family Sciuridae). Ohio Wildlife Res. Sta. Release 131. 21 pp. (Mimeographed.)

Kennicott, John
1857. The quadrupeds of Illinois, injurious and beneficial to the farmer. U. S. Pat. Off. Rep. Ag. for 1856, pp. 54–67.

Leopold, Aldo
1933. Game management. Charles Scribner's Sons, New York. xxi+481 pp., 35 figs.

Lyon, M. W., Jr.
1936. Mammals of Indiana. Am. Midland Nat. 17(1): 1–384. 112 figs.

Middleton, A. D.
1930. The ecology of the American gray squirrel (*Sciurus carolinensis* Gmelin) in the British Isles. London Zool. Soc. Proc., pt. 3, 1930: 809–43. 4 figs., 6 pls.

Mossman, H. W., John W. Lawlah and J. A. Bradley
1932. The male reproductive tract of the Sciuridae. Am. Jour. Anat. 51(1): 89–155. 7 pls., 16 figs.

Necker, Walter L., and Donald M. Hatfield
1941. Mammals of Illinois. Chicago Acad. Sci. Bul. 6(3): 17–60. 15 figs.

Nichols, John T.
1927. Notes on the food of the gray squirrel. Jour. Mammal. 8(1): 55–7.

Osgood, Frederick L., Jr.
1938. The mammals of Vermont. Jour. Mammal. 19(4): 435–41.

Pearce, John
1938. Identifying tooth marks of some northeastern animals on forest vegetation. N. Am Wildlife Conf. Trans. 3, 1937: 690–4.

Seton, Ernest T.
1928. Lives of game animals. Literary Guild of Am., Inc., New York. 4: 9–58; 82–106. Illus.

Stoddard, H. L.
1920. Nests of the western fox squirrel. Jour. Mammal. 1(3): 122–3. 1 pl.

U. S. Department of Commerce
1936. United States Census of Agriculture: 1935. Vol. 1. xxxix+950 pp.

Terres, J. Kenneth
1939. Gray squirrel utilization of elm. Jour. Wildlife Mgt. 3(4): 358–9.

Terrill, H. V.
1941. A preliminary study of the western fox squirrel, *Sciurus niger rufiventer* (Geoffroy), in Missouri. Graduate thesis, University of Missouri. 164 pp.

Whitaker, H. L.
1939. Fox squirrel utilization of Osage orange in Kansas. Jour. Wildlife Mgt. 3(2): 117. 1 pl.

Woods, Gordon T.
1941. Mid-summer food of gray squirrels. Jour. Mammal. 22(3): 321.

Yeager, Lee E.
1936. Fox squirrel seriously damages elm tree. Jour. Mammal. 17(4): 417–8.
1942. Coal-stripped land as a mammal habitat, with special reference to fur animals. Am. Midland Nat. 27(3): 613–35. 8 figs.

Yeatter, Ralph E., and David H. Thompson
1943. Cottontails, tularemia and weather. Ill. Cons. 8(4): 6–7, 36. Illus.

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Recent Publications

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