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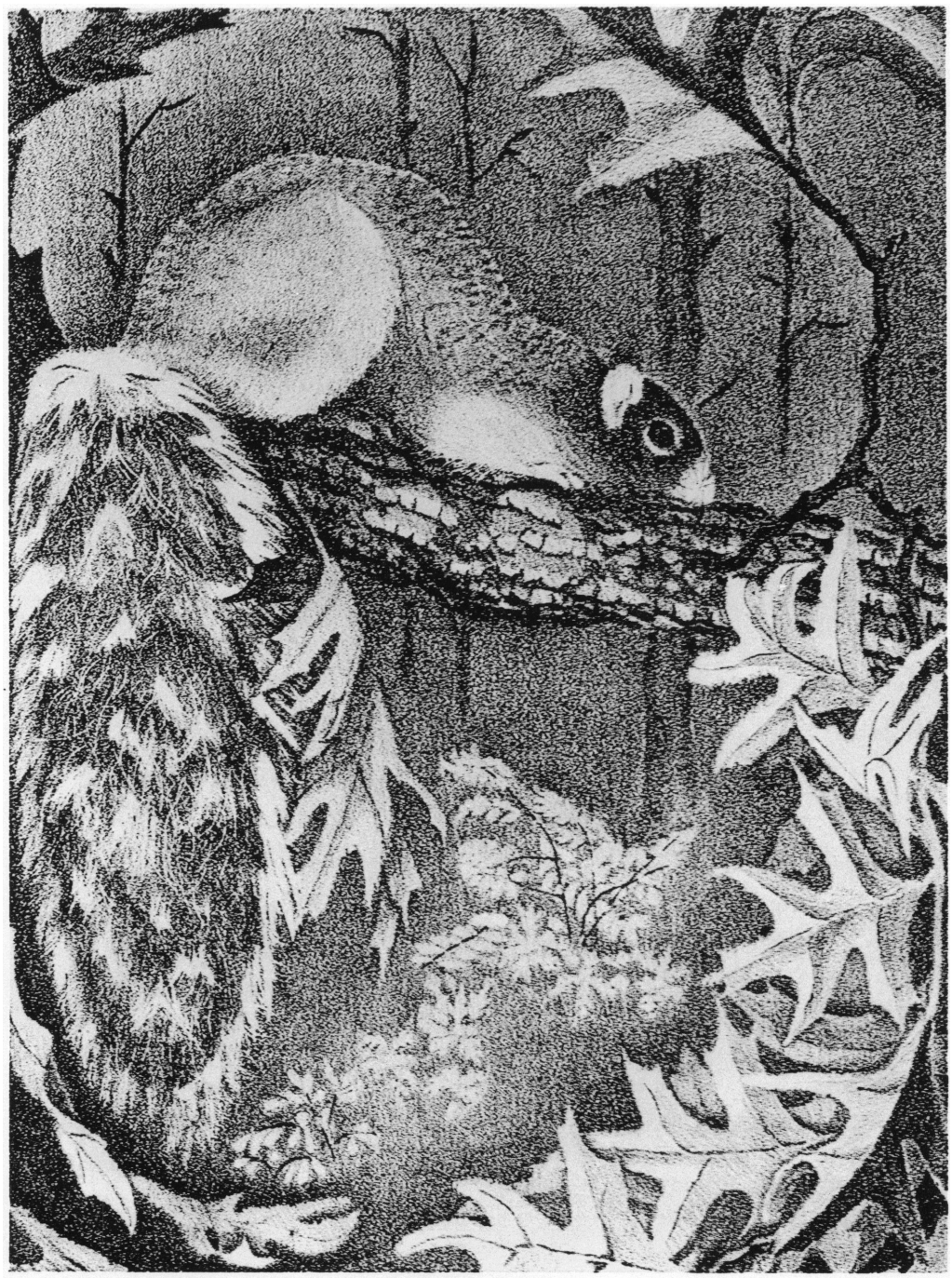

Fox squirrel (*Sciurus niger shermani*) at rest on a turkey-oak limb in the longleaf-pine and turkey-oak forest of the sand hills. From a lithograph of a pencil sketch from life by the author, of a captive taken on the University of Florida Conservation Reserve at Welaka

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Volume 113, article 1, pages 1–72, text figures 1–7,
plates 1–3, tables 1–10

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CONTENTS

INTRODUCTION

THE SPECIES MOST COMMONLY called the fox squirrel, *Sciurus niger* Linnaeus, ranges throughout the eastern United States, in suitable habitat, formerly from the southernmost New England states south to the tip of the Florida mainland (Seton, 1929, vol. 4, p. 89), and now west into North Dakota (Hibbard, 1956), western Kansas (Packard, 1956, p. 7), and Coahuila, Mexico (Baker, 1956, p. 214). This range includes the biotic provinces known as Carolinian, Illinoian, and Austroriparian of Dice (1943), and the Texan and Balconian of Blair (1950), and ventures into the edges of the Saskatchewan, Kansan, Chihuahuan, and Tamaulipan (Blair, 1952).

Investigators have made inquiries into the life history and ecology of this species in the Carolinian biotic province (D. L. Allen, 1942, 1943; J. M. Allen, 1952; Baumgartner, 1938, 1939a, 1939b, 1940a, 1940b, 1943a, and 1943b; Cahalane, 1942; Dozier and Hall, 1944), in the Illinoian biotic province (Brown and Yeager, 1945; Hicks, 1949; Packard, 1956), in the Kansan (Bugbee and Riegel, 1945; Packard, 1956), and within the western edge of the Austroriparian biotic province in Texas (Goodrum, 1937, 1938; Baker, 1944). The above studies all pertain to the western fox squirrel, *Sciurus niger rufiventer*, except for those of Dozier and Hall, Goodrum, and Baker. Dozier and Hall dealt with *Sciurus niger cinereus* (*vide* Barkalow, 1954), and both Goodrum and Baker worked with fox squirrels now recognized as *Sciurus niger ludovicianus* Custis (*vide* Lowery and Davis, 1942).

Some information on the life history and ecology of fox squirrels in the remainder of the Austroriparian biotic province is available in various studies. The most important of these pertain to *Sciurus niger niger* in South Carolina (Audubon and Bachman, 1851, p. 132) and Georgia (Harper, 1927, p. 327), but the writer has offered a little on *S. n. avicennia* (1954, 1956). Where recent investigators have produced annotated lists of mammals for localities in Florida, they have found fox squirrels entirely absent or too shy and scarce to contribute much information (Blair, 1935; Hamilton, 1941; Rand and Host, 1942; Moore, 1946; Ivey, MS; Barrington, MS; Pournelle, 1950; Pearson, 1954; Starner, 1956). The reader who may be familiar with the above-mentioned investigations of the relatively abundant western fox squirrel, *Sciurus niger rufiventer*, will find a difference, therefore, in this presentation of the natural history of *Sciurus niger shermani*. On some subjects that are here discussed, the data obtained were unfortunately so few that the inclination was not to include or to interpret them, had the writer been confident that southeastern fox-squirrel habitat conditions would improve, and that some future student would do a further investigation with more abundant material. However, the present rapid growth of Florida's human population and its resulting rapid elimination of vast areas of relatively natural wilderness are certainly reducing the total numbers of this animal, and few areas, indeed, are being allowed to produce pine timber of a size that offers it real protection. Under these circumstances, it seems important to make rather full use of the field observations obtained.

ACKNOWLEDGMENTS

The University of Florida provided quarters and a laboratory on the University of Florida Conservation Reserve. For arranging assistance to construct special facilities, the writer is indebted to the late Dr. J. Speed Rogers, then head of the Department of Biology. As subsequent acting department head, and as chairman of the writer's graduate committee, Dr. H. B. Sherman helped further this project in many ways. The late Dr. Warder C. Allee, succeeding Sherman as department head and in practice as chairman of the writer's graduate committee, helpfully criticized early drafts of the manuscript. The Graduate School of the University of Florida granted tenure of graduate fellowships. To the personal generosity of Dr. R. E. Bellamy and Dr. W. M. McLane, who were fellow graduate students at Welaka, the writer is indebted in myriad ways. Drs. E. W. Baker, Asa C. Chandler, E. W. Jameson, Glen M. Kohls, C. F. W. Muesebeck, E. W. Stafford, and G. W. Wharton identified parasite ma-

terial. Mr. Daniel B. Beard supported the typing of early drafts. For encouragement to bring the paper to final form, the writer is indebted to Dr. Harold E. Anthony.

THE STUDY AREA AND THE PROBLEM

Field work for the present report on the fox squirrel (*Sciurus niger shermani*) was conducted on and near the University of Florida Conservation Reserve, Welaka, Putnam County, Florida. The plant communities of the reserve have been studied in detail. Laessle (1942) analyzed their composition and succession in relation to soils, drainage, and fire, and provided detailed maps of the plant communities and soils. The physiography of the Reserve that apparently pertains to fox-squirrel ecology, however, is fairly simple. Along the east bank of the St. Johns River lies an area of deciduous swamp forest which is low and seasonally flooded. Inland from this and higher by 5 or 10 feet lies a much larger area of level, open pineland with saw palmetto prominent in the undergrowth. This is the flatwoods. Within the flatwoods are many ponds that tend to be rather circular in outline and apparently occupy sink holes caused by the caving in of limestone underlying the mantle of Pleistocene sands. On the east of the flatwoods area rises a low, extensive area of sand hills. These sand hills appear to have been offshore bars and barrier islands in Pamlico time, and the flatwoods area seems to be identifiable as a terrace of the Pamlico sea (Cooke, 1945, p. 310).

Rain falling on the sand hills seeps and flows out at its edges in low places in the flatwoods. At places of flow there are large springs such as Beecher Spring at the south end of the Reserve. Places of lesser flow or mere seepage are occupied by features known as bayheads. These are exceedingly dense growths of evergreen, broad-leaved forests on low areas at least seasonally flooded. Their density makes a striking contrast to the open pine flatwoods about them. We shall see that the fox squirrel forages in the flatwoods, nests in the bayheads, and does both in the sand hills.

THE SAND HILLS

Before white man brought his cross-cut saw into Florida, great longleaf pines (*Pinus australis*) stood majestically aloof from one another in sunny, open forest which covered the sand hills. Inconspicuously, 40- or 50-foot turkey oaks (*Quercus laevis*) sporadically formed a scanty understory beneath the towering pines. (In 1947 the writer was well acquainted with one stand of this sort that survived in Putnam County.) When the cross-cut saw had cut the virgin pines, and they were gone, a transformation took place. A forest of young turkey oak sprang up and covered the bareness of the sand hills. This was true throughout large areas of Florida in the upper half of the peninsula and north and west Florida where the sand hills are extensive. The progress of this new forest of turkey oak has varied greatly, even locally, dependent in part upon the severity of fire. Turkey oaks on an area that chances to be burned every year on calm days or when the humus is fairly moist may make steady growth, but those around which humus accumulates for several years, finally to burn on a windy day or in especially dry weather, suffer severe damage. Because this tree provides much of north Florida with its firewood, some stands receive severe local reduction by axe. Turkey-oak stands that reflect these extreme conditions and many intermediate ones are present about Welaka.

On the Reserve a program to prevent or extinguish fire was initiated in 1935 and has been maintained with care and success. Turkey-oak stands on the Reserve varied in 1947 from 10 to 40 feet in average height. Doubtless the development of these stands varied with the time when the pines were logged off. Pine saplings have sprung up among the turkey oaks on the Reserve, usually as rather widely scattered individuals and after the turkey oak has established itself as dominant. Where the turkey-oak stands had begun to reach a mature height of 40 to 50 feet on the Reserve, the pines were rising through with

pointed tops above the broken canopy of oaks.

How the fox squirrel lived in the sand hills before the pines were logged off is not known. There were ivory-billed woodpeckers then and greater numbers of pileated woodpeckers that made nest holes in many dead forest giants. It seems likely that fox squirrels denned to some extent in these trees. Audubon and Bachman (*op. cit.*, p. 135), who knew the fox squirrel well a century ago about Charleston, South Carolina, state that it dwells in suitably hollow trees, and, "At other times it takes possession of the deserted hole of the ivory-billed woodpecker (*Picus principalis*)." The only live fox squirrel that Francis Harper (1927, p. 331) saw in the somewhat primitive wilderness of the Okefinokee Swamp 30 years ago was driven from a hole near the top of a 30-foot, dead, pine stub. Ross Allen of Silver Springs told me in November of 1947 that he could recall having captured fox squirrels in tree hollows on three occasions. One of the trees was a live oak (*Quercus virginiana*), and the other two were turkey oaks, one of which was remarkably small.

The only tree-hole den that the writer ever saw a fox squirrel use was apparently a hole made by a pileated woodpecker in a dead place high on the trunk of a 90-foot longleaf pine in the virgin stand mentioned above. While it may be true that the fox squirrel frequently inhabited tree hollows when the sand hills supported an open forest of aged pines, the big pines are now gone, the big woodpeckers are almost gone, and a forest of lowly turkey oak cloaks the sand hills. The problem to which the present work is addressed is, How does this animal, presumably adapted to live in the open forest of great primeval pines of the southeastern coastal plain, live under the conditions that exist at the present time, particularly in the sand hills? Full time was given to this work from February, 1946, through May, 1947. The work included a program of climbing to nests, of collecting a series of specimens for parasites, etc., of recording observations on the ecology of the fox squirrel's habitat in this area, of rearing young, and of observing individuals penned in quasi-natural enclosures. (See pl. 1.)

The Longleaf Pine-Turkey Oak Association

Because fox squirrels on the Welaka Reserve lived primarily in this community, a closer examination of its nature is in order. Laessle (1942, p. 30) recognizes the almost exclusive plant community of the sand hills by the above name:

"The *Pinus australis-Quercus laevis* association is physiognomically xeromorphic. Nearly all plants found in this habitat either have heavily cutinized and hairy leaves or revolute and linear ones, or some other combination of these characters. The arboreal vegetation is open, permitting considerable sunlight to fall upon the ground and allowing air currents free sweep over the herbaceous vegetation. The soil in all parts of the Reserve where this association occurs is Norfolk fine sand [now Lakeland fine sand]. Drainage and leaching are excessive.

"Herbaceous vegetation is seldom excessively dense, bare patches of sand usually being visible even though no fire may have occurred for many years . . . . Wire grasses (*Aristida stricta* and *Sporobolis gracilis*) dominate the herbaceous layer of the association throughout the year. During the late summer and fall a perennial legume (*Kuhnistera pinnata*) may exert local seasonal dominance . . . .

"Shrubs are scarce, except the gopher-apple (*Geobalanus oblongifolius*) which is common nearly everywhere in the association. . . . This association is essentially a two-layered community, the shrubs being too scattered, excepting the gopher-apple which never rises above the herbaceous stratum, to be considered a layer."

CLIMATE AND SEASONS

The latitude here, 29° N., is so low and the study area so distant from that of good investigations of fox squirrels with which data can be compared, that some description of the climate and those observed phenomena of the seasons that appear important to the fox squirrel in the sand hills are provided here. A weather station was maintained at

Huntington, about 6 miles east of the Reserve, from 1896 to 1911, and one has been maintained from 1912 to the present time at Crescent City, about 9 (airline) miles east of the Reserve. Between 1912 and 1925 the summer temperature there rose to a maximum of 103° F. in four of the 13 summers for which records are complete. During seven of these 13 years the temperature stayed below 100° F. During every month of these years the temperature rose at least once to 79° F. From 1913 to 1926 the temperature fell to 32° F. or lower in all 13 years for which winter records are complete. The lowest temperature recorded was 19° F.

Average annual rainfall here from 1896 through 1947 was 53.34 inches. Average monthly rainfall shows a rather odd seasonal distribution. From January through December the averages read 2.26, 3.05, 3.30, 2.93, 4.43, 7.44, 6.98, 7.03, 6.41, 3.93, 1.79, and 2.75 inches, respectively. About 52 per cent of the average annual rainfall comes in the four-month period of June through September, and just a month removed from each end of this wet season the two driest months of the year characteristically occur.

Spring

Late February and March impose the most severe seasonal environmental conditions upon the fox squirrel in these sand hills. My field notes show that the turkey oaks, which had about all abscissed their leaves by January 11, 1947, were just beginning to burst leaf buds generally by March 26, and to be fully leafed out by April 24. The dropping of the turkey-oak leaves in January left the forest startlingly open and bare. This tripled the range of vision for a man and reduced the 30–50 per cent (estimated) canopy to perhaps 5 per cent. From mid-January, then, the sun and wind have full opportunity to accentuate the dryness of spring. By April in the deep, loose sand of the sand hills this means drought. During much of March and April it means excessive heat during the fox squirrel's customary hours of activity. Spring was also the season when neither of the two big fox-squirrel food crops of the year was characteristically available in abundance. The supply of acorns waned through this season, and pine seed was not yet ripe enough to be eaten.

On the other hand, an important competitor for the acorn crop, the deer, became noticeably absent from the sand hills just during this leafless period. The male or pollen cones of the longleaf pine became ripe during this time. Fox squirrels, as is shown below, apparently fed on these to some extent.

Summer

Late May through September is the period arbitrarily regarded as summer in the present paper. Most of the heavy rainfall of this season, mentioned above, came in almost daily afternoon showers. The growth and flowering of vegetation, which characterize spring in many parts of temperate North America but are ordinarily restrained here in the north Florida sand hills by drought, burst forth. Seed of the longleaf pine developed to a point at which fox squirrels began to feed on it by June and was the staple food during the summer. Use of the longleaf-pine flatwoods as a forage area probably intensified in summer, but fox squirrels may have been excluded from some slash-pine flatwoods. Water may stand several inches deep in the slash-pine flatwoods for much of the summer. This is also true in bayheads, but the density of tree growth almost assures arboreal routes of travel for the fox squirrel there. The foraging for longleaf-pine cones during the summer means that the fox squirrel spent a greater portion of its time aloft at this season than at any other.

Fall

This season is October to late December. The first longleaf-pine cones opened and let fall their seed in November (noted on November 8 in 1946), and turkey-oak acorns began to fall early in October (noted on October 6 in 1946). Fox squirrels were still cutting cones from some longleaf pines as late as November 3 in 1946. Deer foraging in the sand hills reached its peak during fall.

Winter

The winter season is late December, January, and early February. The brown turkey-oak leaves clung, flapping noisily, to their trees long after other deciduous trees were bare. In 1947 they were about all dropped by January 11. Fresh deer tracks promptly dis-

appeared from the sand hills and remained exceedingly rare until the trees were well leafed out in May. As stated above, this means to the fox squirrels less competition for the remaining acorn mast. Heat and dryness associated with this bareness do not become excessive in winter. Eagles appeared over the sand hills. Considerable protection from overshooting by man would be afforded to the fox squirrel if the hunting season were closed by the time the turkey-oak leaves dropped. Fox squirrels in the sand hills, despite their wariness, are much too easily seen and killed when the turkey oaks are bare.

RELATIONSHIPS TO OTHER ANIMALS

PREDATORS

GRAY FOXES (*Urocyon cinereoargenteus floridanus*), wildcats (*Lynx rufus floridanus*), diamondback rattlesnakes (*Crotalus adamanteus*), great horned owls (*Bubo virginianus*), barred owls (*Strix varia alleni*), bald eagles (*Haliaeetus leucocephalus*), and red-tailed hawks (*Buteo borealis*) are the predators that the writer has detected in fox-squirrel habitats about the Reserve and that are large enough to take a fox squirrel. When the number of fox squirrels is as low as it was in 1946–1947 at Welaka, these predators would in the writer's opinion rarely take a healthy adult, although any of them might catch occasional young.

GRAY FOX

My field books record fox tracks seen in the sand hills on the Welaka Reserve on 34 days during 10 months of the year. The two months missed were January and May. These records were distinctly bunched in February-March-April and October-November-December, with peaks in March and November. It seems likely that this distribution is but a reflection of better tracking conditions in the sand during these relatively dry months. The fox or foxes followed the sandy truck trails and fire lanes in the sand hills and showed some regularity about traveling certain routes. Only on one occasion did the writer see a fox by daylight in the vicinity of Welaka, and that was while driving a car 10 miles southeast of San Mateo on March 31, 1942, about two and a half hours before sundown. O. Earle Frye, Jr., a fellow graduate student, observed a gray fox running towards him on a fire lane in the sand hills of the Reserve at 9 A.M. in September of 1939. Victor Rich, a member of the Reserve maintenance crew, observed a gray fox running along a fire lane in the sand hills once during the daytime in June of 1940. Despite these few scattered daytime observations, the gray fox is considered to be habitually nocturnal and consequently only a predator on fox squirrels on the unusual occasions when it hunts by day. The stomach of an adult female gray fox which the writer (1946, p. 55) trapped in the sand hills contained a mass of insect parts, but Errington (1935, p. 193) has reported fox-squirrel remains in gray-fox stomachs taken in southern Wisconsin, and Bennett and English (1942, p. 22) found remains of cottontail, opossum, woodchuck, muskrat, and gray squirrel in stomachs of gray foxes in Pennsylvania, which indicate that gray foxes are capable of preying upon animals the size of Florida fox squirrels.

WILDCAT

As the writer (1946, p. 55; 1949, p. 62) has reported earlier, wildcats on the Reserve inhabit the river swamp forest, the xeric hammock, and the bayhead, and travel the fire lanes and truck trails through the longleaf-pine flatwoods. To some extent in the flatwoods and to a greater extent where the fox squirrels nest in the bayheads, the fox squirrels would be exposed to wildcat predation on those unusual occasions when wildcats may hunt by day. Only on one occasion, however, did the writer find the tracks of a wildcat in the interior of the sand hills. This was the morning of May 11, 1947, when fresh, clear tracks followed a fire lane up into the sand hills about 250 meters and turned onto a sandy truck trail for 150 meters farther. These tracks averaged 53 mm. wide and 48 mm. long. Rollings (1945, p. 141) found remains of squirrels in only two of 50 wildcat stomachs in Minnesota. He stated, "Meals of squirrel . . . were taken infrequently . . . representing rare catches or meals of carrion." In California, Grinnell, Dixon, and Linsdale (1937, vol. 2, p. 615) found gray squirrels in only seven of 257 wildcat stomachs examined. Although instances of diurnal activity of the wildcat in north Florida have been recorded by the writer (*loc. cit.*), the rarity of its visits to the sand hills probably gives the fox squirrel even greater freedom here from predation by wildcats than that enjoyed by tree squirrels in Minnesota and California.

DIAMONDBACK RATTLESNAKE

During some 24 months afield on the Reserve in 1940, 1942, 1946, and 1947, the writer personally encountered no diamondback rattlesnakes, although one or two other

persons did during that time. In the sand hills they were apparently very rare, if they occurred at all. Carr (1940, p. 95) indicates that they are most abundant in flatwoods where there are palmettos. Because the fox squirrel forages in the flatwoods, and this rattlesnake eats mammals of its size (Carr, 1940, p. 96), it seems likely that, if the snake hunts diurnally, it may occasionally take a fox squirrel. However, Carr (*loc. cit.*) says that the snake is chiefly nocturnal.

Owls

The writer observed barred owls in the sand hills of the Reserve twice in 1940, October 3 and November 9, and twice in 1946, at sunrise plus three hours on September 26, and at sunset minus 30 minutes, 10 days later. Nelson (1952, p. 23) did not find this owl in the sand hills during his year-long study of bird relations to plant communities on the Reserve, and the seasonal clustering of my observations suggests that it may be present only during a small part of the year. Its hunting activity is thought to be too strictly nocturnal for it to be an important predator on the fox squirrel.

In mature longleaf pine and turkey oak close to the edge of the flatwoods on March 10, 1942, the writer found the nest of a great horned owl that contained two young owls, located about 20 feet up in a longleaf pine. Then and during the next 15 days, 30-odd pellets were collected beneath this nest. Seven years later on January 16 William M. McLane, Paul G. Pearson, and the writer found a great horned owl occupying an old fox-squirrel nest 35 feet up in a 45-foot turkey oak in the sand hills. We removed the well-fledged but still fuzzy young owl and tethered it to the base of a smaller tree close by. During the 100 days before the young owl escaped, McLane collected 88 pellets. Both of these nests of the great horned owl were in the immediate vicinity of numbers of fox-squirrel nests. The first discovered was no more than 100 yards through the very open forest from a fox-squirrel nest which had a blind, naked young one in it. It is of special interest, therefore, that in the first series of pellets William H. Stickle (Moore, 1946, p. 56) found no remains identifiable as fox squirrel, and in the second series Burns (1952, p. 86) also found none. Hoffmeister and Setzer (1947, p. 169) report the rearing of broods of great horned owls in Kansas in the midst of an abundance of fox squirrels, with no evidence that the squirrels were preyed upon to feed the young owls.

The usual restriction of activity of the fox squirrel to the hours of strong daylight probably limits owl predation on it to an exceedingly minor degree. This, also, is essentially the opinion expressed by Audubon and Bachman (1851, p. 137) regarding *Sciurus niger niger*. The pattern of crepuscular activity of the gray squirrel, however, may make that species so vulnerable to owl predation in the open vegetation of the sand hills that such predation serves in part to limit the gray squirrel from that area. Although the gray squirrel was common in the hammocks and frequent in the bayheads that border the sand hills, in all the time the writer spent in the sand hills he encountered it there but twice (June 8 and October 15, 1946).

Bald Eagle

In 1947, in the sand hills at Welaka, the period when the turkey oaks were leafless and the forest floor was almost entirely visible from above extended from about January 1 to April 1. The coincidence of this period with the writer's observations of eagles over the sand hills is interesting: on January 13, late afternoon, two adults flew away together just over the treetops, calling; January 14, late afternoon, two adults and probably three or four immatures flew low over the trees in single file 100 meters or so apart, might have circled, for, in the writer's opinion, a count of individuals passing over would have reached 10; February 26, 11 A.M., one adult, circling high; March 16 about noon, two adults and two immatures all together, circling high above and screaming; March 18, 6:30 A.M., an eagle flew into sand hills from flatwoods; 9:20 A.M., an immature eagle over the sand hills; 10:20 A.M., an adult and an immature (the last two observations progressively deeper into the sand hills area); March 24, 3:15 P.M., a pair of immatures, one apparently heckling the other as they flew screaming at treetop height. On a visit to the Reserve on January 16, 1949, the writer noted an eagle wheel by close overhead at

12:20 P.M. in the sand hills. On January 22, 1949, in the sand hills about 10 miles northeast of Trenton, Gilchrist County, the writer was stalking in good fox-squirrel habitat at 11:30 A.M. when an adult bald eagle screamed near by and came flying low among the trees to alight about 100 yards away in plain view.

It is difficult to attribute this seasonal clustering of records of observations of eagles to the mere fact that eagles were easier to see when the forest canopy was reduced. Canopy in the longleaf pine and turkey oak, while frequently dense enough to screen terrestrial mammals from soaring raptores, rarely is so dense that it effectively screens an eagle from alert eyes below.

According to Bent (1937, p. 328) the southern bald eagle is known to feed on tree squirrels, although apparently it preys primarily on birds and fish. Because it haunts the sand hills of the Welaka area during the hours when fox squirrels are active and during the season when they are easiest to see, therefore, it may be the greatest potential predator on the fox squirrel there.

Red-tailed Hawk

According to Bent (1937, pp. 156–158) this hawk preys heavily on small mammals, including tree squirrels. One of Harper's (1927, p. 330) informants in the Okefinokee Swamp spoke of this hawk as being adept at catching fox squirrels. The writer observed an adult red-tailed hawk perched on the very top of a tall pine in the sand hills on the morning of November 17, 1946. On March 26, 1947, the writer observed a red-tailed hawk apparently incubating on a nest high in a tall pine in the sand hills on the Reserve. Upon returning to this place on April 25, the writer could see two white young birds on the nest. Two adults circled above the nest, screaming at my approach. I could find no waste from their feeding on the ground beneath the nest. On May 25 I heard one screaming in the sand hills east of the Reserve. Although less often seen than the bald eagle, this big hawk may be a more serious predator on the fox squirrel because of its preference for mammalian prey.

Man

The wary habits of the fox squirrel made it a difficult animal for man to stalk successfully in the sand hills. A quiet dog, however, forcing the fox squirrel up a tree before it can get to a good refuge, puts the animal quickly at man's mercy. If lucky enough to reach a mature pine, the fox squirrel may find adequate refuge in its large crown laden with Spanish moss. In the pines that have not attained full height and are still pointed at the top, the fox squirrel has an interesting means of attempting concealment which, although habitual, has apparently not been previously reported. The twig at the apex of such a longleaf pine may be 15 mm. in diameter and covered with needles 200 mm. or more long. The squirrel surmounts this terminal plume of the tree and, bending it over, is hidden above it from the hunter below. A hunter who knows this, however, and is reasonably skilled with a rifle is not baffled by this maneuver.

The distance a fox squirrel will run if not hard pressed is rather remarkable. This may be because desirable refuges for such a large tree squirrel are widely scattered. Once, upon releasing an adult female from a live trap in the sand hills, the writer followed her at an easy run, remaining some 50 or 60 meters behind in order to give her ample freedom to select a refuge. She ran 325 meters to the edge of the sand hills and entered the jungle-like concealment of a bayhead.

Surprised in a bare oak tree in winter, a fox squirrel skillfully employed the stratagem, common to many tree-climbing animals, of keeping concealed behind the trunk of the naked tree. An immature male, also surprised in a turkey oak in winter, ascended only until the trunk was the size of his body, then stayed skillfully behind it as I circled the tree.

REFUGES

In a plant community so open to the sun and wind, and to the eyes of predators, the kinds and numbers of refuges matter greatly to the fox squirrel. Removal of the great virgin pines and severe diminution in numbers of the large woodpeckers must have severely reduced the numbers and kinds of refuges and driven this squirrel to perhaps unac-

customed use of what remains.

Frequently a dead place occurs on one side of a turkey-oak trunk at the ground, possibly caused by fire during the youth of the tree. Some of these places have rotted out so that cavities have formed which at times extend up inside the trunk of the tree. Only rarely was one of these cavities found to be large enough for use by fox squirrels, and there was no evidence of such use. Much more rarely a cavity of fox-squirrel size may be found higher up in a standing turkey-oak tree. Two of the few such holes found by the writer showed evidence of use by fox squirrels, but this use may have been only seasonal or even casual. The infrequent use of woodpecker holes as dens is described in the section on nesting.

Occasionally in the sand hills a mature pine is found which was left by the loggers. Its high spreading branches, unlike those of younger pines, are laden with Spanish moss (*Dendropogen usneoides*). This makes a fine refuge for the fox squirrel and shelters an occasional one from the hunter's gun. Before the lumbering off of the old pines, the ubiquitousness of this type of cover must have permitted a denser population of fox squirrels.

Outside nests constructed by the squirrels provide very important refuges and are described in a section below.

Strange refuges, indeed, are what it is here found convenient to call stump dens. Much careful search revealed only a few of these, but two of them exhibited clear proof of some regular use by fox squirrels, and one of these was used extensively. The stump dens were mostly old stumps of mature pines in the sand hills left after logging, each with a cavity rotted out down through its vertical axis, which formed an enlarged chamber below the ground. As two of these were used as nest sites by fox squirrels, they are described more fully below in the discussion on nests. A screech owl was observed down in the chamber of one stump den on February 11 and 12, 1947.

The most conspicuous and abundant refuges today for an 1100-gram mammal in the sand hills are the ubiquitous burrows of the gopher tortoise (*Gopherus polyphemus*). The burrow of an adult tortoise may be a foot or more wide and 10 to 35 feet long (Young and Goff, 1939, p. 54). The angle of descent is most often between 20 and 30 degrees from the horizontal (Hallinan, 1923). The presence of these abundant and spacious burrows of a vegetarian tortoise greatly influences the lives of vertebrate animals in this severely xeric and open environment. The present writer (1949, p. 62) has reported a gopher-tortoise burrow enlarged and used by the gray fox (*Urocyon cinereoargenteus floridanus*). Both times that the writer encountered a skunk in the sand hills by daylight (1949, p. 61), the animal took refuge in a gopher-tortoise burrow close at hand. A skunk occupied one of the gopher-tortoise burrows which Hallinan (*op. cit.*) excavated. He also found gopher burrows used by snakes. (I once saw a sparrow enter an inhabited gopher-tortoise burrow. Unable to see the bird within the first 3 or 4 feet of the burrow, I waited for it to emerge and collected it. This was April 6, 1947, at 3:10 P.M., and J. C. Dickinson, Jr., identified this bird as a pine woods sparrow, *Aimophila a. aestivalis*.) A cotton mouse trapped in the sand hills February 17, 1947, took refuge, when released, in a tortoise hole 10 feet from the trap. Blair and Kilby (1936, p. 422) observed *Peromyscus floridanus* in gopher-tortoise burrows near Gainesville, Florida.

Members of the tree-squirrel genus *Sciurus*, however, are not known to make any habitual use of burrows in the earth, and it is a little extraordinary that *shermani* appears to have done so. On January 29, 1947, a subadult male fox squirrel which the writer had shot and laid on the ground, while making a field note regarding it, oddly revived. It ran off some 20 feet, then stopped on a tortoise-burrow hill for a moment, shaking and breathing hard. When the writer slowly reached for the rifle, the squirrel disappeared without hesitation down the tortoise hole. Blocking the entrance, the writer returned the next day and dug out the squirrel. R. DeWitt Ivey had the experience of a wounded fox squirrel's escaping from him down a gopher-tortoise burrow in late June of 1948 in mature turkey-oak forest near Gainesville, Florida. On a windy day in the sand hills, February 25, 1947, the writer surprised a fox squirrel in a small bluejack oak, and circled

the tree to watch its efforts to keep out of sight in the rather small naked tree. Then, when the writer walked briskly away in pretense of leaving, the squirrel started down the trunk. Turning back, the writer rushed the squirrel and was only 30 feet behind it in pursuit when it left the base of the tree. Within 150 feet the fox squirrel ran directly to a gopher-tortoise burrow and unmistakably entered it at full speed. The entrance was blocked with leaves and partially blocked by small, crossed roots. To have entered it with such confidence at such speed, it seemed that the squirrel might have used this burrow previously. It was the old burrow of a small gopher tortoise, possibly no longer used by its digger.

An unpublished observation made available to me by Paul G. Pearson of Rutgers University (letter of July 19, 1956) from mammal investigations in the Appalachicola area, follows: "Miss Bette Starner and I were driving on a woods road through typical pine-palmetto flatwoods about two miles northeast of Grand Ridge, Jackson County, Florida, at 2:30 P.M. on July 29, 1955, when we saw a fox squirrel. It had been feeding near the road. We approached at high speed in a truck till we were nearly upon it and then stopped suddenly and took chase on foot. The squirrel ran four or five hundred feet . . . . When we were nearly upon the squirrel, it suddenly disappeared and investigation showed a small gopher turtle burrow. We . . . dug several feet only to see the squirrel go deeper. We followed . . . to a depth of about 4 feet and to a length of 6 feet. When we reached the end of the burrow, the squirrel escaped the hole and climbed a pine tree. The squirrel was then shot . . . ." In response to further questions, Dr. Pearson adds (letter of July 25, 1956), " . . . the flatwoods seemed to be relatively dry . . . . The animal was a female and had recently lactated . . . ."

Although these observations of fox squirrels taking refuge in gopher-tortoise burrows are few, the fact that they are widely distributed suggests that this behavior is in some degree characteristic of fox squirrels in north Florida. The Gainesville observation must have been made 40 miles west-northwest of the Welaka ones, and the Grand Ridge one is 180 miles farther west-northwest, in the range of subspecies *S. n. niger*. Willingness to take refuge in gopher-tortoise burrows when closely pursued, while undoubtedly important to survival of predation by man, particularly since the removal of the primeval pines, need not be considered an incipient character that is forming only in response to selective pressure now clearly exerted by man. (A squirrel hard pressed by man is more likely to live to reproduce if it runs down a gopher-tortoise burrow instead of up a scrawny, 30-foot turkey oak.) As shown in the preceding section, before man and his dog came, red-tailed hawks and eagles were probably the primary predators on fox squirrels in the sand hills. In so extraordinarily open a forest as the primordial pine forest evidently was, gopher-tortoise burrows must often have been the safest refuge from attack by raptores even then. Use of them by fox squirrels may have originally developed, therefore, in response to aerial attack.

MACROPARASITES

Twenty-four fox squirrels collected within 2 miles of the Reserve during a 12-month period from June 7, 1946, to June 2, 1947, were examined for the presence of ectoparasites and conspicuous intestinal worms. When shot, each squirrel was promptly enclosed in a bag and later examined in the laboratory. Ectoparasites were sought by blowing open the animal's hair and examining the inside of the bag. Parasitic worms were sought by slitting open the intestine its whole length, or in some instances pulling the translucent intestine over the edge of a scalpel handle. One of these fox squirrels was taken in a xeric hammock within the sand hills, four in bayheads closely adjacent to the sand hills, and 19 in the longleaf pine and turkey oak which cloaks the sand hills. The number of fox squirrels collected per month was: June, six; July, three; August, two; September, five; October, two; November, one; January, three; and February, two. Sexes were evenly divided. Seven of the males and all of the females were fully adult. Two of the females were preg-

nant, and seven others were giving milk. An acanthocephaline worm, a tapeworm, a flea, two kinds of lice, three kinds of mites, and three kinds of ticks were found on these 24 fox squirrels.

Acanthocephaline Worm (*Moniliformis clarki*)

Asa C. Chandler (1947, p. 3) has reported evidence provided by the writer of an apparent relationship of the incidence of this worm in gray squirrels at Welaka: "Of 12 squirrels collected, 11 of which were adult and one immature, eight collected in the river swamp association were not parasitized, whereas all of three adults collected in the xeric hammock and *Pinus australis-Quercus laevis* associations contained *Moniliformis;* the one immature animal from the xeric hammock association was not infected." The infected gray squirrels were collected, one in June and two in October, of 1946 (see table 1). Of the gray squirrels taken in the swamp, two were taken in August and six in October of 1946. With the possibility of seasonal incidence thus obviated, relationship of this infection in gray squirrels to drier habitats seems, despite the limited data, rather firm. The writer has observed an instance in which a heavy infection by this worm apparently caused the death from starvation and/or exhaustion of a lactating female flying squirrel in a commodious wooden live trap in which an uninfected companion easily survived (Chandler, *loc. cit.*). That heavy infection by this worm may be injurious is further suggested by a heavily infected lactating female gray squirrel found dead on October 9, 1946. Autopsy by the writer revealed no other injury by which to explain the animal's death. It seems possible that infection by this parasite is at least a small, contributing factor in limiting the gray squirrel from the sand hills.

It could not be presumed that any of the 24 fox squirrels examined for *Moniliformis* confined their activities to swampy habitat, and therefore data on incidence of this worm in the fox squirrel cannot be used to test the apparent positive relationship of infection to dry habitat noted in the gray squirrel. Data on fox squirrels presented in table 1, however, substantiate moderately the above suggestion of injurious effect of a heavy infestation on a female squirrel nursing young. The gross weight of the female fox squirrel apparently nursing young and host to 10 worms was 75 grams below the average adult weight. On the other hand, the heavily infested fe-

TABLE 1

Incidence of Acanthocephaline Worms (*Moniliformis clarki*) in Fox Squirrels and Other Squirrels at Welaka, Putnam County, Florida

Species and Date	Habitat	Sex Condition	Weight (in Grams)	Worms
Fox squirrels (*Sciurus niger shermani*)				
July 27, 1946	Sand hills	Lactating female	997.4	10[a]
Sept. 29, 1946	Sand hills	Parous female	1077.8	33[a]
Oct. 17, 1946	Bayhead	Lactating female	1076.5	1[a]
Feb. 23, 1947	Sand hills	Lactating female	946.8	1
Gray squirrels (*Sciurus carolinensis carolinensis*)				
June 11, 1946	Xeric hammock	Subadult female	350.0	Some
Oct. 9, 1946	Xeric hammock	Lactating female	—	Some
Oct. 15, 1946	Sand hills	Adult male	379.5	6
Flying squirrels (*Glaucomys volans querceti*)				
Dec. 31, 1946	Sand hills	Lactating female	68.5	1[a]
Feb. 12, 1947	Sand hills	Lactating female	60.0	14[a]
Feb. 16, 1947	Sand hills	Subadult male	49.3	1
Mar. 13, 1947	Sand hills	Parous female	52.0	7
Mar. 15, 1947	Sand hills	Subadult female	50.4	1

[a] Determinations by Asa C. Chandler; the material, except for the one lot of 10, was retained in his collection.

male not nursing young had a gross weight that exceeded by 4 grams the average adult weight. Evidence in table 1 of a tendency apparent in the fox squirrel data, that is, for *Moniliformis* to infect the female, is partially supported by the data for the other species of squirrels. No evidence of relation of *Moniliformis* infection to season is seen.

Chandler (*op. cit.*) pointed out that this material from Welaka includes the largest specimens of *Moniliformis clarki* known. The following is a better and more detailed statement of the lengths of these worms from the fox squirrel of September 29, 1946, than was available to Chandler. Because of their softness, these worms were straightened out on a horizontal surface without being stretched, and were measured to the nearest inch. To facilitate comparison, the measurements are here given in millimeters. The numbers of worms in the various sizes were:

Number of Worms	Length of Worms (in Mm.)
4	406
3	355
2	304
1	202
5	151
2	126
5	100
7	75
4	50

Some closer measurements than these are available for the *Moniliformis* from flying squirrels, which are closely associated with the fox squirrels in the sand hills and are frequent inquilines in fox-squirrel nests: On December 31, 1946, a single worm 264 mm. long and 4 mm. in greatest diameter was collected. The squirrel taken February 12, 1947, had worms that measured 250, 250, 240, 230, 200, 200, 200, 160, 105, 105, 95, 95, 95, and 85 mm. Washed and with water shaken and blotted from them, these 14 worms weighed 6.5 grams or 12 per cent of the host's net weight. The host collected February 16, 1947, contained a worm 170 mm. long. The flying squirrel of March 13, 1947, was host to worms that measured 230, 225, 155, 140, 75, 65, and 60 mm. in length. After being washed and dropped on a blotter several times these worms weighed 1.95 grams. The host taken March 15, 1947, contained one 50-mm. worm.

For an interpretation of the incidence of *Moniliformis* in flying squirrels in table 1, the following qualifying data are of use. Intestinal tracts of 15 flying squirrels were examined for *Moniliformis* during a period of two and a half months beginning December 31, 1946. Distribution of these examinations by month is December 1, January 1, February 6, and March 7. The sex ratio was eight males to seven females. All four adults were female. Infection recorded for the lactating female December 31, 1946, is additional, for it was a live animal the intestine of which was not examined. A worm observed dangling more than 200 mm. from its anus was collected. All these flying squirrels were taken in the longleaf-pine and turkey-oak association.

Tapeworm (*Raillietina bakeri*)

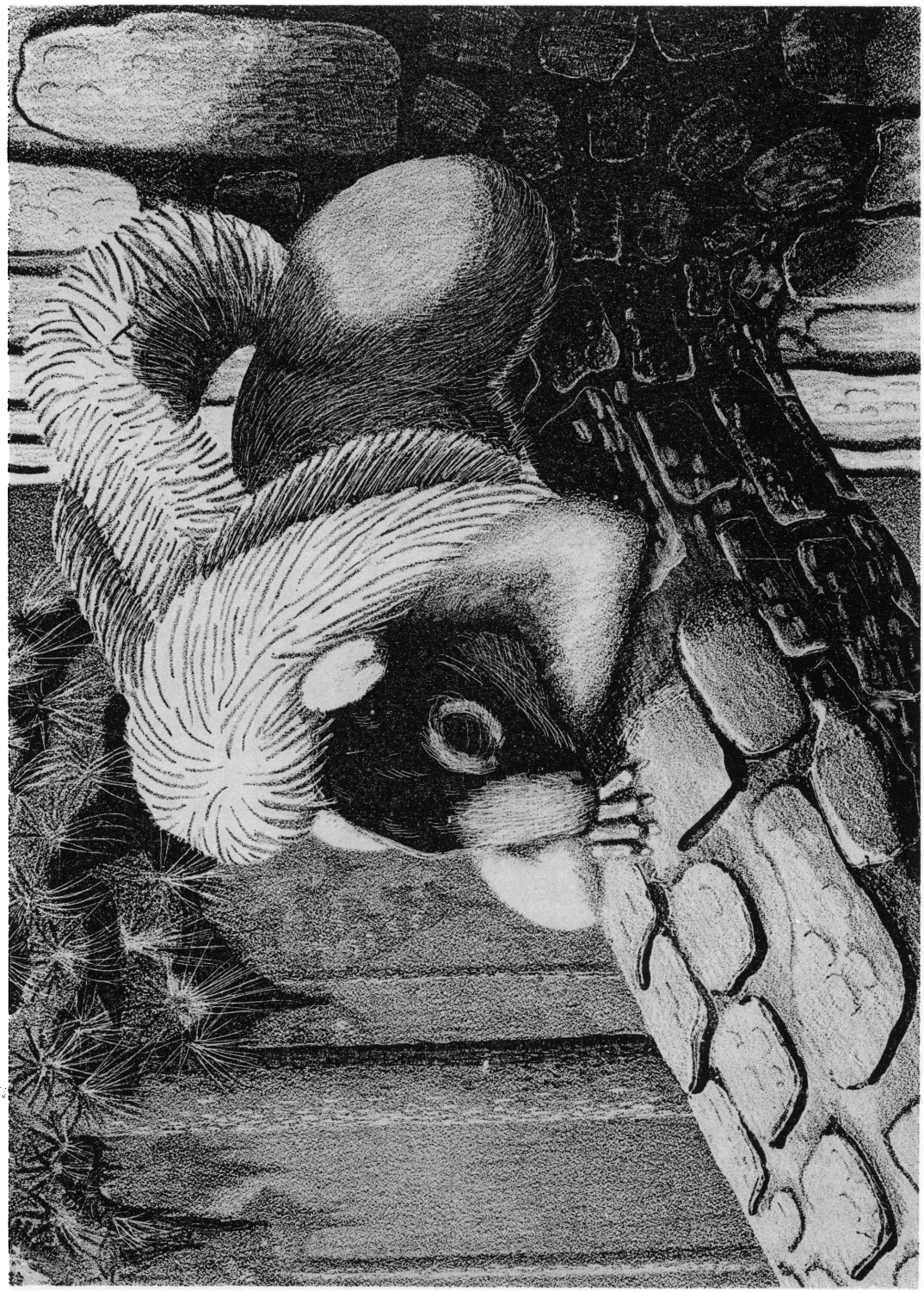
The above-described fox-squirrel material revealed two instances of infection by this tapeworm. The fox squirrel taken October 17 with an acanthocephaline was also host to two of these small tapeworms. A subadult male taken February 26, 1947, in xeric hammock within the sand hills was infected with this tapeworm. The gray-squirrel host to *Moniliformis*, which was found dead October 9, was also infected with *Raillietina bakeri*. Chandler identified this tapeworm material and retained it in his collection.

Morlan (1952) gives a limited report on the ectoparasites of 42 fox squirrels taken during three years of collecting in three southwestern counties of Georgia, about 200 miles northwest of Welaka, where the present writer was working. His period of collecting ectoparasites, April, 1946, to April, 1949, overlapped that of the present writer, June, 1946, to June, 1947. Comparison with his findings is made in the discussion of each ectoparasite and in table 3.

Lice (*Hoplopleura*, *Neohaematopinus*, and *Enderleinellus*)

Lice were collected from 14 of the 24 fox squirrels, but determinations were obtained for only 12 of these. *Hoplopleura sciuricola* Ferris occurred on three males and one adult female collected in June, September, October, and February. *Neohaematopinus sciurinus* Mjob occurred on eight males and one aged,

Fox squirrel (*Sciurus niger shermani*) trimming pine cone. This drawing illustrates one fashion in which a fox squirrel feeds on the seeds of the longleaf pine. High in the tree the squirrel sits on the base of a limb with its back against the tree trunk, holds the bulky cone in its forepaws, bites off the scales, and eats the winged seeds which lie under the scales



Fox squirrel (*Sciurus niger shermani*) in characteristic position of rest on the base of a limb of the longleaf pine, with his tail up sheltering him from the sun

lactating female which was in poor condition. These were collected in June, August, September, October, January, and February. Both kinds of lice were found on two adult male fox squirrels. A third kind, *Enderleinellus* sp., was the only kind found on an immature male taken January 19, 1947, in the sand hills on the reserve. *Enderleinellus* sp. was also the only kind of louse found on a female highway casualty collected 5 miles southwest of Ocala, Marion County, December 13, 1946. E. W. Stafford and C. F. W. Muesebeck identified this material.

Morlan (1952) found only three of his 42 fox squirrels harboring *H. sciuricola*, but 17 of them carrying *N. sciurinus*. On one individual fox squirrel he collected 23 of the latter louse. A decrepit female taken by the present writer in February had an infestation of these lice that must have numbered several hundred.

Mites (*Atricholaelaps* and *Listrophorus*)

Some kind of mites other than ticks were found on 11 of the 24 fox squirrels, but determinations were obtained only for those from nine. The female taken November 11 was host to *Listrophorus* sp. *Atricholaelaps megaventralis* Strandtmann was identified from four male and four female fox squirrels taken in July, August, September, October, November, January, and February. These mites were most frequently found among the bases of the hairs on the tip of the squirrel's tail. E. W. Baker identified the above mites.

In Georgia Morlan (1952) found *H. megaventralis* on 10 of his 42 fox squirrels. One squirrel was host to 63 of these mites.

Flea (*Orchopeas howardi*)

Fleas were present on 16 of the 24 fox squirrels examined and were taken during each of the eight months when fox squirrels were examined. Nine males and seven females were hosts. Four of the seven lactating females harbored fleas, as did three of the other five. Fleas were taken from five of the seven fully adult males and four of the younger five. Collections from infested adults averaged two fleas and did not exceed three. However, 13, 13, and seven were taken from three immature males and five from one subadult male. Fleas from only 13 of the 16 flea-infested fox squirrels were identified. These were all of the present species, with usually one male flea and one or more females per host. Fleas of this species were also collected from two broods of young fox squirrels found on the Reserve in July, 1946. One or more fleas of this species were collected from each of five fox-squirrel outside nests. To collect these one had but to put one's hand into the nest cavity to let the fleas light and then pick them off. Two of these nests were of oak leaves and twigs in turkey oaks in the sand hills in December and February; two were of Spanish moss in a bayhead in January; and one was of Spanish moss in a slash-pine flatwoods in February. Three fleas of this species were collected in the mouth of the ground-level entrance to stump den no. 1 in January. Other Florida locality records obtained of fox-squirrel hosts to this flea are: Gulf Hammock, Levy County, November 8, 1948, adult male host, two male, one female fleas; Trenton, Gilchrist County, December 5, 1948, subadult male host, one female flea. The flea determinations were contributed by E. W. Jameson, Jr.

In Georgia Morlan (1952) found 27 of his 42 fox squirrels infested with this flea. One squirrel had 102 fleas.

Tick (*Ixodes scapularis*)

Only adults of this tick were encountered. The records in table 2 suggest that neither the tick nor the fox squirrel is important to the other. Nine fox-squirrel specimens were taken during the six consecutive months when these ticks were being encountered, but only two were found infected with this tick.

Here again Morlan's (1952) more extensive survey yielded very different results. Although he encountered this tick on six kinds of mammals, he took none from 42 fox squirrels.

Tick (*Amblyomma americanum*)

Cooley and Kohls (1944, p. 94) record nine nymphs of this tick taken from a fox squirrel at Cleveland, Liberty County, Texas, May 12, 1938. In southwestern Georgia Morlan (1952) found 10 nymphs and two adult ticks of this species on six out of 42 fox squirrels examined. At Welaka the present writer obtained no ticks of this species from fox squir-

TABLE 2

INCIDENCE OF THE TICK (*Ixodes scapularis*) BETWEEN JUNE, 1946, AND JUNE, 1947, IN WELAKA, PUTNAM COUNTY, FLORIDA

Date Taken	No. of Ticks	Host
October		
1	1 ♂	Man
11	1 ♀	Feral *Sus scrofa*
November		
2	1 ♂	♂ opossum (*Didelphys marsupialis*)
22	4 ♂, 4 ♀	Yearling ♂ deer (*Odocoileus virginianus*)
24	1 ♀	Man
31	1 ♀	Man
December		
1	1 ♀	Man
10	1 ♀	Man
15	1 ♂, 1 ♀	Man
23	2 ♂	Man
16	3 ♀	♂ opossum
29	2 ♂, 3 ♀	Feral house cat
January		
27	1 ♀	Adult ♀ fox squirrel
27	1 ♀	Immature ♂ fox squirrel
27	1 ♂, 1 ♀	Man
February		
13	1 ♀	Man
17	1 ♂	♂ gray fox
March		
24	1 ♀	Man

rels, although a nymph was collected from a feral hog on October 11, and a nymph taken on man January 10. The writer collected six nymphs of this species from two fox squirrels on December 30, 1948, near Thames, Gilchrist County, Florida, which is some 60 miles closer to Morlan's area of operations.

GULF COAST TICK (*Amblyomma maculatum*)

It may be a little strange that the writer collected but one specimen of this tick, an adult male from man on September 25. Discussing the hosts of the larvae of this tick in southern Georgia, Hixson (1940, p. 183) says: "The fox squirrel is comparatively scarce; nevertheless, it is probably the most important host in the mammalian group. It roams in open grassland and covers extensive areas in its quest for food. Of four specimens collected during the period of greatest larval activity, three were infested with a total of 35 larvae." Hixson (1940, p. 186) remarks further that the animals " . . . found infested with the Gulf coast tick nymph in southern Georgia include the meadowlark, bobwhite, eastern cotton rat, southern fox squirrel. . . . The meadowlark and the bobwhite are the most important hosts. The cotton rat outranks the fox squirrel as a host of the nymph because of its greater abundance and the dissemination of engorged larvae within its range by the principal hosts of the latter."

It is curious that Morlan (1952) obtained no ticks of this species from 42 fox squirrels collected during a three-year period only about 60 miles west-southwest of where Hixson worked. Possibly Hixson worked in an area where the incidence of this tick on feral mammals was kept exceptionally high by the abundance of a domestic mammal host, the sheep, which seems especially suitable for the adult tick.

GOPHER-TORTOISE TICK (*Amblyomma tuberculatum*)

In their review of the genus *Amblyomma*, Cooley and Kohls (1944, p. 104) reported no records of this tick's parasitizing the fox squirrel. The known mammalian hosts for this tick were apparently limited to "dogs and rabbits" and *Geomys pinetus*.

On October 17, 1946, the writer collected eight larval ticks of this species from an adult male fox squirrel and one from an adult female. On October 5 one was collected from an adult male gray squirrel, *Sciurus c. carolinensis*. The only fox squirrel collected in November, an adult female taken on November 17, was host to four of these larval ticks. On November 25 and 29 four and eight, respectively, were collected from man. During the month of December, larvae of the gopher-tortoise tick were markedly more abundant. On December 12 and 31, 16 and 14, respectively, were collected from man. A fox squirrel (not one of the above-described 24) taken this month was a subadult female, which was a highway casualty from 5 miles southwest of Ocala, Marion County, host to six. A young weasel, *Mustela frenata peninsulae*, from near Silver Springs, Marion County, was taken on December 17 with 40.

January of 1947 appears to have seen the peak of numbers of this larval tick. An immature male fox squirrel examined January 19 was host to three. On January 27 another immature male supported 166 larvae of this tick, although an adult female fox squirrel taken at the same time and place had none. Six were collected from a pine lizard (*Sceloporus undulatus*) on January 12; three, three, and 17 from man on January 11, 14, and 26; and nine from a gopher tortoise (*Gopherus polyphemus*) on January 17. Eleven were collected on the sixteenth from a highway-casualty gray fox (*Urocyon cinereoargenteus floridanus*) halfway between Satsuma and San Mateo, Putnam County. In February seven larvae of this tick were collected from a lactating adult fox squirrel on February 23 and seven from an adult male on February 26. Collection of this tick diminished in March to two from a pine lizard on the eleventh.

To summarize, the larvae of the tick *Amblyomma tuberculatum* were found to be infesting eight of the nine fox squirrels collected from October, 1946, through February, 1947. Infestations of fox squirrels and other animals show this to be a well-marked season for the larva of this tick, with a peak of abundance in December and January. That no larvae of the gopher-tortoise tick were found on any of the five adult fox squirrels collected during September (three on the third and two on the twenty-ninth) adds definition to this picture. The sexes of the infested fox squirrels were evenly divided, but, as was true with regard to fleas, the most heavily infested fox squirrel host was an immature. These data are especially interesting, for Morlan (1952) found this tick in Georgia infesting only one of 32,320 mammals, a gray fox.

Infestation of fox squirrels with larvae of gopher-tortoise ticks coincides with the hunting season. As this exposes hunters to infestation, it may be of value to describe the effect of its bite on man. The writer's following observations are from a letter of February 1, 1947, to Kohls: "The bites of *Ixodes scapularis* and the *Amblyomma* have been found to be lingeringly painful, differing clearly, I think, from each other. The *Ixodes* bite was red and painful when discovered. . . . The pain was a dull, sickening one, recurrent whenever the bite was rubbed for a week afterward, and the bite remained noticeable and red for days. The bites of *Amblyomma*, scrotal, abdominal, axillary, etc., are for eight days stinging and nettle-like whenever rubbed. For the first few days several of these were marked by a swelling and a weal 25 mm. in diameter . . . ."

American Dog Tick (*Dermacenter variabilis*)

Only two of the 24 fox squirrels examined carried this tick. Smith, Cole, and Gouck (1946, p. 5) show that this tick is well distributed in Florida. They consider (p. 42) the domestic dog to be almost the sole host of adults of this tick in Massachusetts, where they conducted their field investigations, but indicate that squirrels are sometimes hosts. At Welaka an adult male tick was collected June 11, 1946, from an adult male fox squirrel

TABLE 3

Ectoparasite Incidence on Fox Squirrels (*Sciurus niger niger*) in Southwestern Georgia (Morlan, 1952), and Those (*Sciurus niger shermani*) in Northeastern Peninsular Florida

(Incidence is shown in per cent of squirrel samples examined.)

	Welaka, Florida	Southwest Georgia
Sample of fox squirrels examined	24	42
Hoplopleura sciuricola, louse	.17	.07
Neohaematopinus sciurinus, louse	.38	.40
Enderleinellus sp., louse	.04	.00
Listrophorus sp., mite	.04	.00
Ctenocephalides felis, flea	.00	.02
Orchopeas howardi, flea	.67	.64
Leptosylla segnis, flea	.00	.02
Haemolaelaps megaventralis, mite	.33	.24
Eulaelaps stabularis, mite	.00	.02
Ixodes scapularis, tick	.08	.00
Amblyomma americanum, tick	.00	.14
Amblyomma maculatum, tick[a]	.00	.00
Amblyomma tuberculatum, tick	.33	.00
Dermacentor variabilis, tick	.08	.12
Trombicula alfreddugesi, chigger	.04	.00
Trombicula whartoni, chigger	.00	.07

[a] Listed because Hixson (1940) considered the fox squirrel an important host in southern Georgia. (See discussion in text.)

when the squirrel died three days after capture. This squirrel was in very poor condition, weighing only 925 grams although fully adult. Another adult male tick was taken from an adult male fox squirrel collected June 2, 1947, apparently in good condition and weighing 1175 grams.

Glen M. Kohls of the Rocky Mountain Laboratory identified all the ticks.

In the incidence of *Dermacentor variabilis* on fox squirrels, Morlan's (1952) findings and those of the present writer are in close agreement. Morlan reported five fox squirrels infested of 42 examined.

Chigger (*Eutrombicula alfreddugesi*)

An adult male with rather serious facial wounds partly healed when collected September 3, 1946, in the sand hills, had an infestation of chiggers, *Eutrombicula alfreddugesi* (Oudemans), identified by G. W. Wharton.

Table 3 permits better comparison of the present writer's record of incidence of ectoparasites on fox squirrels in northeastern peninsular Florida with Morlan's (1952) findings some 200 miles northwest. There is close agreement between these two studies on: the high incidence of the flea *Orchopeas howardi*, the high incidence of the louse *N. sciurinus*, the rather high incidence of the mite *H. megaventralis*, and the low incidence of *Dermacentor variabilis*. Each study, however, reports five ectoparasites on fox squirrels which the other does not. This variance must be due in part to the smallness of the fox-squirrel samples in those species for which the incidence is low. However, in the case of the gopher-tortoise tick (*Amblyomma tuberculatum*) the discrepancy is too great to be so explained. It seems more likely to me that the richer soils of the southwest Georgia area provide fox-squirrel habitat which is much less frequently shared with the gopher tortoise. A corollary may be that the species *A. tuberculatum* became differentiated in Florida during the geographic isolation which is thought to have produced the fox-squirrel subspecies *S. n. shermani*, and that the tick is limited in northward distribution by cold.

STUDY OF ACTIVITIES

MAINTENANCE OF CAPTIVES

FIVE BROODS OF YOUNG fox squirrels were taken from their nests at Welaka and retained in captivity for observation. These were kept for a time in the laboratory in small boxes and cages and then transferred outside to larger cages and pens. In 1942 three individuals, representing two broods, were kept for 99, 99, and 95 days. These were Alpha and Beta taken February 12, and Gamma taken four days later. In 1946–1947 six individuals, representing three broods, were kept for 93, 114, 173, 245, 245, and 310 days. These animals were designated, respectively, Eta, Theta and Lambda, taken July 11; Pi and Rho, taken July 29; and Omicron, taken July 21.

Two small natural areas of longleaf pine and turkey oak on the Reserve were selected for fencing in fox squirrels, to observe their behavior under somewhat natural conditions. Each area had two longleaf pines about 45 to 55 feet high, spaced 20 feet apart. Fences were erected at a distance of 20 feet from the trunks of these pines in each area, which made two oblong enclosures each with short and long diameters of about 41 and 62 feet. Other trees inside the enclosures were no higher than 10 or 12 feet, and not close to the fence. The fences were of 1-inch mesh, wire netting secured to peeled pine posts the tops of which were sawed to slant down 30 degrees from the horizontal towards the interior. The bottom of the fence was buried 6 inches in the ground. Along the top of the fence, a 1- by 6-inch wooden rail, which took its slant from the tops of the posts, supported a flat, sheet-metal guard 12 inches wide. A gate provided access to each pen. In order to discourage the squirrels from jumping out over the fences from the pine trees, the tree limbs below 30 feet were removed. An observation shack was built of scrap lumber and placed in the most convenient position outside the pens for observation of the squirrels in both pens.

Some critique of the effectiveness of the structure of these enclosures seems desirable. Placing the fence only 20 feet from the trunks of the enclosed pines permitted adult, wild-caught fox squirrels to climb high in the pines and jump out over the fence. Placing the fence 35 feet out would have prevented this and permitted much more observation of wild-caught adults. The arrangement used proved fairly satisfactory for the observation of young individuals being reared in captivity. The height of the fence was only 4½ feet, and large dogs which (rarely) got into the Reserve, jumped over this into and out of the enclosure. For this reason some captive fox squirrels were lost. Had the fences been made a foot or 18 inches higher, probably this disadvantage would not have existed.

While the position of the sheet-metal guard only on the inside was an economical arrangement, it permitted feral house cats to climb into the enclosure but effectively barred their escape so that they could be destroyed. This one-way guard proved of positive value in one other respect. A hurricane wrenched off some of the sheet-metal guard on October 7, 1946, and three of the young fox squirrels escaped. After the fence was repaired, these young animals rather naively climbed back into the pen, presumably for their food, and were obliged to stay.

In these pens water was provided in a small dish over which a 2-quart mason jar was inverted on a frame to maintain a supply of water in the dish. For a part of the time a 500-cc. Erlenmeyer flask with a pipette tube through the stopper was used in place of the 2-quart fountains. Food was provided in box traps built for trapping fox squirrels (Baumgartner, 1940a, figs. 1–13), the traps being left unset (upside down) except on the occasions when the captives were weighed. A zippered restraining tube of canvas, like that of Shadle and Skarupinski (1935), was constructed to fit over the door end of the box trap. This permitted the animal to run out of the trap into the tube and pinion itself, which facilitated handling and weighing.

When the fenced enclosures for fox squirrels were finished on September 8, 1946, young squirrels that had just been weaned from milk were installed. From then until April 14, 1947, fox squirrels were kept continuously in the enclosures. Eta, Theta, and Lambda were kept 33, 50, and 113 days, respectively. Rho and Pi were both in the pens

193 days. Omicron spent 178 days in the enclosures. While other individuals were placed in the enclosures, for reasons mentioned above they did not remain.

FOOD, FEEDING, AND ELIMINATION

Nestling Food

One brood of fox squirrels was taken into captivity so young that they averaged only 67 grams, or 6 per cent of adult weight. At the other extreme a brood was taken that already had its eyes open and that averaged 238 grams, or 22 per cent of adult weight. These nestling squirrels all accepted milk readily but made no considerable use of solid food until much further grown.

The young captives accepted canned cow's milk deconcentrated, having been thinned 50 per cent with water, or skimmed fresh cow's milk. They did not thrive on either of these alone. Beating up a chicken egg in a half pint of milk was tried, and adding dextra-maltose to fresh skimmed milk seemed more successful. When a baby squirrel balked at feeding, a little honey, chocolate syrup, or strained banana mixed with the milk usually induced the animal to take its fill.

Feeding these sucklings called forth a curious set of apparently instinctive reactions, perhaps stronger in some individuals than others. Each sucking motion seemed to be preceded by a licking out of the tongue and a driving forward of the whole body by the hind legs. Then the sucking motion was accompanied by a strong pushing-away motion of the front feet. Both of these motions were accompanied to some extent by side-to-side sweeping motions of the head. When a little squirrel was held to be fed, its back to the palm of my hand and my fingers clasping its torso so that its head and all legs were free, the combination of these somewhat coordinated and rhythmic movements resembled a fantastic dance, which contributed very little, of course, to feeding success.

When 25 days old[1] and averaging 120 grams, or 11 per cent of adult weight, Alpha and Beta were consuming 25 grams of milk each day. Records of amounts of milk taken by Eta, Theta, and Lambda on five successive days at 41 to 45 days old show averages of 42, 44, 63, 67, and 77 grams per day per squirrel. Gamma took milk at the rate of 109 grams a day when 60 days old. These captive fox squirrels abandoned milk as a staple food when they reached a weight of about 500 grams. In this connection it is noted that a young male squirrel collected in the field weighed 418 grams, or 38 per cent of adult weight, having its stomach full of milk, but that one collected trimming a pine cone at the base of a tree weighed 550 grams, or 51 per cent of adult weight.

When the youngest brood taken failed to grow on cow's milk, a commercial baby food named "Pablum" was offered to them mixed with the milk. With this food they improved promptly. The baby food filled the squirrels up for a notably longer period, and it kept the abdomen firm and warm until time for the next feeding. Milk alone permitted the abdomen to become soft between feedings and, during the night, cold. This preparation was accepted readily by most of the young squirrels even after they were eating largely solid food, but as soon as they were clearly doing well on solid food, at about 51 per cent to 65 per cent of adult weight, I weaned them of this and put them in the open pens.

Longleaf-Pine Seed

When Eta, Theta, and Lambda were 79 days old and averaged about 580 grams, or 54 per cent of adult weight, they accepted avidly the longleaf-pine seed removed from a cone for them. They succeeded, then, in trimming the remaining scales from a cone which had been started for them. At this time, August 24, Pi and Rho, who were 66 days old and weighed about 449 and 502 grams, respectively, showed by their behavior that they liked the pine seed very much, but could not trim the scales from a partially scaled pine cone, even though Rho tried industriously and long. After four days of experience in trimming pine cones, Eta, Theta, and Lambda became fairly adept. Timing revealed that Lambda removed 58 seeds from a cone in 25 minutes, her efficiency reaching three seeds per minute. Her litter mates ap-

[1] Ages of captives were estimated by means described in the section on Growth.

peared to be equally proficient. After nine days of experience with pine cones, individuals of this brood were, in addition to one feeding of Pablum per day, eating the seeds of three and one-third cones each. Nineteen days afterward, Lambda, Pi, and Rho together consumed the seed from 18 longleaf-pine cones as one day's full ration. At this time they weighed about 825, 518, and 585 grams, respectively.

On September 9, when Theta was 95 days old and weighed about 695 grams, or 65 per cent of adult weight, timing of his scaling of the longleaf-pine cones during a seven-minute period revealed that he averaged the consumption of six seeds per minute. This was 12 days after the day that litter mate Lamdba's best rate was three per minute, and 16 days after Theta trimmed his first cone. At this time Eta consumed seed from two cones and Theta from two and one-half cones, at one sitting. These cones contained about 90 to 100 seed per cone.

The captive young fox squirrels had had no opportunity to observe adults cutting cones. It was on September 27, 34 days after their initial acquaintance with longleaf-pine cones as a food source, that one squirrel was first observed harvesting one of the cones that grew on the longleaf pines in his pen. When discovered engaged in this activity, Eta was struggling to carry a large cone along a limb of the tree. Apparently as a result of trying to watch me as he worked, he dropped it. A few minutes later Eta broke off a pine cone from the tip end of a limb and struggled for a while trying to find a place on the limb where he could balance it satisfactorily while trimming it. After several wobbly efforts, which nearly caused him to drop this one, too, he carried the cone in his teeth to the ground. Then at the base of the tree, where I found the remains of three other cones from the tree, he proceeded to trim his prize. Plate 2 shows a fox squirrel successfully trimming a cone up in the tree.

On October 4, when the writer placed a supply of pine cones in the feed corner for rations for brood C, Eta carried off and trimmed them one at a time on the top of a stump 12 or 14 inches high and several feet from the corner. Theta carried his off singly to eat at the base of a turkey-oak sapling or the nearer pine. When Theta finished a cone, he tried to rob Eta or Lambda of cones they had begun, rather than starting another himself. He succeeded in robbing Lambda twice. Eta resisted more successfully, the two male squirrels tugging on either end of the cone, pulling 5 or 6 yards in one direction, then 5 or 6 in another, their continuous vocal quarreling audible quite clearly 30 or 40 feet away. The tug of war was varied by one protagonist's letting go, until the other began to trim the cone. Then, as the victor tore away the scale, the vanquished reached boldly in and removed the seed thus exposed. Lambda made no determined effort to compete with either of the males at tugging, but became adept at lifting out a seed that the victorious male exposed.

On October 8, the day after the hurricane passed, I saw Pi, who then weighed about 575 grams, swinging against the forbidding sky on a pine bough in the high wind, industriously trimming scales from a cone *in situ*. On the fifteenth Pi was again observed trimming a cone *in situ*. This one grew on the end of a twig. She trimmed off the scales while she hung upside down beneath the twig, but when she obtained a seed, she pulled herself up on top of the limb to eat it sitting up. By October 22 the cones produced by the pines in this pen had all been consumed.

The longleaf pine provides one of the most important foods of the fox squirrels in this area and probably does so throughout the range of the pine. The period of use is not especially long, but the quantity of it that is available is enormous. In 1946 the first trimmed cone of the season was found on May 30; in 1947, on June 6. Feeding on this resource reached its peak in July. On July 15 the writer recorded finding freshly trimmed cones in six different places during a walk in the sand hills. On August 3 a note indicates that freshly trimmed cones were found in only three places during about three hours as the writer climbed to fox-squirrel nests in the sand hills. On August 21 is this note: "The eating of longleaf-pine cones by fox squirrels is no longer indicated by piles of freshly cut scales under most of the cone-laden trees. The reddish, old cuttings still lie there marking the eating places, but fresh cuttings are not added as abundantly or as regularly as for-

merly. This has been noticeable for two weeks or more. Cones still occur on some of the trees where they were being greedily consumed a month ago, and there are a good many bearing trees whose fruit has not been touched." On August 24 after a long day of tramping in the sand hills I made this note, "Nowhere in all my ramblings today did I see a freshly trimmed pine cone." Nevertheless, feeding on this resource did continue. On September 3 in about a half-mile traverse of the virgin-pine tract east of the Reserve freshly trimmed cones were noted at five separate sites. November 3 is the latest date that I have for a field observation of a fox squirrel feeding on pine cones. However, William M. McLane saw a black fox squirrel cross Florida Highway No. 20 on December 14, 1948, by Lake Sallilee, Putnam County, with a pine cone in its mouth.

On November 8 it was noticed that about 50 per cent of the cones on longleaf pines in the flatwoods and hammocks had opened. After the cones open and drop their seed, the fox squirrels undoubtedly obtain many seeds in their foraging on the ground, but bobwhite quail (Laessle, 1944, p. 161), and possibly flying squirrels, cotton rats, and cotton mice, compete for the pine seed there.

On June 30, 1946, a survey of 46 longleaf pines in the flatwoods near the Reserve laboratory revealed that, while three of these had no cones, the lot averaged 20.3 cones per tree. Fox squirrels had levied upon cones of only six of these trees at this time. The trees ranged in DBH (diameter breast high, which was calculated from measured girth) from 9.25 to 17.8 inches and averaged 12.2. Only 13 of these 46 trees had flattened tops, spreading out laterally instead of having the pointed, spire-like tops of trees still growing taller. The 13 averaged 13.7 inches DBH and had 23.4 cones per tree. The old pines on the extensive lawn that stretches widely about the laboratories, quarters, and office, although no longer standing in a natural situation, unquestionably grew there under natural conditions for most of their lives and were allowed to remain as ornamental and shade trees when the area was cleared for man's use. On June 24, 1946, 25 of these were found to average 15.9 inches DBH and 50 cones each. The 12 of these which were distinctly flattened out in the crown averaged 16.2 inches DBH and 47 cones each. Perhaps this indicates the mast-bearing that may be expected of the more mature trees.

The manner in which young captives handled pine cones in feeding is described above. Free, wild fox squirrels usually descend and trim the cones on the ground at the base of the food tree; probably young squirrels do this almost exclusively. Adults were occasionally observed trimming cones up in the trees in the manner illustrated in plate 2. Widely scattered scales and fallen cores that had lodged occasionally in forks of turkey-oak saplings offer additional evidence that cones had been trimmed high up in the food tree and suggest that this is the feeding habit of some squirrels (possibly older adults).

Four such accumulations were found on three days in August of 1946 where a fox squirrel had trimmed one or more cones while sitting up off the ground on a log or a stump. The highest of these was a stump 34 inches high. All four places were in an area small enough so that they could have represented the work of one individual. However, five of my captives were observed to feed in this manner.

The male or pollen cones are apparently also eaten to some extent. A free, wild, female fox squirrel was observed eating these cones about four times on March 27, 1947. The remnants of this type of cone have been found on old fox-squirrel nests where it appeared that squirrels had left them.

Live-Oak Acorns

This food was available but in limited quantity for the feeding of the penned young fox squirrels. Gamma could first eat a whole acorn at the age of 68 days, but he could not yet shell one for himself. These acorns were still rather green in late August and on September 2. The squirrels, which were eating solid food at that time, took them eagerly but ate little. By September 9, however, they were eating newly gathered acorns in some quantities. On November 12, when Omicron was 123 days old and weighed about 485 grams, or 45 per cent of adult weight, a pan of live-oak acorns was taken to the pens. Omicron was eating corn at the moment and seemed to be full. Nevertheless, he came and

accepted an acorn to eat. As soon as he had eaten the first, he took a second. Turning it over once with his teeth and forepaws, he carried it off to cache. When he had cached 15, I deliberately gave him one with a hole in it. He took it in his mouth, but dropped it at once without further examination. I gave him a better-appearing one, with a worm hole in it. He examined it by nipping the disk-shaped abscission layer off the proximal end. Immediately dropping it then, he looked to me for another. This time he was given one that was shriveled and pale. He bit the disk off this one and dropped it at once. Receiving a good one next, he ate it. He ate another, cached the next, and then returned for no more.

Omicron ate the acorns in the following manner. At the proximal end he bit off the abscission layer disk. Then from the edge of the shell which this exposed, he bit off pieces, working around the circular edge and turning the acorn about on its long axis between his forefeet. When he had been around the acorn about twice, and half of the yellow-orange kernel was exposed, he began to eat the kernel by biting small pieces off the top. Sometimes he was able to eat the whole kernel without removing more of the shell. On February 6 turkey-oak acorns that had been freshly opened and partly eaten in this manner were found at three different places in the sand hills northeast of the Reserve. Partly eaten ones in all stages were scattered about.

Turkey-Oak Acorns

Apparently the most important single food of fox squirrels in the sand hills is the turkey-oak acorn. This acorn (18 to 24 mm.) is regularly surpassed in size in Florida only by that of the relatively rare swamp-chestnut oak (*Quercus prinus* Linnaeus). The abundance of turkey-oak acorns doubtless varies from year to year, and the crop of 1946 appeared to be heavy only on some of the occasional large trees that stand somewhat alone in open places or project above stands of second-growth turkey-oak. Captive squirrels accepted turkey-oak acorns readily enough, but in 1946 low productivity of trees within any reasonable walking distance discouraged my providing them as staple food.

In 1946 turkey-oak acorns were recorded to be approaching full size on August 21. It was noted on October 6 that they had just begun to fall. On November 17 great stores of turkey-oak acorns were noted on the ground under some of the larger trees in the sand hills to the northeast of the Reserve. By December 2 it was unusual to see acorns on the forest floor of the sand hills on the Reserve, even singly, but in rather open places east of the Reserve one could not avoid walking on them. By February 6 the fact that many good acorns were still lying about under large turkey oaks was noted with surprise. Under one tree northeast of the Reserve at this time it was possible to gather 6 pounds of carefully selected good acorns, and it was noted that many of the large turkey oaks in the area between the Reserve and the virgin-pine tract to the east still had under them an ample supply for fox squirrels. On March 16 it was still possible to gather a quantity of good turkey-oak acorns under trees northeast of the Reserve, but such places were very scarce by then, and while I was at this one, two immature and two adult eagles were circling together high above. Nevertheless, on March 27, 1947, a free, wild, female fox squirrel, which the writer had under observation for six hours in the sand hills on the Reserve, located and consumed five acorns on the forest floor. It is rather interesting that no instances whatever were recorded of fox squirrels' cutting and littering the ground with leafy twigs in order to harvest the acorns.

Cypress Balls

Extensive parts of Florida's vast plains of longleaf-pine flatwoods are dotted with ponds which are ringed or sometimes covered with cypress stands (*Taxodium ascendens*). This mingling of pine and cypress areas provides another apparently satisfactory fox-squirrel habitat. In addition to cypress ponds, these flatwoods areas often include small, slightly elevated areas which are characteristically occupied by hammock growth, including live oaks. Where this is true, the smaller, open, live-oak hammocks are resorted to for nesting as well as for food. Whether hammocks are a part of this habitat essential to the fox squirrel, I do not know.

There are certainly extensive areas of flatwoods sprinkled with cypress ponds but lacking hammocks.

Cypress ponds do not occur in the flatwoods on the Reserve, and the writer had little opportunity to study the relationships of the fox squirrel to them. It is well known to hunters in Florida that fox squirrels nest in the cypresses in these ponds and forage there on the cypress balls as well as out in the pinelands on pine cones. B. Austin Barrington showed me several ponds inhabited by fox squirrels on his flatwoods study area 6 miles north of Gainesville, Florida. This relationship is described further under the subject of nests.

Other Foods

Foods purchased commercially and provided as staples for the captive fox squirrels were raw peanuts in the hulls, grains of dry Indian June corn, sweet potato, chufas (*Cyperus esculentus*), and a laboratory animal food named "Purina chow," which is a mixed food compressed into blocks that average about 12 grams each. The fox squirrels seemed reluctant to change from an accustomed one to another of these. Reluctance to start eating Purina chow was often pronounced, although once the fox squirrels accepted it, they lived well on it as a staple. Adults consumed about 140 grams each per diem of this chow. Apple, halved orange, grape, strawberry, and stewed oatmeal were accepted readily but were not provided with such regularity as to be considered staples. Apple and orange were provided often and were accepted regularly but only in small quantities. The squirrels occasionally ate less than usual of the staple, as though weary of it, and the other foods were provided for variety.

R. Kirk Strawn told me that he saw a free, wild fox squirrel sitting on a fence eating an orange. This was on April 17, 1947, by Lake Winona, Flagler County. He considered that the orange was one picked up under the tree rather than plucked from its branches. The results of my feeding box-trapped, penned adults indicate that the amount of any citrus fruit used as food would be exceedingly small.

When Alpha and Beta were 64 days old and weighed 341 and 286 grams, respectively, they learned to hull and eat raw peanuts. Eta and Theta were first observed to do this when they weighed 407 and 384 grams, respectively. Alpha and Beta had the advantage in this respect of having been penned with a squirrel that was several weeks their senior which provided them with something to imitate. This older one, Gamma, did not himself learn to open and eat peanuts until he weighed about 500 grams. When Alpha and Beta were 92 days old and Gamma was 104, the three together under close observation ate 99 grams of raw peanuts (weighed with hulls removed) in two meals, the first of 50 grams at about 8:00 A.M., and the other of 49 grams an hour before dark. This was all the food they accepted during one whole day.

Alpha, Beta, and Gamma were offered live grasshoppers, which were numerous on the lawn in late April when Alpha and Beta were 84 days old. They quickly took an interest and accepted the grasshoppers with enthusiastic behavior. In eating eight or 10 apiece, they fumbled and lost only a few, although the grasshoppers were only 10 or 15 mm. long. One of Harper's (1927, p. 330) informants in the Okefinokee Swamp said that fox squirrels were very fond of grasshoppers. His comments seem to apply to captives also.

When Eta, Theta, and Lambda were 63 days old and weighed only 446, 437, and 452 grams, respectively, I took them out on the extensive lawn, placed them in the grass, and sat down with them to watch their reactions. Eta and Theta soon took an interest in the small, ovate leaves of *Richardia scabra* (Rubiaceae) and began eating them, masticating noisily. They also chewed grass stems of two kinds, dead pine needles, etc., in the exploratory sampling manner which seems characteristic of young fox squirrels when liberated out of doors after having been confined. Interest in *Richardia* was, however, more than fleeting. Seventeen days later, while caged, Theta accepted and ate eight or 10 leaves of *Richardia*.

Ripe fruits of the gallberry (*Ilex glabra*), the cabbage palm (*Sabal palmetto*), and the gopher apple (*Geobalanus oblongifolia*) were refused by caged young squirrels, which had, of course, not had the opportunity to become

acquainted with these fruits under natural conditions.

Gnawing

In one of the fenced enclosures when Theta was 109 days old and weighed about 705 grams (September 23), he was heard gnawing noisily on something hard. He had found an old cow femur in the enclosure. Examined several days later it was found to be deeply and extensively sculptured by gnawing. Picking up a horse femur somewhere, I placed it in the other pen on October 2 when Pi and Rho were 105 days old and weighed about 560 and 660 grams. One or both of them gnawed on it within four days. Omicron was observed gnawing on the cow femur on October 22 when he was 102 days old and weighed only about 465 grams. Carlson (1940) and Coventry (1940) report other squirrels "eating" bone.

A mysterious act, which seems attributable only to the fox squirrel, is that of biting the sides of stumps. In each of the three recorded instances in which this was observed, there were tooth marks like those of fox-squirrel incisors on the sides of pine stumps which had been left by logging and were still charred from old fires. It appeared in each instance as though a fox squirrel passing by on the ground had stopped momentarily, bit the side of the stump about 6 or 8 inches high, across the grain, and continued on his way. No fox squirrel was observed to do this, and the marks could have been made by the teeth of the pocket gopher (*Geomys pinetus*). However, pocket gophers seldom move about on the surface of the ground and were scarce in the unburned and relatively well-shaded parts of the sand hills on the Reserve.

Caching

Audubon and Bachman (1851, p. 136) comment, "The Fox Squirrel does not appear to lay up any winter stores . . . " and appear to consider that this big squirrel does without eating for considerable periods in the winter. I have seen no free, wild adult cache food, but the following observations of young captives suggest that they do. Two of Harper's (1927, p. 330) informants in the Okefinokee Swamp assured him that fox squirrels buried pine cones in the ground for future use. This is something which my captives were not observed to do. Lack of sign of cones' being trimmed in the sand hills at Welaka in the winter of 1946–1947 convinced the writer that little or no cone-caching was done there. However, this activity may explain McLane's seeing a squirrel with a cone as late as December 14 in 1948.

Gamma was 82 days old and weighed about 600 grams when he cached his first peanut, about a week after he began eating peanuts daily. Alpha and Beta cached peanuts 15 and 17 days (respectively) after they ate their first peanut and began receiving them daily, despite the fact that Gamma was in the same pen with them caching peanuts all but two days of that time. Alpha first cached a peanut at 80 days old, eight days after he weighed 477 grams. Five days after carefully burying his first cache, Gamma ate one peanut and then cached five before eating any more. He searched about somewhat in selecting places to bury his peanuts, usually picking soft, dry sand. He dug a shallow hole with his forepaws and pulled the soil towards him and between his hind legs. Into this hole he rammed the peanut, holding it crosswise in his mouth and striking several blows with it, forcing it deeper than the hole was actually dug. Thus seating it, he let go his hold on it and struck it a series of four or five short, sharp blows with the front of his upper incisors, woodpecker-like in speed as if to drive it in farther. Covering it, then, he sat erect, as in digging, but awkwardly raked the sand from himself towards the hole with his front feet.

Forty-five days after Alpha and Beta ate their first peanuts, and about 52 days after Gamma had eaten his, a check was made on their ability to locate peanuts buried at various depths. A pan 16 by 24 by $1\frac{1}{2}$ inches was filled heaping full with dry, very dusty sand and leveled off to an average depth of $2\frac{1}{2}$ inches. Fifteen peanuts were buried in the pan, five beneath 2 inches of sand, five beneath 1 inch, and five beneath $\frac{1}{4}$ inch. This pan was taken into the 6 by 6 by 12-foot pen in which the three squirrels were currently kept, at their feeding time when they were hungry. Each was given a peanut to occupy him while the pan was being placed, and three or four more were placed half buried on

the pan to attract the squirrels to the pan. Forty-five minutes later the squirrels had evidently ceased feeding, and the pan was removed and examined. Of the five buried $\frac{1}{4}$ inch deep all were gone, of the five buried 1 inch deep four were gone, and of the five buried 2 inches deep all remained. I checked on the hunger of the squirrels and the palatability of the remaining peanuts by offering these to the squirrels from my fingers. The squirrels ate these and one or two more. Very little sand was thrown out of the pan, and not enough holes were evident to indicate that the peanuts discovered had been found by random digging. Cahalane (1942, p. 349) found in five similar experiments with very dry soil that the western fox squirrel (*Sciurus niger rufiventer*) found nuts buried in dry soil only with the greatest of difficulty.

Eta, Theta, and Lambda had no opportunity to cache food until they were 99 days old and weighed about 750, 750, and 800 grams, respectively, when they responded abundantly to their first chance. When Omicron cached the 16 live-oak acorns, as described above, his technique differed from that described for Gamma. Omicron's preparation of a site consisted of only a few quick digging or clearing strokes, or none at all if the cache was being made in leaf mold. Omicron's technique, after he had covered the acorn assiduously by raking leaves and dirt over it, included carefully patting it down tight with his forepaws. It also seemed that Omicron buried each acorn at the base of some small shrub, herb, or bunch of grass.

When Omicron was 198 days old and weighed about 675 grams, the supply of peanuts became temporarily exhausted and Indian June corn was substituted. Omicron came to the feeding corner, ate about two grains of the corn, and then abandoned the corn and went to dig up cached peanuts to eat. As he dug up each peanut, he carried it to the top of the stump and ate it there. The writer left for an hour, then, and, when he returned, the ground was pitted all around the feeding corner in both enclosures as if all three of the squirrels had been very active digging up cached peanuts. Nearly all the holes were 24 to 36 mm. deep, whether in humus or in sand. Several were in pocket-gopher hills.

Drinking

As Alpha, Beta, and Gamma changed from a diet of milk to one primarily of peanuts, they were provided with water and began at once to use it. Gamma was first observed drinking water at 83 days of age. It was noted that, although he appeared to work his tongue in a lapping manner, his lips were submerged, and he seemed to suck up the water. When all three of these squirrels were drinking together on April 12, it was observed that they sucked up the water but that they worked their jaws rather rapidly in the process. Omicron was observed drinking from a dish on March 13 at considerable length, for he had just been etherized so that he could be measured. He distinctly sucked up the water, not extruding his tongue at all. When he had lowered the water level to a point where he could no longer easily reach it, he licked a few times and then left. This licking did not appear to be effective lapping like that of a dog or cat drinking. When he was recovering from ether on April 14, he blundered into the water dish and drank as if perishing. I crouched with my head to the ground and eyes within 8 inches of his mouth, which I could see through the glass sides of the drinking dish. He did not lap the water, or even expose his tongue, but sucked the water up as does a horse.

In their fenced-in natural area Eta, Theta, and Lambda emptied a 500-cc. Ehrlenmeyer flask of water through a pipette in six days, September 14 to 20. They emptied it again between September 21 and 24 in two and a quarter hours less than three days. Between October 3 and 5 at 119–120 days of age they emptied it in two hours less than two days, but they had been without water for several days previously. Eta and Theta must have weighed somewhat over 700 grams each and Lambda somewhat over 825 grams at the time of the first records of water consumption given above.

The only observation that was obtained of a wild, free adult drinking was in the Ocala National Forest about 2 miles south of Lake Ker on Half Moon Road. It was drinking from a rain puddle in the middle of the straight road at 12:20 P.M. on a cloudy day, October 2, 1948, and allowed our car to approach within 100 feet before it fled. Water

supply to an animal as large and active as a fox squirrel is a matter of some interest in a habitat so xeric as that of the sand hills. Ponds are present, but they are few and far apart. On September 13, when Theta was 99 days old and weighed about 700 grams, he was observed to go out on a limb of one of the longleaf pines in the fenced area at sunrise plus 30 minutes and run his tongue up the long, dew-laden needles for water. If dew is frequently so heavy on the pine needles as during this observation, it may be a reliable and important source of water. Brown and Yeager (1945, p. 510) noted that standing water seemed not to be a requirement of fox-squirrel habitat in Illinois and suggested that succulent fruits may serve fox squirrels for moisture, but that fox squirrels may migrate to better-watered areas in prolonged drought.

Excretion

For a short time after brood C were taken from their nest into captivity, they followed a practice that must have kept their nest much more sanitary and dry than it otherwise could have been. The three lay quietly together half asleep in the nesting material of their improvised nest in a 5-gallon aquarium tank. Theta rose, moved to the wall of the tank, stretched himself up against it until he could reach the top, pulled himself up until he hung vertically, and urinated against the glass. As soon as he had finished, he let himself down, snuggled between the others, and dozed again. As is shown below, the nests of these fox squirrels are almost invariably placed against the upright trunk of a tree. A vertical surface would, therefore, be available for such use. When Pi and Rho were 50 days old and weighed about 266 and 300 grams, respectively, they were kept in a 5-gallon aquarium tank with a cover on it that may have prevented the behavior exhibited by brood C. They were consistent, however, in urinating and defecating in the end of the aquarium tank as far as possible from where they slept.

With brood D, which was taken much younger than broods C and E and apparently too young for their leaving the nest to evacuate (weight about 67 grams each), it was accidentally discovered when they were being held to be fed, that one had but to brush the genitalia gently with absorbent cotton to induce urination and the anus to induce bowel movement. This was practiced regularly when these squirrels were handled, for it helped to keep them and their nesting material clean. One wonders whether the mother squirrel keeps the nest clean while they are as young as this by licking the perineal region and so removing their body wastes. When Omicron was 56 days old and weighed 164 grams, he was living in an aquarium tank floored with rough sawdust, and on two days in succession he was observed to defecate at the farthest end of the aquarium from where he slept. He dug a hole in the sawdust with his forepaws and squatted over it to defecate.

When the squirrels were old enough to eat entirely solid food, and were running free in the fenced areas, it is my impression that in defecating they gave no regard to place or position, other than to refrain from doing it in their nests. The feces were firm, blackish pellets, and the squirrel dropped them without halting whatever activity engaged its attention at the moment. The one instance that I recorded of one of them urinating at this stage of life was observed at 6:35 A.M., September 13. Theta, then 99 days old and weighing about 700 grams, was lying along a nearly horizontal limb with his head away from the trunk of the tree and his tail low and drooping over the side of the limb behind him. He appeared to be relaxing for a few minutes after having engaged in a fairly restrained frolic among the limbs of the treetop with his litter mates. The urine ran over both sides of the limb and presently ceased. No movement was made before or afterward to accommodate posture to the act of urinating.

BEHAVIOR IN RELATION TO PHYSICAL CONDITIONS

Daylight

Investigators of the western fox squirrel (*Sciurus niger rufiventer*) have used Standard Time in presenting the times of day when these squirrels were observed active. At the latitude of Storey County, Iowa, where Hicks (1949, p. 291) made his observations, there is in Central Standard Time a difference of three hours and four minutes between time of sunrise on June 20 and that on January 1. Consequently in Hicks's (*loc. cit.*) table 3, which presents time-of-day observations, the animals that he records as active during the single hour between 7 A.M. and 8 A.M. may include some observed during the first hour after sunrise on January 1, the second hour after sunrise on March 7, the third hour after sunrise April 11, and the fourth hour after sunrise on June 15. (See table 4 in the present paper.) His effort to present observed activity in relation to hours of daylight thus went completely amiss.

Presenting data on activity relative to time of day by seasons but still in Standard Time, as Hicks (1949, p. 292) does in his table 4, does not eliminate this error. Squirrels reported in his table 4 as having been seen between 8 A.M. and 9 A.M. in the winter could have been seen during 40 minutes of the first hour after sunrise on January 1, during 52 minutes of the second hour after sunrise on February 27, or during 46 minutes of the third hour after sunrise on March 20, because in the three months of winter alone the times of sunrise vary one hour and 25 minutes. The variation is greater during the three-month seasons of spring and fall. It is apparent, therefore, that even Hicks's seasonal presentation of hourly activity must be regarded as of little worth.

Brown and Yeager (1945, p. 464), who hunted 716 hours in all parts of Illinois and recorded 336 observations of fox squirrels, present a tabulation of times of day in which the squirrels were active from June through October in 1941 and 1942. Their data are also scrambled to insignificance by the use of Standard Time. In making their observations over the state of Illinois at large, they acquired two additional variables in time. There is in June nearly 23 minutes of difference in time of sunrise between the northern and southern ends of the state on the same day, and on any day in the year there is an east-west difference of about 15.2 minutes in time of sunrise. These three errors could all have been avoided by the use of time after sunrise, or before sunset, at the locality of the observation. Tables issued by the United States Coast and Geodetic Survey (1953, pp. 238–248) provide convenient means for changing times recorded in Standard Time to time from sunrise and sunset.[1] Baker

TABLE 4

Differences Between Time as Stated in Hours and Minutes After Sunrise and Central Standard Time in Central Iowa During (A) Course of an Entire Year and (B) Course of a Single Season (Winter)

Dates	Hours After Sunrise			
	First Hour	Second Hour	Third Hour	Fourth Hour
(A)				
Jan. 1	7:40–8:40			
Mar. 7	6:38–7:38	7:38–8:38		
April 11	5:39–6:39	6:39–7:39	7:39–8:39	
June 15	4:36–5:36	5:36–6:36	6:36–7:36	7:36–8:36
(B)				
Jan. 1	7:40–8:40			
Feb. 27	6:52–7:52	7:52–8:52		
Mar. 21	6:14–7:14	7:14–8:14	8:14–9:14	

[1] It should be noted that Local Civil Time would be the best for comparison of observations near midday in different seasons of the year. To take care of both mid-

TABLE 5

TIME IN RELATION TO SUNRISE AND SUNSET OF OBSERVATIONS ON FOX SQUIRRELS (*Sciurus niger shermani*) IN PUTNAM, ALACHUA, AND GILCHRIST COUNTIES, FLORIDA

Time	No. of Nests Examined	No. of Inmates (Except Nestlings)	Ratio	No. Away from Nests
Morning				
1:00–sunrise	12	0	0	0
Sunrise–0:59	54	7	13.0	6
1:00–1:59	92	8	8.7	14
2:00–2:59	63	3	4.7	9
3:00–3:59	61	1	1.6	8
4:00–4:59	53	1	1.9	3
5:00–5:59	26	0	0	4
6:00–6:59	13	0	0	4
Afternoon				
6:59–6:00	0	0	0	1
5:59–5:00	1	0	0	5
4:59–4:00	2	0	0	4
3:59–3:00	4	0	0	2
2:59–2:00	18	0	0	1
1:59–1:00	22	0	0	6
0:59–sunset	23	0	0	1
Sunset–1:00	1	0	0	0

(1944, p. 14) used hours before and after sunrise for time of squirrel activity, but the lumping together of his observations on the gray squirrel and those on the fox squirrel robs his data of specific use.

Referring to *Sciurus niger niger*, Audubon and Bachman (1851, p. 137) say: "This squirrel is seldom seen out of its retreat early in the morning . . . . He seems to be a late riser, and usually makes his appearance at 10 or 11 o'clock, and retires to his domicile long before evening." Records that indicate the times of day when fox squirrels in north Florida were observed to be active and inactive are presented in table 5. This tabulation reveals the slightly incongruous evidences that many fox squirrels appear to be late risers and that their most active period of the day is early, partly overlapping the time of lying abed late. One might speculate that after retiring to its nest before sundown and staying there until after sunrise the squirrel is full of pent-up energy and hungry, so that it is both more active and bolder during its first hour or so of foraging than during the remainder of the day. Once up, therefore, the squirrel is more likely to be observed sooner than later. After the especially active morning period, indications are that the frequency with which fox squirrels may be seen moving about is reduced for the remainder of the day. An exceptional increase in activity shown in the second hour before sunset appears to be real and not the result of any bias that I can detect by reëxamining the original data.

As the seasonal distribution of the observations of active fox squirrels are rather even (by the month, starting with January, 5, 11, 5, 6, 5, 6, 6, 4, 8, 5, 4, and 3), it is interesting to find just a suggestion of a seasonal difference in diurnal peaks of activity.

day and morning or evening observations of animals the activity periods of which are thought to depend on daylight, in one set of comparisons, one might divide the day between sunrise and sunset into an arbitrary number of equal time periods, say 12, with about two more periods of the same length before sunrise and two after sunset. Any one of the periods would obviously be shorter in temperate (northern) latitudes in December than the same period would be in June. These arbitrary time periods, rather than hours of Standard Time, would certainly be more likely to represent the same time of day throughout the year to an animal the activities of which depend on daylight. It hardly need be added that near the polar regions this system would become both inapplicable and not needed.

Thus, from January through June there appears to be greater activity in the late morning and late afternoon and less activity in the early afternoon. As is shown in table 6, from July through December there seems to be a contrasting absence of activity in the late morning and late afternoon and greater activity in the early afternoon. The early-morning activity, in keeping with the suggestion made above, remains strong.

TABLE 6

SEASONAL VARIATION IN ACTIVITY TIME OF *Sciurus niger shermani*

	January–June	July–December
Hours after sunrise		
First	4	2
Second	7	7
Third	4	5
Fourth	2	5
Fifth	3	0
Sixth	4	0
Seventh	3	0
Hours before sunset		
Seventh	0	1
Sixth	1	4
Fifth	2	2
Fourth	1	1
Third	1	0
Second	5	0
First	1	0

Fox squirrels found in their nests in the late morning, afternoon, or early evening, are not recorded in table 6, and instances are rare. An adult male was flushed from a leaf nest at four hours after sunrise in a small cluster of mature live oaks in the sand hills, February 25, 1947. In addition to the possibility that detection of my approach had caused him to hide in the nest, there is the chance that the presence of an adult eagle, which the writer saw circling above, had caused him to retire. Fox squirrels were observed to take refuge in leaf nests at my approach in the middle of the day on two or three occasions. In the early afternoon of March 9, 1947, a visit to one of the stump dens (see section on Nests and Nesting) revealed an immature female fox squirrel in the nest.

Several apparently little-related facts may be assembled here which point to further information on activity. The writer has climbed to 58 leaf nests during the fifth, sixth, and seventh hours after sunrise and to 51 during the three hours before sunset during the period of July through December without arousing from any of them a single non-nestling squirrel. Because, as shown in table 6, these are low periods of activity, and because the data in table 5 lead us to expect a ratio of at least one non-nestling squirrel to eight nests when in nearly full use, this indicates that an adult fox squirrel makes little use of nests during the day, and probably rests lying on a horizontal limb as the young captives were observed to do.

EXTREMES OF HEAT AND COLD

During the height of a hot day my captive fox squirrels lay along horizontal branches of the pines in their enclosures in the resting posture illustrated by plate 3, using the tail for a shade. When on the ground, they sometimes sprawled on their bellies in the shade of a tree trunk or fence post, with all legs comfortably extended straight out from the body. Brown and Yeager (1945, p. 465) report Illinois fox squirrels sprawled on limbs of trees on hot days.

Before sunrise on the morning after the first extremely cold (35° F.) night of the winter of 1946–1947, Rho was out near the tip of a branch among the needles, and Omicron was huddled against the trunk on the base of a limb. Pi was in the leaf nest she had made in the brush. They were observed before they had the opportunity to move because of my approach, and they must have spent the night so, or Rho and Omicron had spent it so miserably in earth nests (see section on Nests and Nesting) that they had left them early to wait for the first rays of the sun. Thirteen days later, just an hour after sunrise, after a night so cold that the water froze solid in the 500-cc. water bottle in one of the pens, Rho was out among the needles of a low branch in the sun, and Omicron and Pi were in Pi's leaf nest. Two days later, February 6, after a night still colder, the same distribution was observed at one hour and a half after sunrise. Four days later, under similar conditions at sunrise plus one

hour and 48 minutes, Rho was again out on a limb in the sun and Pi and Omicron were in the nest. The day before this last instance, howeyer, at sunrise plus two hours and three minutes, Rho was running by the fence in the bitter cold, and Omicron and Pi were in Pi's nest. Rho was in an enclosure alone during all these cold nights. Although he was 244 days old and approaching adult weight at this period (850 grams) and a vigorous, healthy animal, he was not then or at any time in his 245 days of captivity observed to show the slightest interest in nest building. I suspect that he endured these cold nights up in one of the pines or in a terrestrial nest.

Rain

On their third day out of doors in the natural enclosures, Eta and Theta were 97 days old when they were observed to experience their first rain. They were relaxing for a moment on the lower limbs of one of the pine trees an hour and 40 minutes before sunset. The first sprinkling of raindrops stimulated them to leap about among the limbs of the tree in an exhilarated manner. They continued this graceful racing about and leaping among the limbs intermittently for 15 minutes. Eta then descended the trunk and began trimming a pine cone on the ground near the base of the tree. A couple of minutes later a lightning bolt struck somewhere near with a violent crash of thunder. At this Eta leaped to the tree trunk and clung to it about a foot from the ground, perfectly still for a moment. Then he returned to trimming the pine cone.

Twelve days later, when Pi and Rho were eating corn in one natural enclosure and Eta, Theta, and Lambda were variously occupied in the other, at three hours before sunset rain fell smartly for two minutes. All the squirrels ignored the rain entirely. After eight minutes rain suddenly fell in very large drops as violently as if charged with hail. The squirrels all scampered this way and that. Eta, Theta, and Lambda fled wildly from one bit of brush to another, seeking satisfactory cover in vain. They each settled at length, crouching somewhere under a bush. Rho and Pi finally ran up the fence beneath the guard and were nicely sheltered by the guard. About 15 minutes later the rain slacked to a very light drizzle. After a few minutes Theta broke cover, ran up the nearest tree to the first limb, and hunched on the base of the limb, with his wet tail spread over his back and head like an umbrella. Dry and fluffy, Pi and Rho left the fence to eat corn in the feeding corner on the ground, both using their tails as umbrellas against the fine mist of rain. About 10 minutes after Theta had done so, his litter mates ascended the trees, equally as wet as he. Theta sniffed noses with Lambda as she reached his perch, but he then descended to feed. Eta and Lambda remained in the tree and ran rather friskily out on one limb after another and jumped from limb to limb, as if in play. Lambda scrubbed her face once, rubbed her neck forward against a branch once, and made some quick motions that may have been licking ones. In general, however, the three wet squirrels made little overt effort to dry their coats and tails. After about 10 minutes, the rain ceased. Eta descended to join Theta eating corn, and 15 minutes later, Lambda descended to join them. They gradually lost interest in the corn and occupied themselves variously about the enclosure. About 45 minutes after the rain stopped, Lambda and then Eta ascended the nearer pine. They frisked recklessly about among the limbs of the pines, individually at first but eventually with Eta in pursuit of Lambda. This activity lasted about 10 minutes, and, although the squirrels were watched for 25 minutes longer, none of their further activity seemed related to their having become wet.

The above observations of behavior in rain were made in the warmth of September when the squirrels were only three or four months old and new to the natural enclosures. The following observations were made in the cold part of the winter when the squirrels were six or seven months old and had been in the enclosures about four months.

A few minutes after I arrived at the observation shack in midday on February 7 a rain set in softly and steadily. After about 20 minutes Rho and Omicron descended from hiding in the uppermost twigs to the shelter of the tree trunk on the lower limbs of their respective trees. There they sat, sometimes crosswise to the limb, more often crouched along the limb, back to the trunk, tail dan-

gling, chin resting on the wet bark—just letting it rain. Once in a while one or the other reared up for a moment, licked his forepaws, rubbed his face with them, took a lick or two at his sides or flanks, and then settled down again. Ten minutes later than the males, Pi descended to the lower limbs of still another tree and settled at the base of a low limb on the sheltered side of the trunk and behaved similarly. As the rain continued, the squirrels began to use their tails as umbrellas and blankets over their backs, in the same position that they are used as sun shades, shown in plate 3. Then from time to time one or another reared up and took hold of his tail at the base with his forepaws. He worked the whole length of the tail through his forepaws, licking it with his tongue. After 35 or 40 minutes Omicron began to move about friskily. He sprang up on the trunk head up, then whirled about head down, then about-faced again. Dropping to a limb he quickly sprang to another and another, then back to the same place on the trunk. While on the trunk he played on the sheltered side, but on the limbs he leaped about irrespective of rain and wind. Omicron did this for 30 to 50 seconds three different times. Observations early on the mornings of January 21 and 25 suggested that even in winter these captive fox squirrels spent rainy nights on the limbs of the trees.

In as much as these observations are all of young fox squirrels which had had no opportunity to learn their behavior from association with adults, of interest is an observation of an adult male freshly live-trapped in the wilds and released in one of the natural enclosures March 19, 1947. Most of his activity during the first five minutes was related only to trying to find a way out. He did this with great earnestness and dispatch, and with no indication of awareness of the steady rain. After starting to climb one of the trees twice, he returned and ascended to the lowest limb. Once, as he climbed, he paused and shook his head, scattering a shower of droplets from his nape. Upon reaching the first limb he stopped and licked his coat some and ran his tail through his forepaws several times, licking it as he did so. He climbed on to the top, but soon returned to a lower limb and went out to its tip and poised as if about to try a long leap for freedom. Presently, though, he settled down in this position and remained there motionless in the rain for 45 minutes. Observation then terminated. Durward L. Allen (1942, p. 346) and Brown and Yeager (1945, p. 465) report *Sciurus niger rufiventer* active in rain.

In climbing to nests immediately after a rain, the writer has taken care to look for dryness in the interior of the nest, and rarely indeed has found one dry. Because of the scarcity of den holes in trees and the fact that the leaf nests are seldom of construction adequate to shed all the rain, it appears that most fox squirrels in the sand hills get wet or partly wet whenever there is a considerable rain. However, when Pi and Rho were taken from a leaf nest in a bluejack oak on July 29, just three hours after a heavy rain, it was noted that the nest lining at the top was fairly moist while that in the bottom was dry. The young squirrels themselves were quite dry. Of course, the mother squirrel may have added her own body to the shelter of the nest. Leaf nests, even when somewhat wet, doubtless minimize the loss of body heat, however, and perhaps an adult rarely finds itself so far from a leaf nest that it weathers a heavy rain in the open as my young captives did.

PHYSICAL ACTIVITIES

Climbing

In descending a tree trunk, the squirrels proceeded head foremost and employed a gait that consisted of alternating strides of the front legs coordinated with opposite alternating strides of the hind legs. Thus, as the left front leg and right rear leg moved forward, the other two held. In ascending a tree, the squirrel may alternate its legs in this way also, but more frequently it ascends by a series of leaps, the front legs reaching out together as the hind legs propel. Then the front legs hold and guide as the hind legs come forward together. It is much the same as their running motion on the ground. When unhurried, a fox squirrel ascending a pine may leave the trunk on attaining the limbs and continue upward by leaping from one

limb to another. When pressed, however, it is more likely to stay on the trunk all the way up.

Running

Cottam (1941, p. 323) recorded a fox squirrel (*Sciurus niger niger*) running ahead of his car at 12 miles per hour when doing its best. At Welaka on June 4, 1946, James J. Friauf, Jr., pursued a fox squirrel in his car along one of the truck trails on the Reserve. Midway in the run the fox squirrel stopped and reared up to look for a fleeting moment before dashing on. Neither before nor after the pause did the squirrel gain or lose distance from the car during the 110-meter run. The speedometer on the car registered 15 miles per hour during this chase.

In order to obtain a further check on fox-squirrel speed, the writer released a subadult male fox squirrel on a large open lawn at the laboratory at Welaka and timed it to the fence with a stop watch. The distance over which it was clocked measured 69 meters, and a man pursued the animal over this course at a distance of about 10 yards. Its time was 12.5 seconds, which means a speed of 11.9 miles per hour. It was running at about its best. This squirrel had been kept for three and a half months in a 6 by 6 by 12-foot cage and fed and watered regularly, and it seemed to be in good health.

In the section on man as an enemy of fox squirrels, an instance is recorded in which an adult female was pursued at a run for 325 meters before it took refuge. Very likely much longer runs than this could be recorded, for this squirrel was the only one pursued in such a manner as to permit it to run as far as it chose. Usually when a fox squirrel was pursued on foot, an effort was made to frighten it into treeing promptly lest it escape. Audubon and Bachman (1851, vol. 2, p. 137) note this tendency of the fox squirrel to run long distances on the ground.

Jumping

Bangs (1896, p. 147) makes a statement on this subject which has curiously stood unrefuted for 60 years: "It takes to a tree only as a last resort, and then keeps to the trunk and large branches, trying to avoid detection by hiding. I believe it never jumps from tree to tree . . . ."

On July 25, 1946, in a part of the sand hills where 60-foot longleaf pines formed an unusually close stand, an adult female fox squirrel barked at me and then fled to a nest. A rifle shot brought her out of the nest in a vigorous, graceful leap, and she crossed to another tree and another until she had passed through seven. Along this course she hid in one treetop and behind another tree trunk until my circling for a shot caused her to move on. Her aerial acrobatics, while appearing poised and calculated, were not especially swift. She paused to balance before and after leaps, and none of her leaps was over 3 feet.

On February 4, 1947, at sunrise plus 24 minutes a full-grown fox squirrel left the nest when the writer was halfway up to it. The squirrel crossed from tree to tree but did not go very far, and it barked a little. As the writer climbed higher, the squirrel came back closer instead of moving away. As the writer neared the nest, an adult male left it. He joined his mate, and they moved away through the treetops, barking as they went. Both were of tan-phase pelage color. Descending, the writer followed. The male was proceeding slowly through the tree tops venting his displeasure frequently by soft barking. His movements in climbing were expert and so excessively vigorous as to seem an expression of anger. Once he jumped a space which, it was estimated in notes written on the site, would have measured horizontally 7 feet, from a limb to the trunk of the next tree.

On March 27, 1947, a subadult female fox squirrel was followed and kept in sight for six hours. At sunrise plus an hour and 21 minutes she crossed through several trees and descended. However, as I continued to follow her, she climbed more and more, usually ascending an oak but sometimes crossing into pines. At sunrise plus two hours and 16 minutes the fox squirrel had been climbing about for some time throughout the tops of a group of five or six pines, seeming to search the branches on which she walked but finding nothing. Once she jumped from an oak tree to the tip end of a bough of a longleaf pine. She caught the very bud at its apex with her forefeet, swinging down with it 3 or 4 feet and then, as it swung her back up, easily and gracefully using the impetus of the upswing to mount the bough. Another time, when she

leaped from an oak limb to a dead pine limb, and the latter snapped off leaving her without the least support, she rode it to the ground as undisturbed as though the 15-foot fall had been part of her plan. She ascended an oak and crossed over to a pine to examine a fox-squirrel nest about 28 feet up, and some of the limbs. Then she crossed back and descended. She progressed from tree to tree sometimes as far as 40 yards, but traveled probably four times farther on the ground. My moving up closer and sitting down at the base of a tree to watch usually stimulated her to descend, which seems very odd for a tree squirrel.

As the above observations deal with no more than four individuals, it should be added that six of my captives were observed to jump back and forth between the two pines in each of their two quasi-natural enclosures. Theta made about a 4-foot jump to another tree and a 5-foot jump back when he was 114 days old and weighed about 700 grams. Pi at the age of 221 days and weight of 850 grams (January 26) performed a remarkable jump. She was harvesting needle-bearing twigs for an attempt at building a nest, and her search for material took her to the other tree. She brought an 8-inch longleaf-pine twig, heavy with green needles, to the crossing place. The crossing required about a 4½-foot jump with a drop of 2 or 3 feet. She teetered before the jump for at least 90 seconds. She waved her forelegs around struggling for balance, turned about, and shifted the twig in her mouth time after time. Her soft, churring complaints were occasionally audible at 40 feet. When she leaped, the boughs crashed and swayed, but she landed surely, losing neither her balance nor her twig.

While the above observations certainly establish that fox squirrels (*Sciurus niger shermani*) do leap from tree to tree, it must be admitted that they do so less frequently and with much more circumspection than do gray squirrels. As a commentary on the extent to which they employ leaping from tree to tree as a means of escape, it is noteworthy that there were seven instances in which fox squirrels frightened from their nests fled in this manner and seven instances in which they leaped from their nest to the ground. The heights of nests from which these squirrels jumped to earth were 25, 25, 36, 40, 40, 46, and 51 feet. In no instance did hitting the ground from such heights appear to hinder the squirrel's further rapid departure. Indeed, it is a favorite topic among local people who have hunted fox squirrels that these squirrels on provocation leap from their nests at great heights, "parachute" to the ground with a resounding thump, and run off apparently unhurt.

Swimming

When Gamma and Alpha were 55 and 39 days old and weighed about 300 and 175 grams, respectively, they were individually placed in the clear, fresh, sunny waters of a large local spring run and observed as they swam. Gamma swam well and rather high, as he kept his forelegs appressed to his body and swam only with his hind legs. Alpha slipped off the paddle by means of which he was to have been placed in the water. This plunged him beneath the surface, but he rose quickly and swam with his forelegs held close to his sides, stretched down along each side of his venter. At first his hind legs stroked so slowly that his nose sank back under water, but he then sharply increased the tempo of stroking, which kept his head up, and swam as well as Gamma had. They seemed not to mind the experience. Afterward each shook himself as a dog does, and scooted forward on his belly on some cloth.

Digging

These fox squirrels showed very little disposition to dig. Eight adults were live-trapped and kept in pairs in quail pens for a time. The 6 by 6 by 12-foot quail pens were constructed of chicken wire, with boards at the corners. The boards which constituted the lower edge of each side rested on the surface of the ground. Were these squirrels expert at digging, it would, in the writer's opinion, take one only 20 or 30 seconds to dig out through the soft sand floor under the side and be gone. These wild-caught, adult fox squirrels paced their pens, earnestly seeking a way out through the wire mesh, but dug without intelligence. On two occasions holes fully 6 inches deep were found dug by the penned fox squirrels, but these were not dug close enough to the sides of the pens to be effective

for escape. The digging, as noted above, was often rather inefficient when caches were made.

Voice

The barking of the fox squirrel, while like that of the gray squirrel (*Sciurus carolinensis*), doubtless differs from it in volume and pitch. When the writer counted the two kinds of barking noises made by a fox squirrel in the sand hills one day, one thing quickly became clear. The arrangement of the two kinds of sounds differed from the arrangement of the corresponding ones used by the gray squirrel. Even if one's memory for pitch were not adequate to distinguish the bark of this squirrel from that of the gray squirrel, one could identify each quite easily by the arrangement of the two sorts of sounds.

A subadult fox squirrel was apparently feeding at the foot of a pine in the sand hills when my approach disturbed it at sunrise plus two hours and nine minutes on November 3, 1946. It began barking when I was about 40 yards away. When I rushed towards it, the squirrel desisted for the moment to climb higher in the pine. It sat crosswise on a twig and barked at me almost continuously for 40 minutes while I took notes, and continued after my departure until I had walked out of hearing. The two kinds of sounds which it made in barking consisted of one or more high-pitched, explosive, and rather breathless "kwah, kwah" sounds followed by a series of much more rapidly uttered, lower-pitched "kwuh, kwuh, kwuh, kwuh" sounds. The "u's" were sounded as those in chub or grunt. When the number of the louder "kwah" sounds per series were tallied, it was found that they varied in number from one to four, with respective frequencies of 21, 11, four, and one in 37 counts. Tallies of 25 series of the lower-pitched "kwuh" sounds revealed a range of from five to 13 sounds per series, with respective frequencies of 1, 0, 1, 3, 5, 9, 3, 2, and 1. A fairly typical series of barks, then, consisted of one or two "kwah's" followed by about 10 "kwuh's."

This pattern of barks was employed by an apparently non-parous female 25 days later in barking at me in the sand hills at sunrise plus one hour and 44 minutes. An apparently non-parous female followed for six hours on March 27, 1947, on three occasions burst into spirited barking at the writer. One other time she burst into barking apparently at the stimulus of a screaming blue jay. The first outburst of her barking consisted of seven or more loud "kwah's" in series, but further barking then fell into the pattern described above. Two days later in the sand hills at two and a half hours after sunrise an unseen fox squirrel barked near by in the ordinary pattern. On April 5 at sunrise plus one hour and 11 minutes an adult male fox squirrel aroused from a nest barked at the writer in the same pattern. No barking by *Sciurus n. shermani* heard by the writer has been noted to differ from this pattern other than as mentioned, or when heard from so great a distance that only the "kwah's" could be discerned.

The pattern in the barking of the fox squirrel differs nicely from that which Seton (1929, vol. 4, p. 41) ascribes to the barking of the gray squirrel. He indicates that barking gray squirrels start each series of sounds with the lower, rapidly uttered, short sounds and end it with one or more long, louder, higher-pitched sounds. The writer found that this applied correctly to gray squirrels on the Welaka Reserve. The explosive bark of the adult gray squirrel begins with a rapid series, often with increasing or decreasing tempo, and corresponds to the "kwuh-kwuh-kwuh" sound made by the fox squirrel. This series of rapid barks is followed by a series of two or three long nasal squalls, something like "kwaaaa, kwaaaa," with the "a's" sounded as in flat, corresponding to the "kwah, kwah" of the fox squirrel. This reversal of the order of the two kinds of sounds which distinguishes the barking of fox squirrels from that of the gray squirrels seems to have escaped earlier notice.

Gamma was 85 days old when he was first heard to bark. This was occasioned by a dog's approaching his cage. Alpha was 110 days old when he first barked, with no evident provocation. When Eta and Theta were 97 days old and in one of the natural enclosures, Theta suddenly burst into violent barking at something the writer could not see, and Eta ascended the tree to join him in barking.

When Alpha and Beta were lifted from their nest high in the top of a slash pine,

Alpha uttered a piercing cry. Placed in a cloth bag he repeated this cry several times until his litter mate was put in with him. When these blind baby fox squirrels were handled, it was noticed that they voiced their piercing cry when turned belly up. This cry is usually of one rather short note "eeeeer" of such surprising volume and high pitch that about the third sounding of it gives one a sensation of acute headache. The same piercing cry was voiced by the members of the other broods of nestlings that were taken captive. The most advanced age at which a fox squirrel was noted to scream was 107 days when the pet, Gamma, was suddenly recaptured after a few minutes of freedom at the edge of the woods.

A third kind of vocal expression, the one most frequently used by these fox squirrels, is a churring, chucking, or series of growling grunts. Baby squirrels only 40 days old romp and wrestle and bite each other gently, grunting curious little growling grunts the while. At 67 days old, when approached by another squirrel while he was eating a peanut, Alpha churred and advanced a few steps threateningly towards the other squirrel. A young fox squirrel at times attempted to take food from almost any other rather than seek a piece of its own, and the possessor usually churred and moved away. The seeker came hardly as an aggressor but more as a wheedler, chucking plaintively, and sometimes even grovelling to get at the food. When each was 66 days old, for example, Pi wanted pine seed from a cone that Rho was trying to trim. She whined in short grunting notes, embraced him from the rear, reaching for the seed, and wrestled her way gently and plaintively under him on her back to a good position for taking the seed from his teeth or forepaws whenever he obtained one. When she got one from him, he did not get it back, but, after some querulous churring, sought another seed from the cone. When Eta was 83 days old, he and his litter mates were several times stopped short of satiation with milk and Pablum so that they might be encouraged to eat some solid food. On these occasions Eta staged a brief tantrum which consisted of scrambling violently this way and that and of emitting a series of loud, whining, staccato grunts. In the above section on jumping it is related how Pi complained vocally before making a difficult leap from one tree to another.

It is the writer's impression that the various churring sounds uttered under the circumstances described above are basically the same sound given a wide variety of expression by a difference in volume and duration of utterance. When the squirrel voicing the sounds was strongly irritated, the sounds were loud, short, and uttered in rapid sequence, and gave an impression of surly anger or warning of impending violence. When the squirrel was playing or begging, the sounds were lower, softer, and enunciated more slowly. In every instance recorded in my notes, of which the above are only representative samples, the voicing of the churring note may be construed to represent complaint or dissatisfaction.

SOCIAL BEHAVIOR

Apparently under the circumstances now prevailing in north Florida, fox squirrels live thinly scattered through the sand hills and pine flatwoods and cypress-pond habitats. They appear to be rather solitary. Only on three occasions did the writer observe adult fox squirrels together. On October 17 at sunrise plus two hours and 45 minutes an adult male and female were observed in a very small bayhead at the edge of the sand hills. They were 20 or 30 yards apart, one climbing actively about in the tops of the slash pines and the other climbing about in the brush on the edge of the bayhead. Collected, both proved to be adults with a tooth-wear class of six (Moore, 1956, p. 47). The testes of the male were large and scrotal, but the vulva of the female was imperforate. The mammae of the female gave milk, and her uterus was flat and empty.

On February 4, 1947, at sunrise plus 24 minutes the writer aroused a female, and a male with enlarged scrotal testes, from a single nest in the sand hills on the Reserve. Their behavior is recorded above in the discussion of jumping. From the data in figure 1 and the discussion of breeding seasons given below, one wonders if this male were not

sharing a nest with a pregnant female who was in a receptive condition.

After the writer had been sitting motionless at the base of a tree in the sand hills for an hour on July 4, 1946, at sunrise plus an hour there was the scratching sound of a fox squirrel descending a tree, and a fox squirrel appeared running easily over the forest floor with another pursuing it 6 or 7 feet behind. Round and round they ran in graceful, undulating, silent chase. At frequent intervals they stopped and poised alert and still as if watching and listening, and then they resumed the chase. They rarely ran more than 50 or 60 feet without such a stop. Some of these pauses were made on the ground, when the squirrels stood up straight and high on the hind legs, in what Ernest Thompson Seton has called, for ground squirrels and prairie dogs, the "picket pin" pose. Other pauses were made when the squirrels leapt 2 or 3 feet up onto the trunk of a small tree and clung there. This play was marked for its persistence and grace and also for its sedateness. After about four minutes of it, they were momentarily disturbed by the scratching descent of another fox squirrel beyond them. The one pursued fled a little distance towards the writer, and the pursuer ran 4 or 5 feet up a small tree. In a moment, however, the newcomer was accepted without further ado in the party, and the graceful, undulating chase was resumed. Soon, however, interest in the pursuit gradually waned, and casual foraging usurped its place. The squirrels separated then. Because the squirrels had performed at a distance of 150 to 175 feet from the observer and when the air was full of morning bird noises, the silence of their chase may have been only apparent. By 15 minutes after the first had appeared, the three squirrels had drifted separately out of sight to be seen no more. This behavior does not fit well in figure 1 as summer breeding season courtship, but better as the restrained play of subadults, five and a half months old, born during the previous winter breeding season.

Evidence of Territoriality

When Pi and Rho were first brought in from the nest and placed in a box of cypress shavings, an older brood of three which had been in captivity for several days was placed with them. Pi and Rho immediately cowered but seemed neither terrified nor repelled. The older nestlings accepted the small strangers by sniffing them interestedly and curling up on them or wrestling a bit.

Seven days later a very different reaction occurred. Pi and Rho had been kept in a 10-gallon terrarium with nesting material for the whole seven days without seeing the other brood, which had been removed after the first hour or so a week before and had not even been kept in the same laboratory where Pi and Rho could have heard or smelled them. The larger brood of three was placed in the commodious terrarium again with Pi and Rho. Rho immediately broke into wrathful scolding—a loud rapid churring which sounded nasal and rose to an intense squeal that seemed to represent violent disapproval or anger—and struck at the nearest invader with his forepaws. He continued this behavior for three or four minutes, sitting up in a stiff half-crouch, scolding and quivering about the mouth with intensity of emotion. Occasionally he emphasized his vocal attack by striking forward and downward with both forepaws at one of the introduced brood. Several times he rushed forward and struck one of them in this manner. Once he thrust his head forward with the blow as though to bite, and actually made contact with his muzzle, although his mouth was only slightly open.

The introduced brood took this behavior very quietly. Theta approached Rho twice during Rho's rampage, calmly and gently sniffed his face and neck and otherwise ignored the tirade and the light blows received, and each time proceeded past Rho to examine some wood chip or other object. Rho then continued to direct his abuse at the others. Lambda tried to sniff noses with him, and Eta seemed about to do the same, but both recoiled at the increased tempo of his vocal attack. After three minutes, the three larger squirrels crouched together at the end of the terrarium farthest from the nest end, with their heads down as though cowed or subdued. Then Rho subsided. One minute later he was lying snugly between two of the larger brood. For the several hours they were subsequently left together, there was no further evidence of unfriendliness.

Six days later, on August 11, the larger

brood, at 66 days of age, was brought into the laboratory again and, for convenience, placed in the terrarium occupied by Pi and Rho. Rho, now 53 days old, resented this intrusion even more explosively than he had the previous one. Eta, Theta, and Lambda cowered submissively before their scolding junior. For several minutes he kept them cowed, usually poised away from them a little but jumping at whichever one stirred head or foot. As before he gradually calmed. At this time the older squirrels averaged 445 grams in weight to Rho's 331.

Three days after the above incident, Pi and Rho were introduced into the cage which had been occupied for many days by Eta, Theta, and Lambda. The larger brood gave no impression of strong resentment. When Rho approached any of the larger squirrels at a time when the latter was eating a peanut, however, the larger squirrel churred angrily and approached Rho as if to cuff him. Rho then cowered meekly. With Rho, therefore, we have a record of no defense of his nest box when he was first put into it, two examples of vigorous defense against larger squirrels introduced into his nest box after he had become established in it, and one record of meek submission to those same older nestling squirrels when he was placed in their cage. This appears to be evidence of a limited territoriality, certainly strong in this one male nestling, and related to the immediate area of the nest.

Another incident, somewhat similar to some of the above but with interesting complications, took place in one of the natural enclosures which Eta, Theta, and Lambda had been occupying for nearly a month on October 4, when Omicron was first released in it. Omicron was a nestling of 84 days and weighed about 400 grams among immatures of 120 days weighing over 700 grams each. Theta approached the younger squirrel aggressively and literally pounced upon him. Omicron cowered submissively. Theta smelled the young squirrel over carefully but gave it no further rough treatment. Omicron lay still, and presently Theta left him to return to feeding on a pine cone. Omicron resumed his interested exploration of the area. When he came near Lambda, she rushed upon him much as Theta had and apparently nipped him, for he squalled and fled. Lambda pursued him, but one of the males (Eta or Theta) charged in and pounced upon Lambda, pinning her down as she cowered, and partly turned on her back. She lay quietly. After standing poised over her for a few seconds, he turned and left her without inflicting any punishment.

Eighteen days later Omicron, who then weighed 460 grams, was taken from a small cage at the laboratory and placed in one of the natural enclosures with Pi, who weighed 640 grams and had been established in the pen for 32 days. It was noted three days later that Omicron made a distinct move out of Pi's way whenever she came towards him. Once he was observed to sneak towards her with his tail fluffed over his back. At this Pi rushed threateningly at him as though she were provoked. Omicron fled promptly, and Pi did not pursue. These two instances of aggression by immature females on a young intruder appear to be, in part, manifestations of territoriality involving a more extensive area.

Dominance

Several demonstrations of dominance within a brood were observed in addition to the above behavior of Theta towards Lambda. On the same day that that incident took place, Eta displayed marked intolerance towards Lambda. His feeding place on the stump was close to the pile of longleaf-pine cones which had been provided for Eta, Theta, and Lambda. Several times when she came to the pile of cones and began to trim one, he chased her savagely. The males were observed to show no intolerance of each other. Twenty-one days later, during a period when the squirrels' ration of acorns was being placed in the unset box traps, it was observed that Theta and Lambda crowded into the 6 by 6 by 24-inch trap for acorns without bickering. Once during the same morning, however, when they were eating acorns about 2 or 3 feet apart, Theta made a little rush at her, churring angrily. She fled only 5 or 6 feet, and peace returned.

In general the three females of the captive broods seemed inclined to be submissive and diffident to their more irritable and aggressive sibling males.

REPRODUCTION AND GROWTH

The size of litters of young of *Sciurus niger shermani* examined by the writer varied in number from one to four, with frequencies, respectively, of one, seven, two, and one. The sex ratio of the nestlings is 11 males to 14 females. Only two broods were unisexual; the single brood of one and a brood of two were all females. Males predominated in both broods of three but were outnumbered by the females in the one brood of four. Each of two lots of embryos collected by the writer numbered three.

Some of these broods were too young when observed for their pelage color to be evident. Of the 15 individuals of these broods of nestlings in which the color was evident, four were strongly melanistic. One brood of three contained two males of the black-bellied phase. A brood of two contained one male of the black-bellied phase, and the brood of two females contained one strongly melanistic one. The ratio of strongly melanistic nestlings to nestlings of other colors approximates that for the whole sample of *S. n. shermani* in museum material, as reported elsewhere (Moore, 1956, pp. 53, 56).

Parent squirrels were observed at or near five of the seven nests in which the writer, while working quietly and alone, found young broods of nestlings. The adult was frightened from the nest in three instances and hid in the tops of near-by pines. On two other occasions the writer at the nest observed an adult squirrel show itself running on the ground near the nest tree. In these two latter instances the nestling squirrels had uttered the piercing distress cry. One adult frightened from the nest did not leave it until the writer had climbed to within 10 feet, and it barked once or twice as it ran off. It climbed a pine in sight and stopped on a twig partway up for a moment to look back before ascending to hide in the top. All the other adult squirrels observed from brood-nest sites sought cover directly without stopping to bark or even to look back. In no case were two adults seen near a brood nest.

Breeding Seasons

Data pertaining to seasons of reproduction are presented in figure 1. Seton (1929, vol. 4, p. 44) reports evidence that the gestation period of the gray squirrel (*Sciurus carolinensis*) averages about 44 days. Until data become available on the gestation period of the fox squirrel, the 44-day gestation of the closely related gray squirrel must serve as a guide and is the basis for the length of the dashed lines in figure 1. For fox squirrels of the subspecies *rufiventer*, the age at the time their eyes open has been reported by Brown and Yeager (1945, p. 486) to be four weeks. In the absence of such data for Florida fox squirrels, 28 days is used in figure 1 to determine the approximate time of birth from the date of eye opening in cases for which the latter is known. The present writer provided some evidence in the section on Food, Feeding, and Elimination, which indicates that young fox squirrels begin to subsist on solid food (hence leave the nest and forage) at about 90 days of age or at a weight of 500 to 550 grams. The gestation period, age of opening of eyes, and age of leaving brood nest, thus estimated, together provide a suggestion of the outlines of the two breeding seasons. These coincide remarkably well with the dates when adult animals were found to be lactating and in oestrus. These combined data indicate the presence of a rather well-defined winter breeding season.

Interestingly enough this season apparently begins with conception at the end of November when the turkey-oak acorns, the fox squirrels' greatest food resource, have been falling for two months and are at or just past their peak of abundance on the ground. This is about an even month sooner than the species begins its spring breeding season in Michigan, Ohio, and Illinois (Allen, 1942, p. 362; Baumgartner, 1940b, p. 3; and Brown and Yeager, 1945, p. 483). Because the locality of the studies in eastern Texas by Goodrum (1937) and Baker (1944) is at approximately the same latitude as that of the present study, it would be interesting to know whether the species *Sciurus niger* breeds earlier there also. Goodrum (1937, p. 501) states that the "winter breeding season" begins in December, apparently meaning for both gray and fox squirrels. It seems that by "breeding season" he means the time of mat-

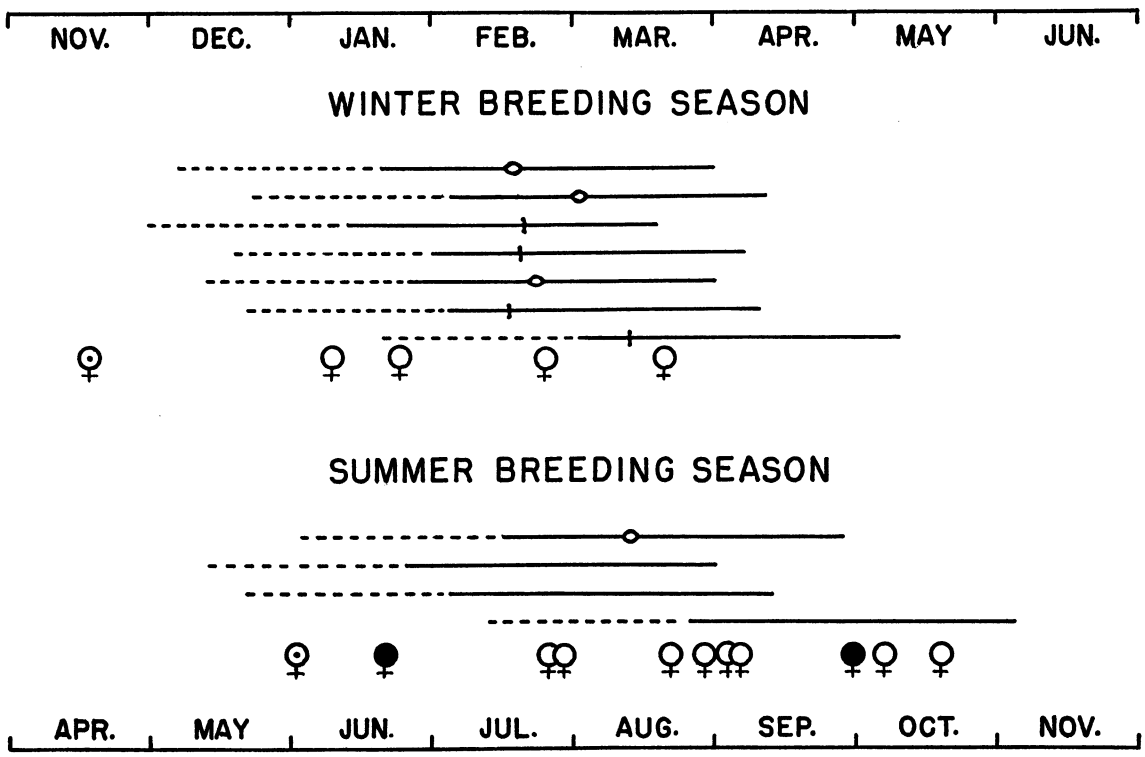


FIG. 1. Breeding seasons of *Sciurus niger shermani*. Lines represent individual broods examined. Dashed portions of these lines indicate calculated time of assumed 44 days *in utero*, and solid parts show the calculated time of 80 days in the brood nest. The eyelets in four of the lines indicate dates when eyes of these broods opened, and therefore the dates from which the ends of the lines were calculated. In broods in which one examination provided all the data for estimate of dates of birth, etc., the date of examination is marked by a small vertical line. The female symbols indicate dates when females in breeding condition were examined, those with perforate vulva being distinguished by a dot, pregnant ones with the symbol filled in, and lactating ones open. Broods in the winter season were all examined in 1942 except the third and fourth (counting down) which are of 1947. All summer season broods were of 1946 except the last which is of 1947.

ing or season of oestrus, for, he continues, "After the winter mating season all squirrels, especially the gravid females, seclude themselves to a marked degree . . . the females are hard to find during January and February." He also states, "The fox squirrel gives birth to its young approximately two weeks earlier than the gray." On the basis of these words it appears that fox squirrels in eastern Texas mate about the last of December and are pregnant through January and the first half of February, which would correspond closely to the season reported for this species in Michigan and Illinois. With the advantages of another year and records for gray- and fox-squirrel specimens totaling 550, but without offering any data, Goodrum (1938, p. 671) advances the beginning of the winter season, in which "they bring and suckle their young," to December 15. This appears to put the beginning of the winter breeding season of the fox squirrel in eastern Texas midway between that in the Michigan-Ohio-Illinois area and that in north Florida.

The summer breeding season in north Florida, as illustrated in figure 1, appears to extend over a greater length of time than the winter one. The pregnant female examined September 29, with three embryos averaging 9 grams in weight and 90 mm. in length, particularly extends the season, being about three months late for what appears to be the proper beginning of the summer breeding season and about three months early for the

winter one. Brown and Yaeger (1945, p. 476) demonstrate that the summer breeding season of this species in Illinois is as nicely defined as that of winter.

One female examined on June 20 was apparently at the peak of oestrus but at the same time contained three embryos weighing 8.0, 7.7, and 8.9 grams.

Growth

Some growth records were kept on representatives of five broods of young fox squirrels taken from nests in the vicinity of Welaka. The ages of those young squirrels were unknown, but for use in the interpretation of various other data and for a better understanding of growth, estimated ages have been assigned to data on four of the broods. The ages of Alpha, Beta, Gamma, and Omicron are estimated from dates of their eye opening. The date of the eruption of the upper incisors in Alpha and Beta, as well as that of their eye opening, is known. The first of these dates but not the latter is known for Eta, Theta, and Lambda, and by this tenuous bridge their age, also, is estimated. Growth data on the other captive squirrels represent the growth of *S. n. shermani* better than do growth data on Omicron, for he was taken much younger and did not grow so well under the artificial conditions imposed.

It has been found to be convenient in the handling of *S. n. shermani* in field and laboratory to recognize four age classes of this squirrel:

1. The nestling feeds primarily on milk and lives in a nest with its litter mates. It weighs less than 550 grams and is less than 85 days old.

2. The immature feeds primarily on solid foods which it finds and opens itself, and it soon separates from its litter mates. The immature has a fuzzy pelage easily distinguished from that of older squirrels and weighs between 500 and 750 grams.

3. The subadult has glossy pelage like that of an adult, but still has not acquired fully erupted permanent premolars, and weighs less than 900 grams (in the seven specimens for which I have weights).

4. The adult has fully erupted permanent premolars and exceeds 900 grams when in good flesh. Body measurements of adults, according to data presented earlier (Moore, 1956, p. 59) average 610 mm. for total length, 284 mm. for tail length, 84 mm. for hind-foot length, 18 mm. for ear length from crown, and 1077.8 grams in weight. In the same publication table 3 provides individual variation in skull characters of adults.

Indications are that these fox squirrels spend about one and a half months in the uterus and about two and a half months in the brood nest. By five months after birth they may be subadults. A female nestling, marked and measured at about 50 days of age and returned to her nest, was live-trapped 91 days later on May 24, 1947. Her growth in body measurements and weight was total length, 415 mm. to 600 mm.; tail length, 208 mm. to 305 mm.; hind-foot length, 71 mm. to 83 mm.; ear length from crown, 15 mm. to 19 mm.; weight, 312.5 grams to 875.0 grams, in the 91 days. When live-trapped at about 140 days of age she was in subadult pelage, and her vulva was imperforate. The captive Omicron was noted to have scrotal (but small) testes at 246 days of age, which were noted to be mature in size when the animal was 278 days of age, when the scrotum was also about three-quarters bare and black, a criterion of adulthood in *S. n. rufiventer* (Allen, 1942). Baumgartner (1940b, p. 4) states that fox squirrels in Ohio, "attain sexual maturity between the seventh and eighth months, thus eliminating the possibility of squirrels born in the first breeding season taking part in the second breeding season of the same year."

Gamma's two litter mates were given by the writer to a member of the maintenance staff of the Reserve. He kept them in a 6 by 6 by 12-foot, wire-mesh pen. One of them died in the spring of 1952 slightly over 10 years of age. William M. McLane considerately obtained the carcass for me, and the entire skeleton has been preserved. Wear on the jaw teeth has not been excessive; they fit nicely into tooth-wear class six (Moore, 1956, p. 47). The incisors, however, are literally in bad shape. Each upper incisor is worn off smoothly at what would be the surface of the gum, and in a plane at right angles to the long axis of the tooth. Each lower incisor protrudes from the bone to about the usual extent, but instead of being worn off on the concave posterior surface to a tapered cutting edge, it is

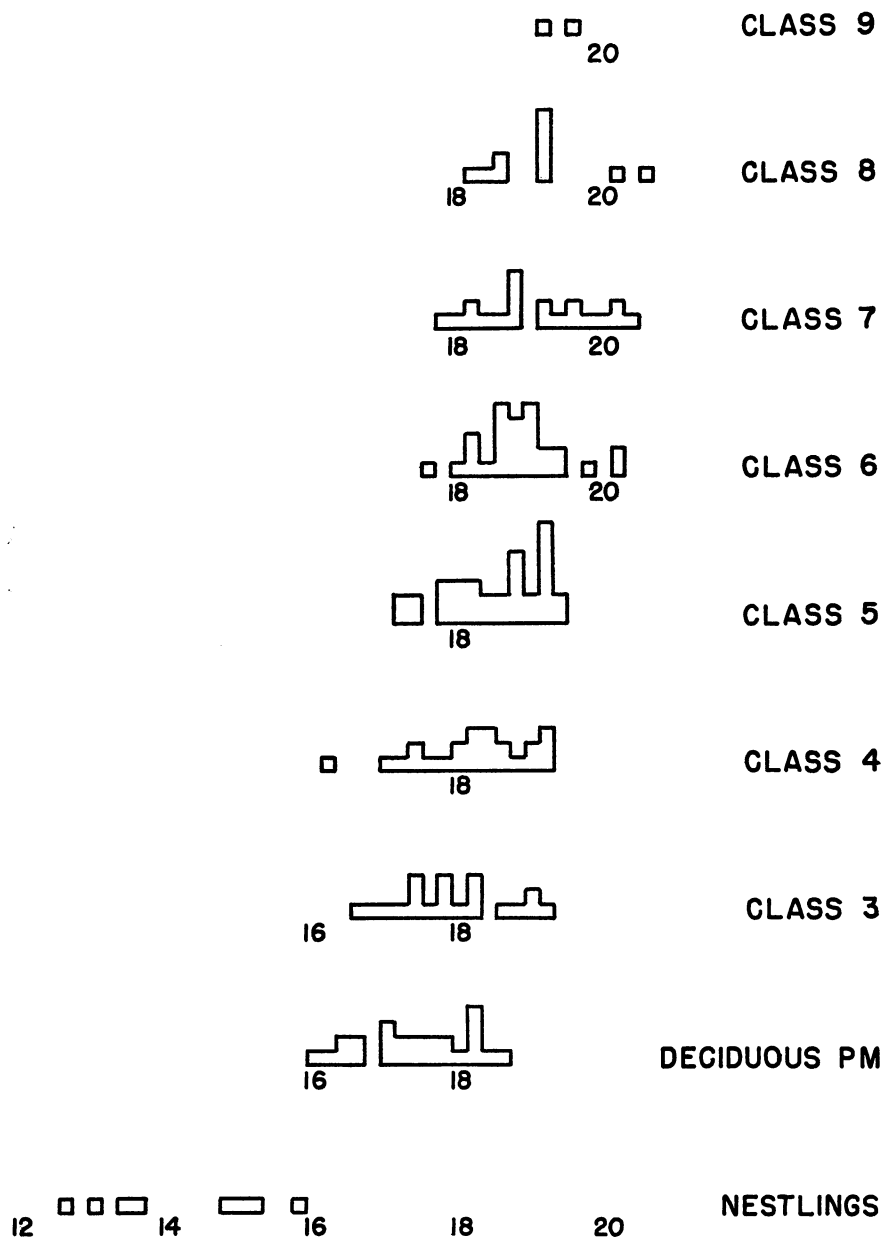


FIG. 2. Growth of diastema in the fox squirrel (*Sciurus niger shermani*) in relation to higher tooth-wear classes, possession of deciduous premolars, and time of leaving brood nest. Diastema in millimeters on the horizontal, tooth-wear classes on the vertical.

also worn off in a plane at right angles to its long axis. There is heavy annulation on the outer surface of the right lower incisor. All the incisors have large, bony outgrowths about their proximal ends, as though an improper kind, or lack of a proper amount, of wear may have prevented the teeth from moving forward as growth continued at the basal end, and, therefore, further growth caused protrusion in the other direction through the bone of the jaw. On the mandible this growth protruded through the bone in a dorsolateral di-

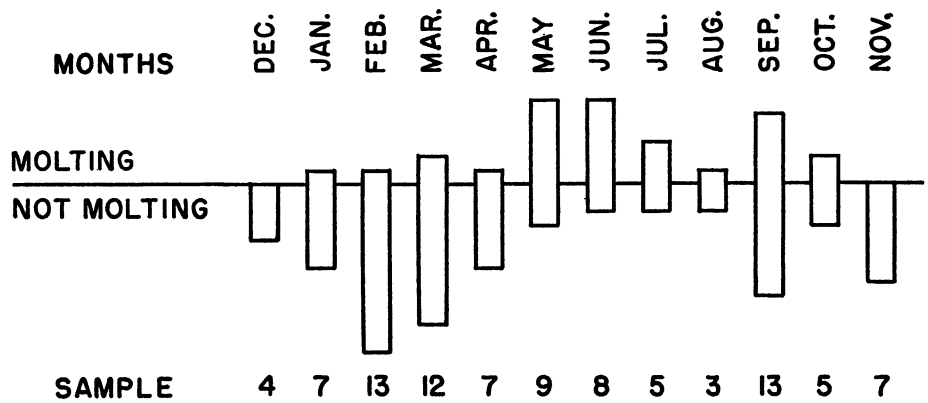


FIG. 3. Indications of season of molt for adult fox squirrels (*Sciurus niger shermani*) from a sample of 93 museum specimens in which adulthood is indicated by their being in tooth-wear class of five or higher (Moore, 1956, p. 47). Although molt may occur the year around, there is evidently a zenith for it in May and June and a nadir in November and December.

rection, quite out of line with the proper curvature of the tooth, and exposed the root of the tooth. The left upper incisor produced a bony excrescence directly lateral from its root, which protruded 8.5 mm. from the surface of the rostrum, with long and short diameters of 13 and 10 mm. The right upper incisor seems to have produced a bony outgrowth within the rostrum.

Having found that the diastema was the most variable skull character of the 16 characters compared (Moore, 1956, p. 51), the writer suspected that it grew after maturity, so plotted sizes of it in the whole sample of *Sciurus niger shermani* against the scale of tooth-wear classes. Their relationship, illustrated in figure 2, is one of greater diastema to higher tooth-wear class, even beyond class five. As class five has been validated as a criterion of adulthood (1956, p. 48), there is an indication here that the rostrum continues to elongate after maturity is reached.

MOLT

On April 16 when Gamma was 91 days old he showed molt signs on his wrists, his middorsum at the shoulders was getting black, and a black spot had appeared in the middle of his back. His litter mates had already developed black saddles on their shoulders, one of them about April 1, and the other about April 8. By April 16 they were both much blacker on the whole dorsum. By May 5 Gamma had molted away all the old hair from his back, without any molt lines forming there, but during the previous three or four days molt lines had become well defined down his hind legs and about 2 inches out on his tail. Beta showed beginnings of molt about the same time as did Gamma, although only about 75 days old. Molt lines on her wrists and a molt line across her shoulders were the first evidences noted. Alpha exhibited the same first signs of molt, but these did not appear until about April 22 when he was 81 days old. By April 28 Beta's molt line had progressed from her shoulders towards her tail, leaving only the new coat on four-fifths of her back. Her venter had now quite lost the warm tawny orange color that had characterized her as a nestling, and was much paler, but the under side of the tail retained the orange color. On May 1, when Alpha and Beta were 90 days old, their molt was complete on their backs and forelegs, but the hind legs were still woolly with the old hair. A molt line had moved out on the tail about an inch on Beta and somewhat less on Alpha.

On September 9, when Eta, Theta, and Lambda were 95 days old and Rho was 82 they were all in molt. The new black hair was coming in noticeably on the venters of Eta,

Theta, and Rho, the three young captives of the black-bellied phase, and Lambda had a prominent molt line about her thighs and upper forelegs. It seems worth noting that on this same date in 1946 Gamma's two litter mates, now four years and 237 days old, were in the same condition of molt as Lambda. As noted above, they molted in April at the end of their nestling period four years before.

Records were kept of molt incidental to examination of museum study skins of *Sciurus niger shermani* as well as in personal field collections, so that data are available for about 170 skins. Rigorously ruling out the immatures and subadults by considering only individuals with a tooth-wear class of five or higher enables one to obtain a fairly clear indication of the season of molting of adults of this race. This is presented in figure 3, and it shows that molting may occur in adults at virtually any time of year. No molting records are available for November or December, but the samples are small. On the other hand the figure shows an emphatic peak of molting in May, June, and July when the majority of individuals examined were in molt. Probably a larger sample for August would show this to be the case in that month, too. However, tapering off is clearly evident in September. There is no indication of more than one molt per year for adults, and one molt a year is what Brown and Yeager (1945, p. 471) report for both fox squirrels and gray squirrels in Illinois. The close approximation to the summer solstice of the height of molting incidence and to the winter solstice of the smallest incidence suggests at least a loose relationship to the relative length of daylight.

NESTS AND NESTING

To obtain several kinds of information about the fox squirrel, the writer climbed to its nests with climbing irons or spurs. In order to obtain such data as might be secured on breeding, it was necessary to climb to some nests every month of the year. The total number of nest examinations made by the writer was 506, and these are distributed through the months of the year as follows, beginning with January: 21, 118, 67, 15, 21, 31, 59, 60, 7, 8, 45, 54. A form evolved for recording information on each examination of a nest was mimeographed on 3 by 5-inch cards to facilitate field recording and subsequent analysis. The date, Eastern Standard Time, locality by coordinates, species of tree, and kind of plant community were recorded. Height of nest above the ground, height of nest tree, and average height of forest immediately about the nest tree were obtained as follows: a point measuring 6 feet above the ground was marked on the nest tree, and from a horizontal distance approximately equal to the height of the nest, the investigator picked off 6-foot intervals by eye from ground to nest. With the nest height so estimated, the height of the nest tree and the average height of the forest were estimated in relation to the height of the nest. Mean height of shrub stratum and choice of five degrees of density of shrub stratum about each nest tree were estimated. The kind of nest, the recency with which it seemed to have been used, and the proportion, to the nearest 5 per cent, of the various materials used in its construction were estimated. Places that were available for the recording of kind of lining material, inquilines, or food sign in the nest, and evidence of gnawing on limbs about the nest were utilized where applicable. Brief comments on fox-squirrel inhabitants and references to other pertinent notes recorded elsewhere also were occasionally written on the card. Under difficult field conditions the virtual check-off, or multiple-choice, system employed when possible on the cards proved of much value.

In addition to this general acquisition of data on fox-squirrel nests, a special area was selected for an exhaustive study of the nests in it. The locations of nests in this 52.3-acre (21.2-hectare) tract in the sand hills of the University of Florida Conservation Reserve were mapped by triangulation with a compass, and repeated examinations were made of their condition, as is described below.

KINDS OF NATURAL NESTS

Virtually all the fox-squirrel nests examined by the writer were built in the open on the bases of limbs of trees. Nests of this kind have been called by various authors "leaf nests," "drays," or "outside nests." The writer recognized five kinds of these outside nests in the field study: brood nest, closed resting nest, open resting nest, pairing nest, and ruin. Variants were observed to be built by the captive young squirrels. In addition to these leaf nests, there are tree-hollow dens and stump dens, which were observed in the field, and ground nests made in quasi-natural enclosures by young captives.

Brood Nest

The fortuitous finding of three broods of *Sciurus n. shermani* in 1942 by the author's climbing to only 13 nests led him to undertake this life-history study, but the 493 nest examinations made in 1946–1947 resulted in the discovery of only seven more broods. There are, therefore, only these 10 brood nests on which we may proceed with certainty to generalize. Half of these brood nests were in the longleaf-pine and turkey-oak community, and the others were in other plant communities on its fringe or surrounded by it. In the longleaf pine and turkey oak three brood nests were found in longleaf pines, one in a turkey oak, and one in a blue-jack oak. In a small xeric hammock community within the sand hills a brood nest with nestlings in it was found in a laurel-leaved oak. Outside the sand hills three of the four broods were found in slash pines, and the other in a fine, close stand of fairly large, second-growth, longleaf pines to which wielders of the cross-cut saw had, for some reason, not yet returned. This longleaf-pine stand oc-

cupied a small area of ecotone between flatwoods, bayhead, and sand hills.

Sciurus niger shermani apparently places most of its nests in which young are born high in a tall pine the top of which is still spire-shaped with upward growth, and which is in a stand dense enough to permit some movement by the squirrel from the nest tree to other trees through their crowns. The second-growth longleaf pines of the sand hills only occasionally form so dense a stand, but slash pines (*P. elliotti*) growing in wet flatwoods and in youthful bayheads provide these conditions frequently. Perhaps for this reason, in proportion to the small part of the general area that slash pine stands occupy, the stands of slash pine that border the sand hills contained a very high number of the brood nests that were found. This placing of the brood nest high in the spire of a pine is a departure from the general practice of placing resting nests, and the location of a closed nest in such a site is probably good evidence that the nest was built for newly born young. It should also be noted that this placing of brood nests in the spires of still-rising pines appears patently to be an adaptation to conditions of second growth.

The structure of the nests found that contained nestling fox squirrels varied considerably, and there is some indication that this variation is related to the age of the brood, which further suggests that when the young have grown heavy and their movements have become vigorous, the parent squirrel moves her brood from their pine-spire nest to one much lower and well supported by the crotch of a large limb. The writer's observations of presumed second nests reveal that they may be open at the top or domed over only with Spanish moss. A primary brood nest, on the other hand, in the spire of a longleaf pine, was the shape of an egg, with the small end up, strongly walled and roofed by intertwined pine twigs, many of them still having their needles, and lined with Spanish moss. The entrance was through the top a little to one side of the apex, and was closed by the fluffing of the Spanish-moss lining. (See fig. 4A.) One interesting variant was a well-shaped, domed nest which was constructed 30 per cent of a crib of twigs and 70 per cent of dried grass. Usually the walls and roof consist primarily of leafy twigs, either turkey-oak twigs with leaves or pine twigs retaining the needles. I have found the interior of such a nest to be quite dry when it was examined only two hours after a heavy rain. There is generally a lining, which has most often been discovered to be Spanish moss, although sometimes pine-straw, cured wiregrass, or broomstraw were used.

Closed Resting Nest

All roofed-over nests not containing a brood of nestlings were included in this category, even when their location high in the spire of a pine suggested that their purpose may have been to serve as a brood nest. There is no evidence that the male squirrel contributes to the building of brood nests, but lone males do sometimes occupy closed resting nests. As the writer collected on one occasion an adult male fox squirrel which was engaged in cutting leafy pine twigs and constructing a nest of them (September 3, 1946), it seems probable that adult males do build the nests that they occupy by themselves. This adult male, incidentally, was letting fall about 50 per cent of the leafy twigs as he attempted to fit them into the nest. Perhaps this clumsiness could be attributable to the scabbed-over wounds of considerable extent on his face. Holding leafy pine twigs in the mouth to fit them into a nest with others must have been highly painful. Closed resting nests appear to differ in construction in no consistent way from brood nests, but are rarely placed so near the top of a tree as the primary brood nests are in pines. However, were sufficient data available of brood nests to enable one to distinguish certainly the primary nests in which broods are born from the secondary ones to which it is believed they must frequently be moved, then it very likely would be possible to distinguish virtually all of these, even if unoccupied, from the functionally different closed resting nests.

Even with a presumed admixture of a small number of unidentified brood nests, which would contaminate the sample of closed resting nests, however, the writer has been unable to demonstrate any tendency for higher placement of closed resting nests than open resting nests. This is true not only in relation to elevation above the ground, but also in

TABLE 7

COMPARISON OF PROPORTIONAL NUMBER OF OPEN NESTS AND CLOSED NESTS (INCLUDING BROOD NESTS) OF *Sciurus niger shermani* BY THE MONTH IN THE VICINITY OF WELAKA, FLORIDA

Month	No. of Nests	Per Cent of Open Nests	Per Cent of Closed Nests
September	6	50	50
October	8	50	50
November	28	53	47
December	26	42	58
January	11	19	81
February	60	34	66
March	35	52	48
April	11	45	55
May	12	67	33
June	27	67	33
July	49	30	70
August	45	29	71

percentage of height of nest tree, and in percentage of mean height of surrounding forest. Closed resting nests built in turkey oaks (76) were compared with open resting nests built in turkey oaks (61). When closed resting nests built in pines (14) were compared with open resting nests built in pines (24), the number of the open resting nests averaged a little higher. If brood nests (7) are included in the comparison restricted to pines, they have evidently been placed in the most sheltered and secluded sites, for their locations average highest in percentage of the nest-tree height, but do not occur above the mean forest height, as do some open and closed resting nests.

The seasonal changes in relative numbers of closed and open nests are shown in table 7. In September, October, and November the two main types of nest construction were found in about equal numbers, and in December, January, and February, the greater number were closed nests. One could attribute this change to the fact that the latter three months are the three coldest of the year. In March and April the two kinds of nests were again found in about equal numbers. In May and June open nests become more numerous. This change may actually have been a lagging response to the hot, dry seasonal condition reported above in the description of spring. The most extreme change of all in the proportion of closed and open nests came when closed nests were found preponderant in July and August. The change to closed nests should have come sooner in order to furnish protection against the seasonal rains reported above in the account of summer. Perhaps one should expect a lag if this change to closed nests is a response to the afternoon rain showers of summer, as the responses to rain of the captives in quasi-natural enclosures suggest that summer rain is not a serious discomfort. It can be noticed that these two periods of a greater proportion of closed nests coincided perhaps even more closely with the two breeding seasons than with winter cold and summer rain. One might expect this to be an important factor. However, the evidence presented below on the number of nests used by any one squirrel in the North Five Area shows that the number of nests that are to be used at any one time for broods of young is a small proportion of the currently functional nests—too small to account for a large shift to closed nests at the beginnings of breeding seasons. Perhaps the best explanation is that the combined stimuli of weather and pregnancy induce the only very active nest *building*, and that primarily (if not only) closed nests are built. The more gradual shift to the preponderance of open nests then could be explained by the deterioration of these same nests to the open type through casual or careless use.

Open Resting Nest

Nests that were cup-shaped but provided with no roof were placed in this category. Individual nests on which a series of three or four observations were made were sometimes found to have been changed from a closed to an open resting nest. A number also were observed to fall into disuse and ruin, and were classified then as ruins. Fox squirrels spending the night in open resting nests lined with Spanish moss surely, when in critical need, pull and fluff the moss up over themselves to form a temporary roof for protection from unusually cold weather or mosquito attacks. Omicron was observed to do this against mosquitoes in his outdoor cage at an age of 86 days. The squirrel's great tail may serve as adequate cover on many occasions. Young captives in the open nest that one of them built in one of the quasi-natural enclosures were observed to cover themselves with their tails.

Pairing Nest

Having encountered only one nest evidently belonging in this category, the writer would hesitate to recognize it as a distinct kind did it not differ markedly in structure. This nest was in the sand hills 40 feet high in a 45-foot longleaf pine where the mean forest height was about 50 feet. The nest was unusually open, wide, and shallow, and was constructed 75 per cent of pinestraw and grass. Ten per cent of leafy twigs and 10 per cent of bare twigs constituted an unusually low proportion of this most basic material, and the proportion of pinestraw and grass was extraordinary. Five per cent of "leaves," presumably turkey oak, was also recorded, but the lining was of pinestraw and grass. An adult male with turgid testes occupied this nest together with a female, presumed adult, when the nest was approached at sunrise plus 22 minutes on February 4, 1947. (Their observed behavior is recorded above under the heading of Jumping.)

Ruin

Any kind of outside nest that had deteriorated beyond use was classified as a ruin. Partial nests the construction of which had been terminated by some interruption and had not been completed were also placed in this category, because, as these aged, they were very difficult to distinguish from the remains of a formerly functional nest. Young squirrels probably made most of these abortive nest-building attempts.

Tree-Hollow Den

Only one example of what appeared to be a fully satisfactory den in a tree hollow was observed. This was 50 feet high in a living, 95-foot, longleaf pine in the virgin pine area mentioned in the Introduction. The den entrance was on the trunk in the center of about a square foot of exposed, dead wood. This patch of dead wood was surrounded by living

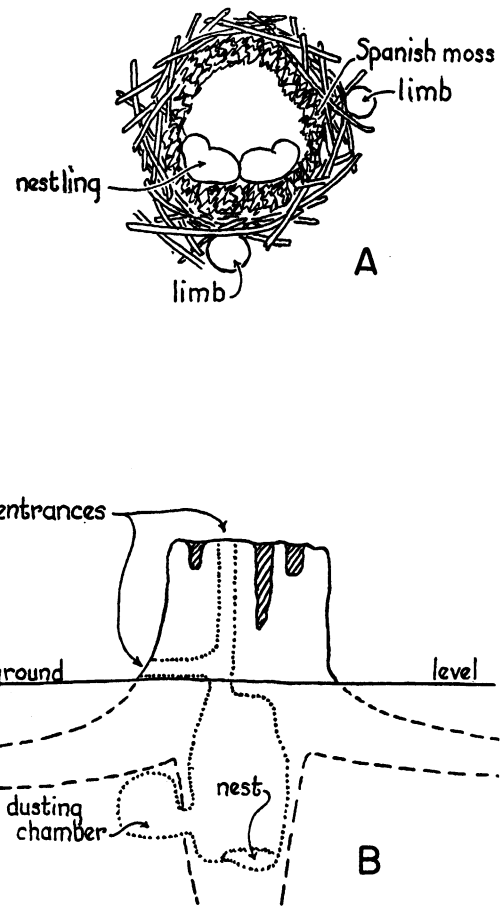


Fig. 4. A. Sectional view of a fox-squirrel brood nest. B. Sectional view of a fox-squirrel stump den. Both on the University of Florida Conservation Reserve at Welaka. The nest in the stump den was 35 inches below the ground level. The sketch was made at the stump-den site. The dusting chamber was about 10 by 10 by 12 inches.

wood. There were small, woodpecker holes in similar dead patches on two other trees within 100 yards, which appeared to be the work of the red-cockaded woodpecker. The entrance to the den cavity showed much work of fox-squirrel teeth, and was about 3 inches in diameter. Enlarging it from the size made by a red-cockaded woodpecker would have been extensive gnawing work for a fox squirrel, however, for the hole pierced 3 or 4 inches of pitch-laden wood before it reached the hollow heart of the tree. A pregnant fox squirrel was fleeing towards this hollow and was only a few yards from it when she was collected.

Stump Den

In the sand hills of the Reserve near the northeast corner on March 3, 1946, W. Frank Blair and R. E. Bellamy encountered two fox squirrels and gave chase. The squirrels fled to an old pine stump and entered a hole in it which led down to a cavity in the heart of the stump underground. Bellamy later showed this stump to the writer. The narrow passage down through the middle of the otherwise rather solid top of the stump was knotty, and the knots had been gnawed where the passage was narrowest. The bare and weathered outer surface of the stump had been freshly and extensively clawed by dogs. Further clawing by dogs was noted when the stump was reëxamined on May 24, and again on January 12, 1947. Fleas collected about the entrance on the last date were found to be *Orchopeas howardi*, the common squirrel flea.

On March 9, 1947, the writer excavated the earth beside this stump, cut into the stump with an ax at the nest chamber level, and found and captured in the nest an immature female fox squirrel. A sketch was then made of the stump, passage, den, and ground level, which is reproduced here as figure 4B.

Four other similar stump dens were found on the Reserve in the sand hills. On three of these, hair and wear indicated some use, but no regular or long-continued recent use of them was evident. The fourth one differed by having a broken-off top instead of being an old saw-log stump. This one was located in nest group 5 of figures 5, 6, and 7. It showed somewhat more signs of use and was excavated April 28, 1947. There was a nest chamber of a fox squirrel inside the stump 18 inches below the surface of the ground. A small quantity of pinestraw and grass made a rather good nest. There were fleas, which escaped, and several fox-squirrel tail hairs caught in splinters in the stump.

NESTS BUILT BY CAPTIVES

Brush Nests

In the quasi-natural enclosures the captive young fox squirrels were restricted in the availability of nesting tree sites to two 40-foot longleaf pines in each enclosure. Perhaps for lack of opportunity to observe an adult squirrel build nests, the young squirrels first built their leaf nests about 6 feet above the ground in the tops of a dense cluster of small, scrubby, turkey oaks. The first was a tightly constructed nest built in a *Smilax* tangle there in the second pen by Pi, when she was 101 days old. Fifty-two days later she built a second nest of leafy twigs of the turkey oak in the same site. This time it was an open nest, and in it late in the evening of November 19 she was covered by her tail. Two days later this nest had been added to. On December 5 it had been tumbled down as if by rough treatment, but the very next day she had repaired it by the addition of several leafy turkey-oak twigs and was sharing it with the much younger male, Omicron.

Tree Nests

The young female Lambda made her first effort at tree-nest building in one of the pines of the first enclosure at the age of 178 days. This was entirely a failure, and she cut, tried to place, and dropped 57 leafy pine twigs in the effort. Few of these twigs were as long as 3 decimeters and they averaged about 1 decimeter. Their shortness was evidently a contributing cause of the failure to make a nest.

At about age 207 days (January 12) Pi built a nest in enclosure number 2 high in one of the pine trees but on a limb about 3 or 4 feet out from the trunk. It fell out after one or two days, but she was still using her brush nest. On January 25 and 26 Pi worked at nest

building again, cutting and dropping some 75 or more leafy pine twigs. On January 30 she finally had a second leafy pine-twig nest constructed, but two days later, after a windy rain storm, it was gone.

Terrestrial Nests

When the litter mates Eta, Theta, and Lambda were 113 days old and had been out in the open, quasi-natural pens 18 days, about a half hour before sunset Eta was discovered watching the approaching investigator with only his head showing from a small hole in the leaf litter on the ground. Inspection revealed that Lambda was with him, and that they were occupying a nicely formed terrestrial den, apparently made by merely hollowing out a place down in the leaf litter where it was more than usually deep. The bottom, sides, and roof of this den appeared to be pinestraw, dried grass, and turkey-oak leaves which had fallen there. The chamber was nearly spherical in shape, and its sides were so smooth as to suggest that Lambda may have done some rearranging. A nearly horizontal passage a foot long led to the open. Six days later five such terrestrial nests were found hidden in the leaf litter of their pen. All had thin flooring over the sand, or in one case none at all, and the roofs were all somewhat thin for protection from rain. On November 6 when Lambda was 153 days old and surely of about adult weight, she was observed to be occupying a better terrestrial nest with a thicker roof in deeper leaf litter. As noted elsewhere she was 179 days old when she first tried building a tree nest, and she never built a nest in turkey-oak brush as did Pi. When she tried to build the first tree nest, Lambda had a terrestrial nest. Its entrance was flimsily closed with wiregrass, and, as was characteristic of all of these terrestrial nests, its roof was a natural part of the general surface of the fallen leaves, needles, and grass. The smoothly formed chamber was about 5 inches deep and 12 inches wide and had only a trace of lining on the bottom. Although there had been rain, the nest seemed dry enough to be habitable, and she was evidently sharing it with Rho, who had been introduced into her pen. Although Pi had built and rebuilt nests in the small turkey oaks and shared them with the younger Omicron during the time that Eta, Theta, and Lambda had only terrestrial nests in the other enclosure, her litter mate Rho did not regularly share them, if at all. There were terrestrial nests in both enclosures and Rho is presumed to have made and used several in his.

FOX SQUIRRELS IN THE NORTH FIVE AREA

In order to obtain some quantitative data on numbers and kinds of nests, and possibly squirrels, in an area of known size, the writer selected a tract eminently suitable for fox-squirrel nesting and also quite as large as could be inspected entirely in a reasonably short length of time. During late July and the month of August examinations were made of all the 65 nests found in this 52.3-acre tract. The cards made for each nest identified it by locality and description, but this nest survey yielded such surprising evidence of the number of nests per individual fox squirrel that a map of the locations of nests of the area, and further inspections of the nests, seemed in order. In late September the location of the nests by triangulation with compass was begun. A second climbing to the nests on the area was accomplished in November and December, and the surveying for a map was completed concurrently. A third check of all the nests was made in February.

The area selected for this special scrutiny was in the sand hills of the University of Florida Conservation Reserve within reasonable walking distance of the laboratory and quarters. For convenience this area is called North Five, because it constitutes all of Compartment Five north of Truck Trail 14. (The Reserve is divided into compartments on the foresters' maps for experimental work and fire control.) The 52.3 acres of North Five support *Pinus australis* and *Quercus laevis* associes on Lakeland fine sand. The forest is mostly turkey oak, and its average height in the vicinity of the nests is generally about 35 to 45 feet, which is about optimum development for a dense stand of turkey oak for an area as large as North Five, and about at optimum stage for fox-squirrel

nesting. A glance at figure 5 reveals that the western and west-central parts of North Five had no fox-squirrel nests, and this fact is attributed to the consistently smaller trees there. In areas of North Five where the fox-squirrel nests were commonest, older turkey oaks predominated, and most of the nests were in these. The longleaf pines were scattered rather thinly among the turkey oaks, although in better density than encountered off the Reserve. Many of the pines were just rising above the tops of the turkey oaks and beginning to bear a crop of cones, and there were but a few older ones as high as 60 or 65 feet. The pines provided an abundance of summer food for fox squirrels, and the oaks a fairly good crop of acorns for the remainder of the year. Much improvement in acorn production could be obtained by the removal of perhaps half of the turkey oaks and opening up the forest, but while this would improve the conditions of feeding, it would reduce cover and movement from tree to tree, which are advantages for a nesting area.

July–August Nest Inspection

The July–August examination of nests in North Five was conducted mostly in the latter month, only 16 of the 65 nests being climbed to in July. At this time removal of certain of the fox squirrels for the program of collecting ectoparasites, study specimens, and young squirrels to rear contributed to the knowledge of the population of North Five to the following extent: an adult male fox squirrel observed running along the west boundary of North Five on June 9 had turned to flee away from the North Five Area just before it was collected. Because there seemed otherwise to be a relative scarcity of adult males in the area, and because fox squirrels fleeing after release from live traps tend to run away from their presumed nest sites (Packard, 1956, p. 29), this individual may have been a resident of North Five. An immature was collected June 19 on the extreme northeast corner of North Five. A female barking from the center of what has subsequently been labeled as nest group 5 was collected June 20. The three embryos that she carried may well have been destined for a brood nest that was later found empty in this nest group. On August 14 a male in tan-phase pelage was aroused from the indicated nest in nest group 1 and collected. His tooth-wear class (Moore, 1956) of nine denotes considerable age, and his testes were enlarged. A female of the black-bellied phase, which left the indicated nest in group 4 on August 20, was collected. Her mammae gave milk readily, but the hair about them showed no wear or disarray from suckling young. This squirrel may have been one of the three whose play, observed July 4, is reported under Social Behavior. Lastly, a brood of young (Pi and Rho) were taken from nest group 2 on July 29.

Population Density

At the time of the July–August nest check, nest group 1 was occupied by an old rutting male. In nest group 2 a female fox squirrel probably in the tan-phase was rearing a brood of two nestlings. A male with tan-phase pelage and enlarged testes was flushed from the indicated nest in group 3, and he did not flee out of the nest group area. While an adult male may possibly have been responsible for all the nests in nest group 3, it seems more likely that the writer may have failed to observe a female fox squirrel in that nest group, particularly because of the presence there of a presumed brood nest. In nest group 4 the lactating female in the black-bellied phase had probably just weaned, or had in some way lost, a brood. She showed no signs of pregnancy or oestrus, and her tooth-wear class was six. Nest group 5 had presumably been occupied by the pregnant female collected there June 20. Her tooth-wear class was eight, and her successor to this nest group, frightened from the indicated nest during the August inspection, had the appearance of a subadult. It appears, then, that all the four well-established nest groups, with eight, six, nine, and eight active nests, respectively, may be the work of old adult females, one subsequently preëmpted by a subadult female, and one shared by an adult male. By contrast the aged male of group 1 had only two nests. From these facts and assumptions the fox-squirrel population of North Five may be estimated to have included during July–August, 1946, four adult resident females, two adult resident males, about two subadults or immatures, and two

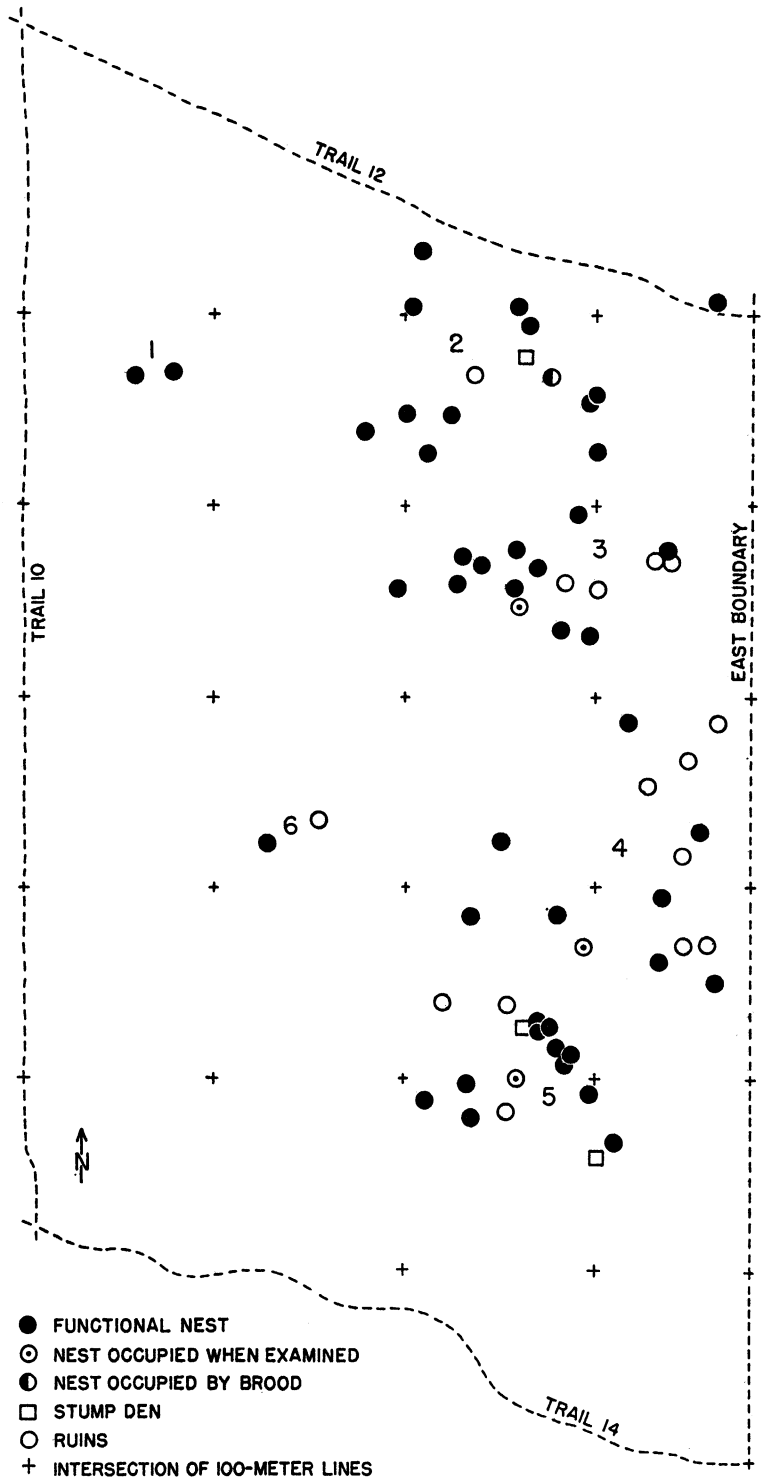


FIG. 5. Results of the July–August, 1946, inspection of fox-squirrel nests on 52.3-acre North Five Area in the sand hills of the University of Florida Conservation Reserve at Welaka. Numbers indicate nest groups believed to have been built and maintained by single individuals or, in one instance, a pair.

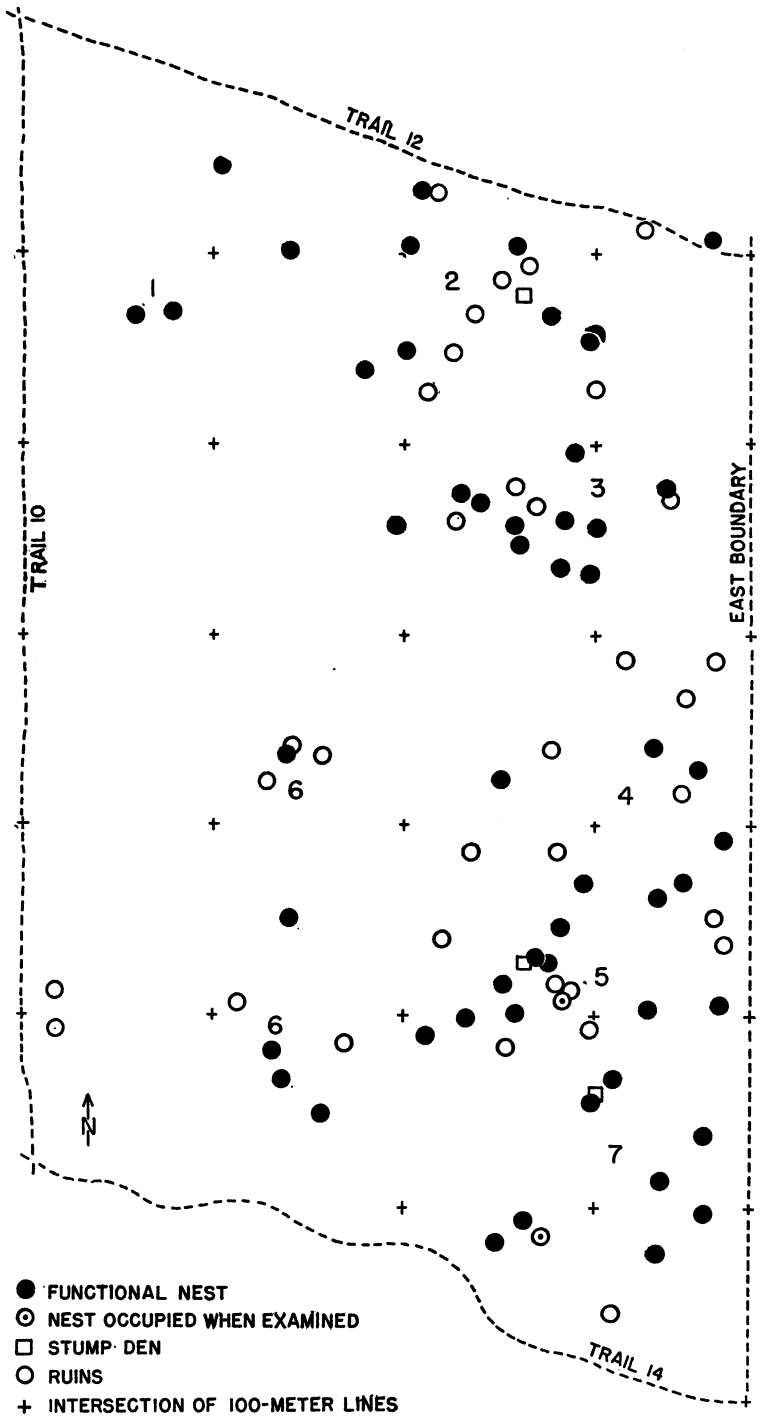


FIG. 6. Results of November–December, 1946, inspection of fox-squirrel nests on the 52.3-acre North Five Area on the University of Florida Conservation Reserve at Welaka, Florida. Numbers indicate groups of nests evidently maintained by single individuals.

(or potentially five) nestlings. The most stable portion of the squirrel population is surely the breeding females, and it seems indicated that there were four here in the 52.3 acres. There was, thus, only one breeding female to each 13 acres. For a figure on population density to compare with the figures of Brown and Yeager (1945, p. 456) for Illinois, it seems necessary to include all but the nestlings. This would be eight squirrels to the 52.3 acres, or one animal to each 6.5 acres. Such a population density is probably near optimum for this plant community, with the turkey oak dominant, because the present study was done on a reservation and also because the stand of turkey oak was as near to optimum development as in any area observed. Population densities of fox squirrels in turkey-oak stands in other parts of north Florida, which are ordinarily more flagrantly hunted over, cut over, and burned over, are unquestionably lower still.

November–December Nest Inspection

Although a population density in the summer breeding season was obtained for the North Five Area, several unanswered questions appeared to justify another complete check of the nests. Were the nests of the summer breeding season occupied during the fall non-breeding season? Had the squirrels that had been removed been replaced by others? Were the numbers and kinds of nests changing? After two months had passed, another examination of all the nests was begun in November and completed in December.

The results of this re-inspection reveal a number of changes. The old male that had been removed from nest group 1 during the summer inspection had not been replaced, but the female occupying group 2 had apparently extended her nesting area somewhat towards group 1 by building two new nests, although she was using only five of the eight older nests that had been in use in the summer, including, however, the one from which the nestlings had been taken. Nest group 3, which had previously contained an adult male and possibly a resident female, was apparently occupied, but only five instead of eight nests were in use. Group 4, from which the black-bellied female had been removed, was also apparently occupied, but the number of nests in active use had decreased from six to three. On the area of nest group 5, where the pregnant female had been collected in June, four nests rather than nine were in current use. A new nest group, number 6, was established, with three nests in active use, and another, number 7, with seven nests in active use. Fox squirrels were observed during this re-inspection in nest groups 5 and 7 flushed from the nests indicated in figure 6. The fox squirrel in nest group 7 was a black-faced, nonparous female in the buff phase. Apparently there were six squirrels occupying North Five during this November–December check, and the number of nests in active use per squirrel had decreased from an average of 6.6 to 4.7 per nest group. There had evidently been a complete replacement of the removed squirrels which had occupied nest groups in North Five.

February Nest Inspection

Although the fox-squirrel population had been disturbed by the careful examination of every nest twice in the preceding eight months, it seemed worth while to check all the nests again in February for whatever information could be obtained. Figure 7 and table 8 show some of the changes that had taken place. None of the nests in nest groups 1 or 2 were in active use. Possibly the resident female in group 2, having had her summer brood taken by man and her every nest climbed to twice by man since then, had moved out of the area at the approach of the time for bearing her winter brood, as a direct result of this harassment. Nest group 3, known during the summer nest check to have been occupied by an adult male, was now found to be occupied by a rutting male sharing a nest with an adult female. (This fact substantiated somewhat the unproved supposition that an adult female may have been present in this nest group during the other inspections in addition to the observed male.) The behavior of this pair is described under sections on Jumping and Pairing Nest. Nest group 5 was apparently occupied but with only one nest in active use. Nest group 6 was occupied by an adult male with testes scrotal and enlarged, and nest group 7 was found to be occupied apparently by the same

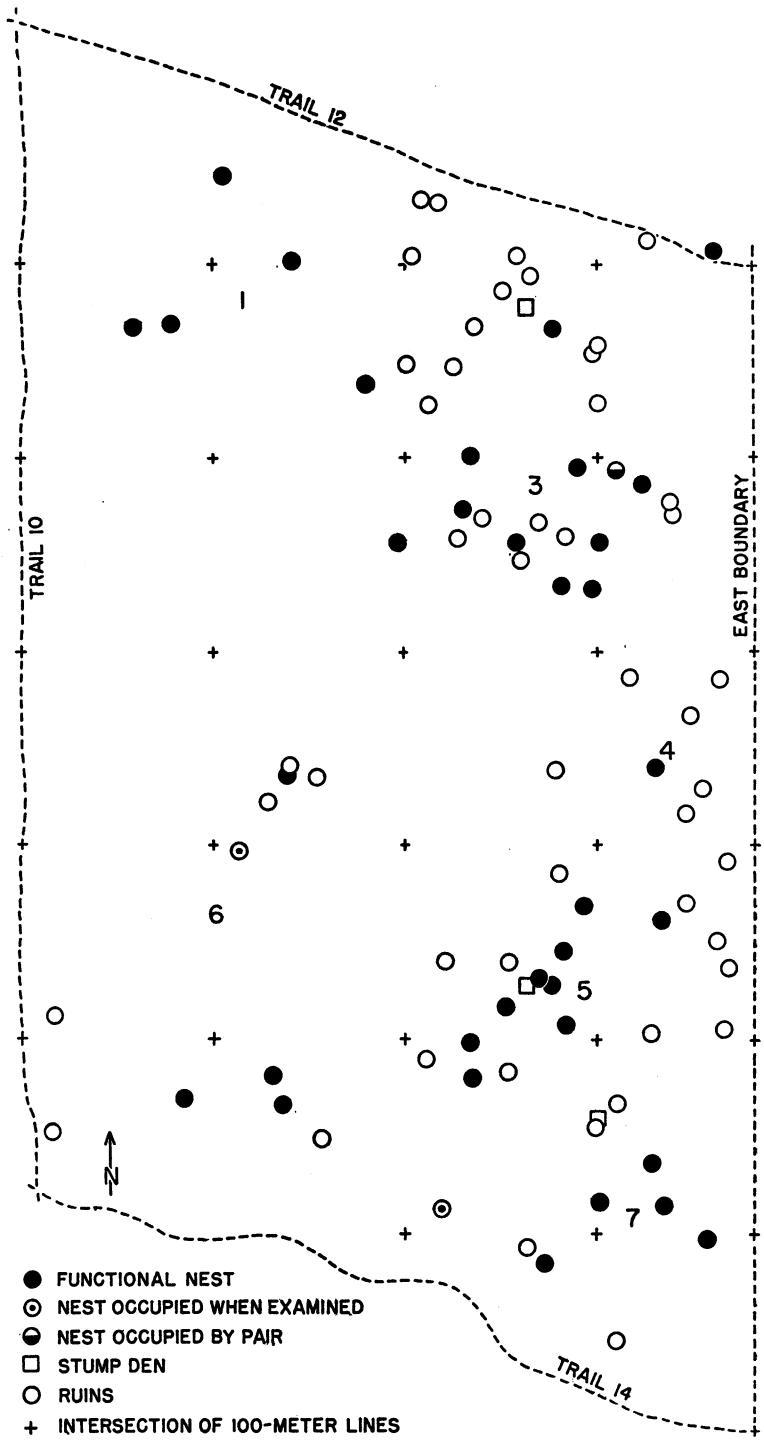


FIG. 7. Results of the February, 1947, inspection of fox-squirrel nests in the 52.3-acre North Five Area in the sand hills of the University of Florida Conservation Reserve at Welaka. Numbers indicate groups of nests evidently maintained by single individuals or, in one instance, a pair.

TABLE 8

NUMBERS AND KINDS OF FOX-SQUIRREL NESTS FOUND ON 52.3 ACRES OF LONGLEAF-PINE AND TURKEY-OAK SAND HILLS IN NORTH FLORIDA, IN THREE CENSUSES MADE IN SUMMER, FALL, AND WINTER OF 1946–1947

	July–Aug.		Nov.–Dec.		Feb.	
	No.	Per Cent	No.	Per Cent	No.	Per Cent
Total nest structures	65	100	86	100	90	100
Ruins	15	23	34	40	52	53
Open resting nests	19	29	25	29	22	24
Closed resting nests	28	43	27	31	16	18
Brood nests	3	5	0	0	0	0
Nests in active use	33	51	30	35	13	14
Nests apparently spare	13	20	22	26	25	28

non-parous female encountered there on the previous inspection. Nest group 4 apparently had no nests in current use. No brood nests were found. Altogether during the February re-inspection there were apparently about five resident fox squirrels in four nest groups on the North Five Area, and active nests per nest group were down to an average of 3.0.

The fox-squirrel population of this 52.3-acre tract may be presumed to have varied from about eight at the most in July–August (including the removals) to about seven in November–December (removals now replaced), and to about five in February. The decline is attributed to the disturbance of repeated climbs to the nests by man, and eight is considered the best figure. This is a population of only one squirrel per 6.5 acres and is considered high for this habitat. No population so low as this has been reported for fox squirrels in a continuous oak woodland in studies elsewhere. *Sciurus n. shermani* is larger than *S. n. rufiventer*, adults weighing 1078 grams, or about 350 grams more than adults of *rufiventer*, but this alone does not appear to account for such a difference in population density. Although the longleaf pine and turkey oak are the primary habitat for fox squirrels in north Florida (excluding the cypress ponds that occur in longleaf-pine flatwoods, which were not studied), it evidently has a far lower carrying capacity for fox squirrels than habitats reported on by various authors in midwestern United States, presumably because on the southeastern coastal plain the fox squirrel became adapted (including its larger size) to very open forests of great longleaf pines, interspersed in the sand hills with a secondary growth of turkey oaks. Removal of the mature pines reduced the carrying capacity of the sand hills for the fox squirrel, particularly under hunting pressure by man, by thus removing the most abundant refuges suitable for tree squirrels and reducing the summer food.

The data presented here on the number of nests per resident adult squirrel are unique in the large and growing literature on this species. Probably several factors enter into this proliferation of nests. The advantage that the use of numerous nests might offer, in the suppression of the population of the irritating, nest-inhabiting parasite, the squirrel flea (*Orchopeas howardi*), may be of considerable importance in the warm climate. As noted in the section on Macroparasites, the adult squirrels appear to have some means of keeping down the numbers of these fleas on themselves. If these ectoparasites remain in a nest uninhabited by squirrels for only a short period before abandoning them or dying, as seems likely, then it is possible that an adult squirrel may keep the nuisance at a tolerable level by generally using its several nests in successive periods of occupancy. A mother squirrel may shift her brood to a fresh nest one or more times during their nestling stage, at least in part for this advantage. The data on brood nests suggest that the broods are so shifted.

A second factor that favors the abundance of outside nests per individual resident fox squirrel in this habitat is their value as

refuges in an area where other refuges suitable to the behavior patterns of tree squirrels are extremely scarce. In such low, very open forest there surely is survival value to a large tree squirrel in having numerous leafy nests in any one of which it may spend the night. The availability of these nests for diurnal refuge from man, and the squirrel's willingness to retreat to one of them at the approach of man when it feels it is still unobserved, very likely contribute much to the ability of this squirrel to resist extirpation from this habitat by man. Up to the time of the field work of the present study, hunters who were both ruthless enough to shoot into nests and wasteful enough of ammunition to continue to do so for such poor return were probably rare. If postwar prosperity reduced the hunter's concern for his shells more than other factors increased his concern for sportsmanship and conservation, the remnant population of fox squirrels in the sand hills may have suffered severely.

No data are available on the home range of the fox squirrel in the southeastern coastal plain. Above reported is an instance of an adult female's running in one direction (out of North Five, incidentally) for 325 meters before disappearing into the thick growth of a bayhead. Also, the non-parous female that was kept under observation for six hours after having been discovered on Trail 10 directly west of what is nest group 1 on figure 5, wandered casually about in North Five as far as 300 meters east of Trail 10 in nest groups 3 and 2. Packard (1956, p. 26) demonstrates that males of *S. n. rufiventer* range farther than do females in Kansas, and it seems not unlikely that male *S. n. shermani* range farther than the females, too.

Nest Histories

In nest group 3, which was occupied through all three censuses and about the occupants of which something is known, we may follow the condition of its nests through the three inspections over a span of five and a half months. John M. Allen (1952, p. 45) reported similarly on the histories of the nests of gray squirrels, and (p. 43) of gray and fox squirrels mixed, of three inspections in three successive winters in Indiana, but offers no population densities for the areas involved nor other indication of the number of nests built and used by an individual. In nest group 3 of North Five, the summer inspection was made on August 3, 12, and 14 and revealed five closed resting nests, one of which had all the characteristics of a brood nest except nestlings, seven open resting nests, and four ruins. The second inspection, accomplished on November 13 and 18, showed that apparently only two of these were still closed nests, two having become functional open nests, and one a ruin, but that two more closed nests were now in use, one built up from an open nest and one built up from a ruin. By the third inspection on February 1 and 4 there was but one of the original five closed nests still in operation as a closed nest. Three of them were now open nests, and one was a ruin. The two closed nests that had been built up from an open nest and a ruin, examined in November, had also now become open nests, but two entirely new closed nests had been built.

In the summer inspection there were seven open nests in this nest group. By November, three of these were still functioning as open nests, but three had degenerated to ruins, and one had been built upon to make a closed nest. In addition one functional open nest had been built up from a ruin. By February only one originally open nest was still a functional open nest, but one other was an open nest again after an interim service as a closed one. Three of the original open nests were now ruins, and one was entirely gone.

Of the four ruins found in nest group 3 in August, one had disappeared by November, one was still a ruin, and, as stated above, the other two had been added to and made functional. A new ruin was also found. In February, of the original four ruins one was entirely missing, one was still a ruin, one had returned to being a ruin after revival to open-nest status, and one had gone back to open-nest status after having been built up to be a closed nest. The ruin first reported in November was still the same.

In summary it may be seen that nest group 3 had had five, four, and three closed nests at the three successive inspections, seven, six and seven open nests, and four, three, and seven ruins, respectively, making a

total of 12, 10, and 10 functional nests. This nest group was occupied by an adult male of tan phase with enlarged testes. He was routed from an open nest at sunrise plus two hours and 23 minutes on August 12 and from a special, open, newly built nest 40 feet high in a 45-foot pine at sunrise plus 22 minutes on February 4 together with a female. The nests in this group were in 10 turkey oaks, seven longleaf pines, and two bluejack oaks.

It seems worth while to give similar detail for another nest group. Nest group 5 was first inspected on August 20 and 24, at which time it included eight closed nests. By the second inspection which, for this nest group, was December 21, 22, and 23, there were seven closed nests, but only three of them were the same. One had been built up from an open nest, and three were new. The four others of the original eight closed nests were now: one open nest, one nest fallen out, and two ruins. By the third inspection, which was February 25 for this nest group, only one of the original eight closed nests was still the same, the other two having become open nests. The closed nest of December, which previously had been an open nest in August, was still a closed nest in February. Of the four closed nests new in December, two were still closed nests, one was an open nest, and one a ruin.

This nest group had only one open nest in August, and its history is in the paragraph above. In December there were three open nests, one previously a closed nest and two new. By February the first of these had disappeared, one of the December new ones was a ruin, and the other had remained an open nest. There were two ruins in the first inspection, and the condition of these did not change in the subsequent examinations.

In summary of nest group 5, it may be said that through the succession of inspections the closed nests had numbered eight, seven, and four, the open nests had numbered one, three, and four, and the ruins had numbered two, four, and four, respectively. This is the nest group from which a pregnant, parous fox squirrel had been removed in June. During the nest inspection of August, however, a squirrel was routed from a closed nest in the middle of the group at sunrise plus two hours and three minutes on August 20. Although observed but fleetingly, it appeared to be a tan-phase adult or subadult. During the second inspection of this group a similar or the same squirrel was routed from a different closed nest in the center of this nest group at sunrise plus two hours and 20 minutes on December 23. No squirrel was seen during the February inspection, but the only nest of the lot estimated to have been used very recently chanced to be the very last one reached. As this was at sunrise plus four hours and six minutes, and the nest was on the edge of the nest group, the squirrel may have slipped away quietly during the inspection of the other nests, or it could have been occupying the stump den. The tree nests in this nest group were in 11 turkey oaks and five bluejack oaks.

Nest group 6 is in a part of North Five where bluejack oaks are more frequent, perhaps most frequent, and one more of its 13 nests are in bluejack oaks than are in turkey oaks. Spanish moss is also abundant enough here to contribute between 15 and 70 per cent in the construction of eight of the nests, six of them in bluejack oaks. There was no more than a trace of Spanish moss in any nest in nest groups 3 and 5. Because of these differences it seems worth inquiring whether one can detect any related differences between this nest group and the two preceding ones. Such an inquiry is hampered by the fact that this nest group was built after the July–August nest survey, but there also is value in scrutinizing it because of its very newness.

Nest group 6 was first inspected as such on December 22 and 23. At that time it included three closed resting nests, six open nests, and one ruin. A non-parous female fox squirrel of buff-phase pelage and having especially black cheeks was frightened from one of the closed nests at sunrise plus three hours and 26 minutes. When the next inspection was made on February 25, 26, and 27, one of the two original closed nests was unchanged, and the other was a ruin, but there were three new ones. The February inspection revealed that only two of the six original open nests were surviving as such and that no new ones had been built. Two survived as ruins, and two had entirely disappeared. Four ruins were examined on the

February inspection. During the inspection on February 26 a non-parous female fox squirrel in the buff phase and with especially black cheeks was frightened from a closed nest in the nest group at sunrise plus one hour and 52 minutes.

In summary of the two inspections of nest group 6, it is evident that the closed nests numbered three and four, the open nests six and two, and the ruins one and four. Total functional nests for the two inspections were nine and six. The number of nests that had fallen out of place (three) seems high, for only three out of 16 in nest group 5, and one out of 15 in nest group 3, fell out during the same period. As two of the nests that fell out were from turkey oaks and two were without Spanish moss, this high rate of falling out may best be attributed to inexperience of the resident.

The rather surprisingly high number of functional nests evidently maintained by individual fox squirrels is one of the interesting revelations of this part of the investigation. Durward L. Allen (1942, p. 351) counted all the fox-squirrel nests in a 40-acre woods in Michigan in July and August of 1939. His area had certain remarkable similarities to the present one: a substrate of sand and a history of having formerly been a nearly pure stand of pines (*Pinus strobus*), after the logging off of which the present stand of black oaks had sprung up. At the time of this count of 69 outside nests and one tree hollow den, it can be found that he recorded a population of 10 squirrels. This amounts to 4 acres and seven nests per squirrel in July–August in the Michigan area compared to 6.5 acres and eight nests per squirrel in July–August in the Florida one. The number of nests per squirrel in the latter locality may be badly skewed by the apparent possession of only two nests by the old male, and by the inclusion of individual squirrels in the population which were not known to nest on the area in the same sense as did the residents that maintained the nest groups the histories of which are recounted above. Even though knowledge of the population on the Michigan area is also scanty, it is interesting to note the apparent similarity of 4 acres and seven nests per squirrel for the Michigan area to 6.5 acres and eight nests per squirrel for the Florida area. It seems desirable to add in the case of the Florida area that about 12 nests per *resident adult* fox squirrel, with about seven in useful condition, is believed by the investigator to be a more correct and significant ratio. Baumgartner (1938, p. 687), who reports on fox squirrels in Ohio woodlots, gives approximately one used nest per adult fox squirrel. Baumgartner's conclusion, in the absence of any discussion to support or qualify his bare details, that the method of leaf nest counting "provides a readily obtained index for comparative population studies" is therefore shown to be untrustworthy for general use.

NEST MATERIALS

To construct a nest it appears that the fox squirrel generally takes most or all of the materials from the nest tree itself. Pine twigs usually form the basic material of the nest in a pine tree, and oak twigs most often hold the nest together in an oak tree. However, the fox squirrel does mix its materials. In 61 instances materials were recorded in a nest which could not have come from the nest tree. These were nests in the sand hills, 14 of them in longleaf pines, 14 in bluejack oaks, and 33 in turkey oaks. Ordinarily some naked twigs are used in the foundation of the nest. Table 9 shows that bare twigs were observed in 98 per cent of 138 nests in the sand hills. It also shows that leafy twigs, Spanish moss, leaves, pinestraw, and grass are the other principal materials and that Spanish moss, grass, and pinestraw provide most of the lining.

Another difference in materials of nests in the different kinds of nest trees (table 9) appears in the more frequent use of Spanish moss in longleaf pines and bluejack oaks, and the infrequent use of leaves and leafy twigs in the pines. This is in large part a matter of availability, but some importance must also be attached to the comparative qualities of the materials. Leafy twigs of turkey oak are of the greatest value, in the writer's opinion. The leaves are the broadest generally available and hence the best at

TABLE 9

MATERIALS USED IN CONSTRUCTION OF OUTSIDE NESTS BY FOX SQUIRRELS IN THE SAND HILLS ABOUT WELAKA, FLORIDA

(Figures are percentages of the specific sample of nests in which the material occurred.)

	All Nest Trees (138 Nests)	Nests Lining	Turkey Oak (83 Nests)	Longleaf Pine (35 Nests)	Bluejack Oak (23 Nests)
Spanish moss	45	38	33	63	57
Leafy twigs	66	4	73	46	61
Leaves	47	26	55	20	52
Twigs	98	1	98	97	87
Grass	25	32	24	20	30
Pinestraw	19	33	12	34	17

shedding rain. The twigs are angular enough to hold their position in the nest rather well once set, and the tenacity with which the leaves cling to the trees, mentioned in the introductory description of winter, is no doubt enhanced if the twigs are cut while the leaves are still green. Turkey-oak leaves brought from the forest floor are excellent material and, combined even with leafless oak twigs, can make a nearly rain-proof nest. Making a winter nest appears to require more skill than handling leafy twigs. Leafy twigs of bluejack oak appear to be generally of less value, but I have a record of one closed nest of this material which was quite dry inside, two hours after a hard rain.

Spanish moss is probably used as extensively as it is, where available, because it is easy to carry and to shape. There is no indication that it sheds rain well, but it is probably excellent insulation, and many of the best nests are lined with it and roofed with leafy oak or pine twigs. The long needles of the longleaf-pine twigs probably shed rain rather well when the twigs are woven into a rather tight basket and provided with a good lining. Pinestraw and dried grass are carried up from the ground and occasionally provide substantial portions of nests. There is a definite seasonal shift in the North Five Area from leafy twigs of turkey oak for closed nests in the summer (rain) to pinestraw and dried grass or Spanish moss in the winter (cold). This is no doubt partly response to seasonal availability, but the characteristics of the material seem also to be involved.

It may best be noted here that on January 22, 1947, 13 fox-squirrel nests were examined in a generally longleaf-pine flatwoods area 7 miles north of Gainesville, Florida. Six nests were in cypress ponds, three in cypress-tupelo ponds, two in a very small xeric hammock, one was in slash-pine-tupelo swamp, and one in the flatwoods proper. All these contained some Spanish moss, and in seven of them it constituted 80 per cent or more of the nest. Shredded strips of cypress bark (*Taxodium ascendens*), a fine soft material, was present in small quantities (10% or less) in two nests. Leafy twigs were the most important constituent of six nests, leafy cypress twigs, in two; tupelo (*Nyssa biflora*), in one; and unspecified, in three.

LOCATIONS OF NESTS

Fox squirrels in the north Florida sand hills build their outside nests virtually always against the trunk of a tree, or against one of its main uprights. The spreading habit of the bluejack oak sometimes makes the nest appear to be out on a limb even when it is against one of the main uprights. Two fox-squirrel nests located in one tree are evidently a rarity. The writer clearly recalls only two instances. Both trees were unusually old

TABLE 10

RELATIVE HEIGHTS (ESTIMATED IN FEET) OF FOX-SQUIRREL NESTS, NEST TREES, AND SURROUNDING FOREST IN THE SAND HILLS, WELAKA, FLORIDA

Height	Turkey Oak			Bluejack Oak			Longleaf Pine		
	Nest	Tree	Forest	Nest	Tree	Forest	Nest	Tree	Forest
65–69	—	—	—	—	—	—	—	5	2
60–64	—	1	—	—	—	—	2	1	1
55–59	—	5	2	—	—	—	3	3	1
50–54	2	8	6	—	—	—	0	1	2
45–49	0	21	14	—	2	4	3	8	6
40–44	2	29	34	1	4	7	4	8	3
35–39	8	43	33	2	7	5	6	4	9
30–34	27	32	26	4	7	6	9	1	4
25–29	56	17	6	6	5	3	3	1	1
20–24	44	2	—	10	3	—	2	—	—
15–19	16	—	—	4	1	—	—	—	—
10–14	2	—	—	2	—	—	—	—	—

and tall turkey oaks, and the nests in each case were built one about 10 or 15 feet above the other. The lower was a ruin in each case and may have been abandoned to complete disuse after the higher one was built.

Data on the heights of nests relative to those of the nest trees and the mean height of the surrounding forest are presented in table 10. Estimating the height of the nest is described at the beginning of the section on Nests and Nesting.

Scrutiny of table 10 reveals the ordinary and exceptional heights of fox-squirrel nests in the three kinds of nest trees commonly used in the sand hills. It also indicates that these fox squirrels habitually place their nests below the general height of the forest. One may see there, also, that the bluejack oak is usually a lower tree than the turkey oak although occurring in forest of the same height.

Fox-squirrel nests were found in the turkey oak (*Quercus laevis*), the bluejack oak (*Quercus cinerea*), longleaf pine (*Pinus australis*), slash pine (*Pinus elliotti*), sweet bay (*Magnolia virginia*), loblolly bay (*Gordonia lasianthus*), *Taxodium ascendens*, live oak (*Quercus virginiana*), laurel oak (*Quercus laurifolia*), and black gum (*Nyssa biflora*), in approximately that order of abundance. The plant communities in which nests were found are longleaf pine and turkey oak, bayhead, cypress pond, slash-pine flatwoods, and xeric hammock, in about that order of frequency. Longleaf-pine flatwoods are omitted deliberately, for only one (unoccupied) nest was found in this plant community away from pond borders (slash pine) or the borders of other plant communities.

SUMMARY

THE PRESENT PAPER REPORTS the first field study of the fox squirrel (*Sciurus niger*) in an area of the southeastern United States extending from Virginia to Florida, Kentucky, and Louisiana. Unlike field studies of the successful *S. n. rufiventer* of the northern Mississippi Valley, which is apparently expanding its range because of changes wrought by man, this study is of the fox squirrel of the southeastern coastal plain which has probably diminished greatly in numbers and range because of changes wrought by man. *Sciurus niger shermani* was investigated in the sand hills of north Florida in a fire-maintained plant community which is common over a wide area of the southeastern coastal plain, the *Pinus australis-Quercus laevis* associes. This plant community was changed suddenly and radically from a tall but very open forest of primeval longleaf pines with turkey oak indifferently represented as a secondary, lower level dominant, to a virtually pure stand of turkey oak, relatively close-ranked and low. The question to which the present report addresses itself is, How does this very large tree squirrel, after having evolved presumably in the open stands of large pines, live now in the lowly oak forest which has succeeded the logged-off pines?

The principal predatory enemies of *Sciurus niger shermani* are apparently the bald eagle, the red-tailed hawk, and man. Suitable refuges for so large a tree squirrel in this low, open forest of deciduous trees are virtually absent and may have brought about the following developments in behavior unusual for a tree squirrel.

1. A fairly well-established tendency is here first reported for this arboreal squirrel to take refuge, when hard pressed, in the burrows of gopher tortoises underground.

2. Instances are reported of the use by the fox squirrels of hollows that extend down through the tops of old stumps to nesting chambers underground.

3. An escape behavior, which may have developed since the removal of the old pines and which is presumed to be employed only against man, involves hiding in the top of a second-growth longleaf pine by ascending the plume-like apical twig so that the twig bends over horizontally under the squirrel, and the squirrel lies on top hidden from all below.

4. It is shown to maintain what may prove, when more is known about fox-squirrel nesting habits elsewhere, to be an excessive number of leaf nests per individual squirrel, thus providing more refuges.

Sciurus niger shermani was found to harbor infestations of acanthocephaline worms (*Moniliformis clarki*), occasionally heavy infestations which may be harmful to the host. A tapeworm (*Raillietina bakeri*) was also found. A sample of 24 fox squirrels collected throughout a single year were searched for ectoparasites. Ten kinds were found. In order of greatest to smallest number of squirrels infested they are: 16 squirrels, the common squirrel flea (*Orchopeas howardi*), of which no more than three fleas were found on any adult squirrel, but which were more numerous on younger ones; nine squirrels, the louse (*Neohaematopinus sciurinus*); eight squirrels, the mite (*Atricholaelaps megaventralis*); eight squirrels, larvae of the tick (*Amblyomma tuberculatum*), for which a season of October through March is shown, with an abundance peak in January; four squirrels, the louse (*Hoplopleura sciuricola*); two squirrels, adult ticks (*Ixodes scapularis*); two squirrels, adult ticks (*Dermacentor variabilis*); one squirrel, mite (*Listrophorus* sp.); one squirrel, chigger (*Eutrombicula alfreddugesi*); one squirrel, the louse (*Enderleinellus* sp.). Ten of the 12 squirrels infested by lice were males.

Several broods of young fox squirrels were taken from nests and reared. After they had been weaned, they were placed in enclosed 40 by 60-foot natural areas of longleaf pine and turkey oak for further observation. Field investigations were carried on at the same time, principally of the nesting of free, wild, fox squirrels, and data on both free and confined animals are integrated in the remainder of the report. In the sand hills the principal food in fall, winter, and spring is turkey-oak acorns, and in summer field evidence indicates that longleaf-pine seed is a primary food. The young captives began burying acorns and peanuts soon after they

were old enough to eat these, some without ever having seen another squirrel do so. They buried considerable numbers of excess peanuts and disinterred and ate them when they were needed. Captives drank water by suction from open dishes. Although the fox-squirrel habitat here studied is apparently occupied irrespective of standing water, subadult captives drank as much as 83 cc. each (average) in a day when water was available. Perhaps it is a general practice to drink by licking dew from the needles of the longleaf pine as one young captive did. Excretion by captives was done in ways which tended to keep the nest clean, but away from the nest defecation and urination were accomplished without evident modification of other behavior.

Several reports of the activity periods of fox squirrels in relation to daylight hours have used Standard Time for a comparison of the early morning activity peaks in different seasons of the year, which is shown to be meaningless. The use of sunrise plus or minus so many hours and minutes for morning observations and sunset plus or minus so many hours and minutes for evening observations of diurnally active animals is suggested. *Sciurus niger shermani* is found to be most active in the second hour after sunrise and continues rather active through the fourth. The principal means of seeking relief from midday heat in hot weather appears to be to sprawl on the base of a high horizontal limb, face away from the trunk and tail spread as a shade above the back. Even in the fenced areas where tall pines were available for such a resort, however, captives sometimes sprawled on the bare ground instead, in the shade of a tree trunk or fence post. The closed, arboreal leaf nests are evidently the ordinary resort of fox squirrels from cold, but young captives, which had never observed an adult build a nest in a tree, first made nests in the deep grass and leaf litter on the ground and occupied these. Rain, except when violent, was slow to drive captive fox squirrels to cover. Good closed nests of leafy twigs of turkey oak kept fox squirrel inmates dry even in heavy rains, but the squirrels apparently endure or ignore light rain by sitting on the base of a high horizontal limb, back to the trunk and tail up as an umbrella.

Running speed on the ground of a free, wild *Sciurus niger shermani* was registered on an automobile speedometer at 15 miles per hour and that of a released captive was timed by stop-watch in a close pursuit over a measured 69 meters, at 11.9 miles per hour. The greatest distance was run by an adult female; on release from a live trap, she ran through the open, longleaf-pine and turkey-oak forest, when pursued but not hard pressed, to a jungle-like bayhead, 325 meters distant. Free, wild, fox squirrels jumped 2 or 3 feet from tree to tree as an ordinary means of moving about, and one was observed to jump 7 feet. One subadult female captive jumped 4½ feet between trees, from the tip of one pine limb to that of another, with a longleaf-pine twig in her mouth. In half the instances in which nests containing fox squirrels were climbed to by the writer, the squirrels fled from tree to tree, and in the other half they leaped to the ground. The heights of these jumps to the ground ranged from 25 to 51 feet. Captives placed in open water swam well and used only the hind feet for propulsion. Digging was indulged in by captives but without evident purpose or useful result. This fox squirrel barks as does the gray squirrel but significantly with a reversal of the order of the two component sounds, a fact that appears to be first reported here.

A very young captive male belligerently defended its nest box when other (larger) young were introduced into it. Other incidents that suggest very limited territoriality are described. Males dominated the females in the captive broods, but a female of an older brood dominated a male of a younger brood.

The few litters of nestlings examined averaged 2.27 in number of nestlings. About one in four nestlings were strongly melanistic. No more than one adult was seen near a brood nest, but one presumed parent was sometimes seen briefly. There are two breeding seasons, some young being born apparently in January and February and others in June, July, and August. The fact that the fox squirrel appears to adhere to the same seasonal breeding pattern as its northern relatives, even at this low latitude, is thought to be a result of its dependence on strongly seasonal mast crops. Winter-season young are conceived at the peak of abundance of the

turkey-oak acorns, and summer broods are conceived as longleaf-pine seed reaches the edible stage in greatest abundance. The rostrum continues to grow longer even after the squirrels are mature. Young squirrels molt apparently at about three months of age. Adults apparently molt only once a year, and at almost any time of year, but there is a peak of frequency in summer.

The writer made 506 examinations of outside nests of *Sciurus niger shermani*. Nests were classified as brood nests, closed resting nests, open resting nests, and ruins. Brood nests were those that contained nestlings. Some brood nests conformed to a pattern of special location and structure which would encourage a person to identify similarly built and located ones as brood nests. However, several broods were found in nests not distinguishable from closed resting nests. The latter type is any domed, or roofed-over, nest that did not contain nestlings. Open resting nests are cup-shaped nests without roofing. Ruins are remains of any of these kinds of nests that are in such a state of disarray as to indicate no use as a nest by a fox squirrel without the rearrangement or addition of materials. Outside nests were almost invariably placed against the main trunk of a tree, closed and open resting nests at the same average height. Only one nest was found occupied by a pair of adults, but it was open, unusually wide and shallow, and located very high; hence it is regarded as a separate type and called a pairing nest. Only one tree-hollow den in use was observed. This was apparently an enlargement of a hole made by a red-cockaded woodpecker 50 feet high in a longleaf pine. Old stumps of pines in five instances had narrow vertical cavities down through the top to a chamber below the surface of the ground, which showed some evidence of use by fox squirrels. Two were excavated and found to have nests, one containing a young female fox squirrel. This is the first report of fox squirrels nesting naturally underground.

The young captive fox squirrels, never having observed adults build nests, made snug lairs or nests in the thick leaf litter and wiregrass on the ground in their fenced natural areas and occupied these for months. Only the females of the young captives built tree nests, but an adult male was observed in the field building a nest.

The outside nests studied in the field were made of various combinations of twigs, leafy twigs, leaves, Spanish moss, dried grass, and pinestraw, in that order of frequency. Leafy twigs of turkey oak seemed the favorite material in the relatively rainy summer season. Spanish moss would probably be used more if it were more generally available in the turkey-oak woods. In turkey oaks and bluejack oaks the nests averaged about 25 feet above the ground and about 10 or 12 feet from the top of the tree. In longleaf pines nest heights average about 35 feet above the ground and about 10 feet from the top.

A complete inspection was made in July and August of all the 65 nests in a 52.3-acre area here called North Five in the longleaf-pine and turkey-oak community on the University of Florida Conservation Reserve. The nests evidently in use were arranged in five natural groups, and the evidence obtained was that each of these groups was occupied by an adult individual, or possibly in one instance a pair. The population density is estimated at one squirrel (older than nestling) to 6.5 acres or one adult female to 13 acres. The locations of all the fox-squirrel nest trees in North Five were carefully mapped, and the subsequent histories of their nests were noted by re-inspections in November–December and in February. Each adult female evidently kept about eight functional nests available for her use in an area about 100 to 150 meters in diameter. This is the first study of fox squirrels that provides a good indication of the number of outside nests maintained by individuals.

CONCLUSION

While there are too many variables and too few decisive data on particular aspects of so brief and generalized a study for conclusions to be drawn, a concluding comment on the general focus of the study seems nevertheless apropos. The rare, shy fox squirrels populating the turkey-oak forests, which have replaced the original, open, longleaf-pine

forest in the sand hills of the southeastern coastal plain, apparently remained (1946–1947) at low density on the reservation at Welaka, Florida, even after 10 years of protection, and in habitat where the nesting facilities were judged to be especially good and scattered second-growth longleaf pine had been permitted to attain sufficient size to produce an apparently considerable supply of summer food. There were few important enemies other than man, but the large size of the fox squirrel and the virtual absence in turkey-oak forest of refuges suitable for a tree squirrel make it peculiarly vulnerable there to man. Several kinds of behavior, some of which seem extraordinary for tree squirrels, were possibly developing here in response to selective pressure partly, or even largely, exerted by man. These appeared to have survival value but were not enabling the animal to prosper.

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