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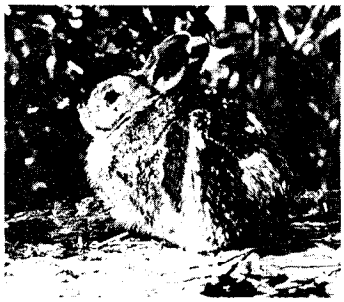

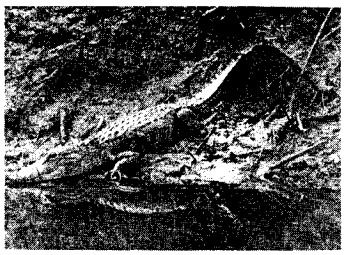

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ENVIRONMENTAL IMPACT RESEARCH PROGRAM

TECHNICAL REPORT EL-86-6

EASTERN GRAY SQUIRREL (*Sciurus carolinensis*)

Section 4.7.1, US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL

by

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A wildlife species account for the eastern gray squirrel (*Sciurus carolinensis*) is provided as Section 4.7.1 of the US Army Corps of Engineers Wildlife Resources Management Manual. The account is developed as a general guide to provide the Corps District or project biologist with basic information on the biology, ecological requirements, and management technology for the species throughout its range. Major topics covered include status, characters and measurements, population attributes, habitat requirements, management, and census and sampling.

The geographic range of the eastern gray squirrel is described, and the economic importance of the species is discussed. Characters used to distinguish between the gray squirrel and the fox squirrel (*Sciurus niger*) are presented, and several techniques for estimating the age of squirrels are described and illustrated. The section on population
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attributes includes details on population densities, sex and age ratios, movements, breeding biology, and mortality. Food, cover, and water requirements are discussed under habitat requirements. The management section provides recommendations for timber stand management and selection of techniques to improve squirrel habitat. Methods for estimating squirrel populations and measuring habitat variables are presented under census and sampling.

PREFACE

This work was sponsored by the Office, Chief of Engineers (OCE), US Army, as part of the Environmental Impact Research Program (EIRP), Work Unit 31631, entitled Management of Corps Lands for Wildlife Resource Improvement. The Technical Monitors for the study were Dr. John Bushman and Mr. Earl Eiker, OCE, and Mr. Dave Mathis, Water Resources Support Center.

This report was prepared by Mr. James W. Teaford, Wetlands and Terrestrial Habitat Group (WTHG), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). Mr. Chester O. Martin, Team Leader, Wildlife Resources Team, WTHG, was principal investigator for the work unit. Dr. Frederick S. Barkalow, Jr., Department of Zoology, North Carolina State University, generously provided information on gray squirrel biology and management. Review and comments were provided by Mr. Martin and Dr. Wilma A. Mitchell, WTHG, and Mr. Larry E. Marcy, Texas A&M University.

The report was prepared under the general supervision of Dr. Hanley K. Smith, Chief, WTHG, EL; Dr. Conrad J. Kirby, Chief, Environmental Resources Division, EL; and Dr. John Harrison, Chief, EL. Dr. Roger T. Saucier, WES, was Program Manager, EIRP. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division (PGAD). Drawings were prepared by Mr. David R. (Randy) Kleinman and Mr. John R. Harris, Scientific Illustrations Section, PGAD, under the supervision of Mr. Aubrey W. Stephens, Jr.

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NOTE TO READER

This report is designated as Section 4.7.1 in Chapter 4 -- WILDLIFE SPECIES ACCOUNTS, Part 4.7 -- SMALL GAME MAMMALS AND FURBEARERS, of the US ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL. Each section of the manual is published as a separate Technical Report but is designed for use as a unit of the manual. For best retrieval, this report should be filed according to section number within Chapter 4.

EASTERN GRAY SQUIRREL *(Sciurus carolinensis)*

Section 4.7.1, US ARMY CORPS OF ENGINEERS
WILDLIFE RESOURCES MANAGEMENT MANUAL

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The eastern gray squirrel is a small game mammal that occurs primarily in the eastern hardwood forests of North America. The natural range of the species extends from the Atlantic Coast to the eastern border of the Great Plains, and from the Gulf Coast to just north of the United States-Canada border (Fig. 1). The range has been extended through introductions into Quebec, New Brunswick, British Columbia, and Nova Scotia, and isolated colonies have been established in California, Oregon, Washington, and Montana (Barkalow and Shorten 1973). Five (Hall 1981) or 6 (Barkalow and Shorten 1973) subspecies of the eastern gray squirrel are recognized; their respective ranges are shown in Figure 1.

* The scientific names of plants referred to in the text are given in the appendix at the end of this account.

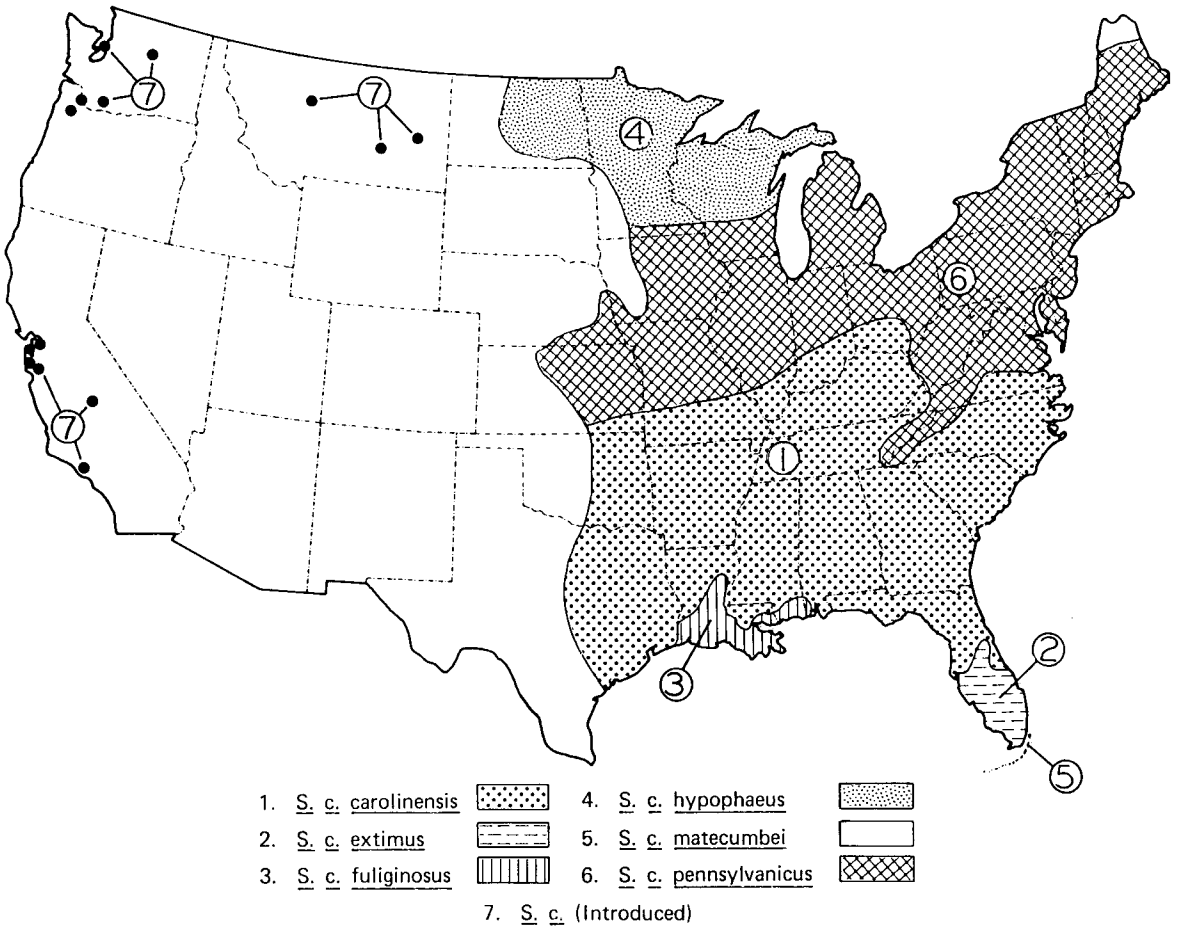


Figure 1. Distribution and subspecies of the gray squirrel (*Sciurus carolinensis*) (from Barkalow and Shorten 1973)

STATUS

The gray squirrel is an important North American game species and is hunted in every state within its natural range (Dalrymple 1970). The combined annual harvest of gray squirrels and fox squirrels (*Sciurus niger*) totals roughly 40 million animals (Flyger and Gates 1982). Harvests are highest in the South and lowest in the northwestern and northeastern portions of the range (Dalrymple 1970, Flyger and Gates 1982).

No subspecies of the gray squirrel is listed as threatened or endangered by the Federal Government (USDI 1980). However, albino squirrels are protected statewide in Illinois (L. Franklin, Illinois Department of Conservation, Springfield, pers. commun., August 1982).

CHARACTERS AND MEASUREMENTS

Description

The normal color pattern of the species is grayish above with white underparts, but 4 other color phases also occur. Melanistic (black) squirrels are frequently found in northern and northeastern parts of the range, but they are rarely found in southern regions. Complete or partial albinos occur throughout but are apparently more common in the South. Reddish-brown and silver-gray phases occur but are less common than the melanistic or albino forms (Barkalow and Shorten 1973).

External measurements for the species are: total length, 430 to 500 mm; tail length, 210 to 240 mm; and hind foot length, 60 to 70 mm. Body weights range from 400 to 710 g, with a general increase in average body weight from the southern to the northern part of the range (Hall and Kelson 1959). Body weight may show a daily fluctuation of up to 90 g based on the contents of the stomach (Barkalow and Shorten 1973), and weight varies by season with the highest weights generally recorded in December and the lowest weights found from May through August (Kirkpatrick and Hoffman 1960).

Characters useful in distinguishing between the eastern gray squirrel and the fox squirrel are given in Table 1. The two species can generally be distinguished on the basis of size, pelage, and tooth characters, but some overlap may occur. Uhlig (1955) noted that the extra peg-like premolar characteristic of gray squirrels was absent in 5 of 22 gray squirrels checked, while Schwartz and Schwartz (1981) stated that this tooth may be absent in about 1 percent of the gray squirrel population.

Sex Determination

The pelage characteristics of male and female gray squirrels are identical, and sex determinations are based on the external genitalia. Males have a penis with a baculum (penis bone) and testes which temporarily descend into the scrotum during the breeding season. Females may be identified by the vagina and the mammary glands with 4 pairs of teats (Schwartz and Schwartz 1981).

Age Determination

The 4 age categories generally recognized for the gray squirrel are nestling, juvenile, subadult, and adult (Barrier and Barkalow 1967). The specific criteria for each age category are listed in Figure 2.

Table 1. Characters useful in distinguishing gray squirrels (*Sciurus carolinensis*) from fox squirrels (*S. niger*)*

Character	Gray Squirrel	Fox Squirrel
Total length	430-500 mm	454-698 mm
Average weight	0.54 kg	0.77 kg
Typical body pelage	Gray with white underparts	Reddish yellow with orange underparts
Typical tail pelage	Long hairs white tipped	Long hairs tawny or rusty orange tipped
Dental formula	$I\frac{1}{1}\ C\frac{0}{0}\ P\frac{2}{1}\ M\frac{3}{3} = 22$, has peg-like upper premolar	$I\frac{1}{1}\ C\frac{0}{0}\ P\frac{1}{1}\ M\frac{3}{3} = 20$, lacks peg-like upper premolar
Long bones	White in color	Pink to reddish in color

* From: Allen 1943, Brown and Yeager 1945, Barkalow and Shorten 1973, Hall 1981, Schwartz and Schwartz 1981.

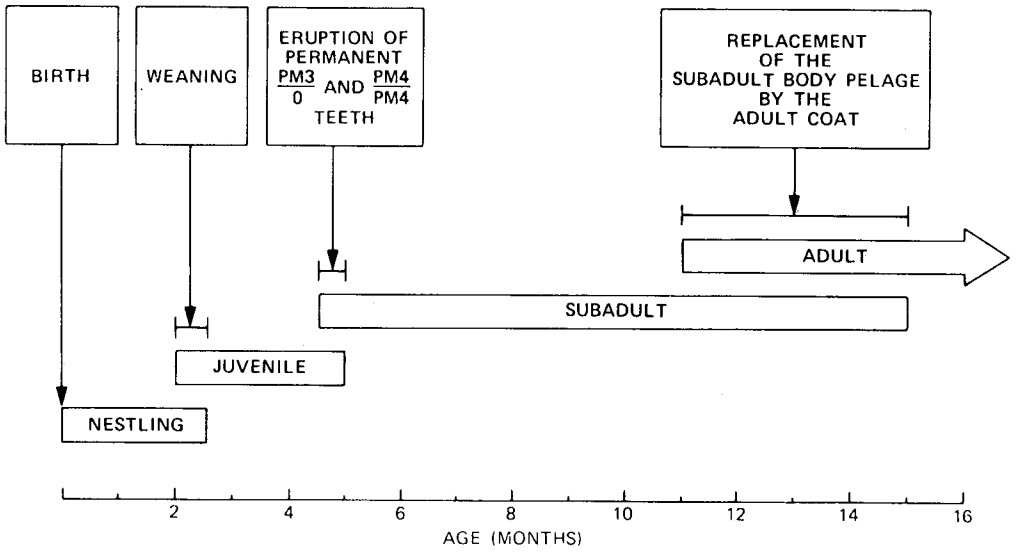


Figure 2. Age categories of the gray squirrel (after Barrier and Barkalow 1967)

Gray squirrels can be placed into age categories on the basis of pelage characteristics. Figure 3 combines the tail pelage characteristics described by Sharp (1958a) and the rump pelage characteristics described by Barrier and Barkalow (1967). The rump pelage technique is of limited use for aging squirrels in the winter pelage (late fall to early spring) and is not applicable to the summer pelage (Barrier and Barkalow 1967). The tail pelage technique, developed in Pennsylvania, did not give satisfactory results when checked against known-age squirrels in North Carolina (Barrier and Barkalow 1967); Barrier and Barkalow (1967) acknowledged that the rump pelage technique may be limited regionally as well. It is therefore recommended that these techniques be used in combination to supplement each other.

Gray squirrels can be accurately aged to year classes during any season using tooth characteristics determined from razor-sectioned teeth; this method is known as the cementum annuli technique (Fogl and Mosby 1978). The procedures and aging criteria for this technique are given in Figure 4.

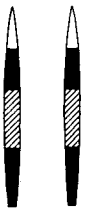
Several other aging techniques have been developed for the gray squirrel, but none are as accurate as the cementum annuli technique nor as simple as the pelage characteristics techniques. However, the following techniques and references are listed for additional study: the external genitalia technique (Allen 1943, Brown and Yeager 1945); the baculum weight and length technique (Kirkpatrick and Barnett 1957); the epiphyseal cartilage technique (Kirkpatrick and Barnett 1957, Carson 1961); and the eye lens weight technique (Fisher and Perry 1970, Hefner 1971).

POPULATION ATTRIBUTES

Densities and Indices

Estimates of gray squirrel fall population densities range from 0.5 (Barkalow et al. 1970) to approximately 14 (Mosby 1969) squirrels/ha (0.25 to 5.7/acre) (Table 2). Small woodlots with excellent habitat have been observed to support sustained populations of 14 squirrels/ha (5.7/acre) (Mosby 1969), while a density of 3.2 squirrels/ha (1.3/acre) is considered high for extensive forested habitats (Nixon and McClain 1969).

Gray squirrel populations may exhibit significant fluctuations from year to year, but they are not considered cyclic. Fluctuations are generally correlated with the availability of hard mast food supplies during the preceding fall. Fall-to-fall densities have been observed to double or even quadruple

<table>
<tr><th>PREBASAL STREAK</th><th>GUARD HAIRS</th><th>MOLT</th><th>TAIL</th><th>AGE CATEGORY</th></tr>
<tr><td rowspan="3">DISTINCT
  </td><td rowspan="2">ALL WHITE TIPPED (4-BANDED)
  </td><td rowspan="3">NOT APPLICABLE</td><td>Ventral surface of tail bone completely masked by appressed hairs, dark lines or bars obscure.
  </td><td>ADULT</td></tr>
<tr><td>Short appressed hairs present on lower third of tail bone, upper two-thirds bare; 2 or 3 dark lines or bars prominent.
  </td><td>SUBADULT</td></tr>
<tr><td rowspan="3">INDISTINCT

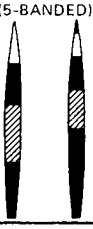
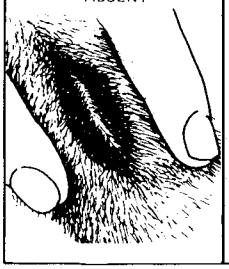
OR</td><td>BOTH WHITE TIPPED (4-BANDED) AND BLACK TIPPED (5-BANDED)
  </td><td rowspan="2">Ventral surface of tail bone bare; 2 or 3 dark lines or bars prominent.
  </td><td rowspan="2">JUVENILE</td></tr>
<tr><td>ALL BLACK TIPPED (5-BANDED)
  </td><td>New recently molted hair at least on nose and crown, the new, coarser, and more glossy fur contrasts with the soft, rather lusterless nestling coat. Molt line usually evident on head or body.</td></tr>
<tr><td>ABSENT
  </td><td></td><td>No evidence of molting on head, neck, or back. No new replacement hair visible on crown. Pelage on body very fine and soft with a dull and often shaggy appearance. The white terminal band of the tail hair at least 1/3 the total length of hair itself.</td><td>NOT APPLICABLE</td><td>NESTLING</td></tr>
</table>

Figure 3. A guide to determining the age of gray squirrels based on pelage characteristics (after Sharp 1958a, Barrier and Barkalow 1967)

AGING GRAY SQUIRRELS BY CEMENTUM ANNULI IN RAZOR-SECTIONED TEETH

I. Pull M-3 tooth and store in formalin solution.

II. Place tooth in decalcifying solution for 24 hours.

DECALCIFYING SOLUTION

SOLUTION A	
Sodium citrate	100 g
Distilled water	50 ml
SOLUTION B	
Formic acid (90%)	125 ml
Distilled water	375 ml

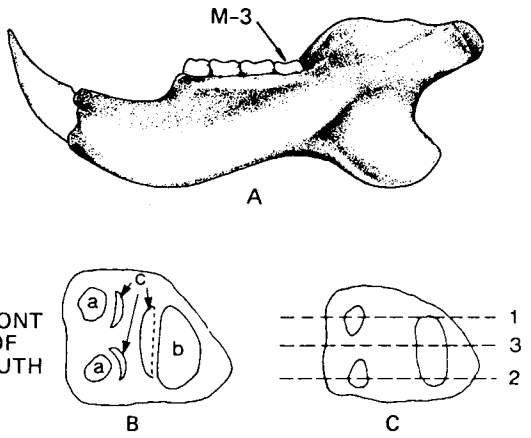
A mixture of 2 ml of Solution A and 2 ml of Solution B in a 5-ml vial decalcified a squirrel tooth in about 24 hours.

III. Rinse tooth in tapwater, place upside down (roots upward) and make 3 longitudinal cuts using a single-edge razor blade so that each of the 3 roots is bisected.

IV. Use fine-pointed jewelers forceps to move the sections through the following staining sequence:

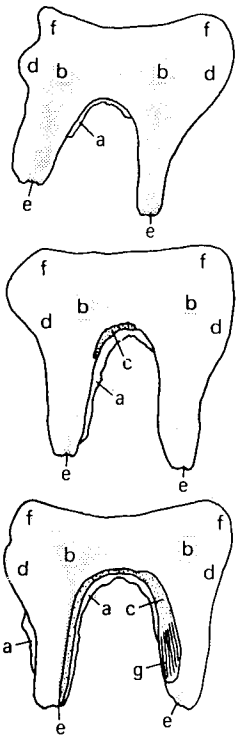
Harris' Hematoxylin	10 seconds
Tapwater	Rinse
Lithium Carbonate Bluing	to desired color
Tapwater	Rinse
Eosin Y (1% in water)	10 seconds
Tapwater Wash	5-10 seconds

V. Place stained sections on a slide, immerse in a drop of water and examine under a compound microscope at 100-200x.



(A) M-3 tooth of the Gray Squirrel.
(B) Basal view of M-3 squirrel tooth showing: a) anterior roots, b) large posterior root, and c) areas of thickest cementum.
(C) Basal view of M-3 squirrel tooth showing first, second, and third longitudinal cuts made with a single-edge razor blade. Each cut bisected a root.

a Peridontal Tissue
b Pulp
c Cementum
d Dentine
e Root Tip Opening
f Crown
g Annuli



(D) Diagramatic representations of razor-sectioned M-3 teeth of the gray squirrel indicating the development of immature teeth and cementum annuli in an adult tooth.

AGING CRITERIA

1) 3 months of age – Pulp occupies 50-80 percent of the root; root tip wide open; cementum not apparent.

2) 6 months of age – Pulp occupies one-third or less of the root; root tip constricting; thin layer of summer cementum layer visible.

3) 9 months of age (born in early spring and died before winter cementum deposited) – Pulp occupies less than one-third of root; constriction of root tip and part of root canal obvious; thick summer cementum layer present, but no winter band.

4) Adults – Each dark winter-cementum band counted as 1 full year; a summer band counted as one-half year in age.

Figure 4. The cementum annuli technique for aging gray squirrels (from Fogl and Mosby 1978)

Table 2. Regional variation in fall population estimates for gray squirrels

State	Habitat	Fall Population Estimates (per hectare)	Fall Population Estimates (per acre)	Census Technique Used	Source
	Forest Habitats				
Texas	Hammock (oak-magnolia-sweetgum-pine)	3.5	1.4	Time-area count	Goodrum (1940)
	Poorly drained bottomland hardwood (overcup oak-bitter pecan-willow oak-blackgum-bald cypress)	2.2	0.9		
	Well-drained bottomland hardwood (postoak-hackberry-shumard oak-elm-pecan)	1.7	0.7		
Texas	Bottomland hardwood-hammock mix (laurel oak-pine-water oak-sweetgum-hickory-blackgum-overcup oak)	8.2	3.3	Time-area count	Baker (1944)
	Hammock (loblolly pine-white oak-blackgum-red oak-water oak)	1.5	0.6		
West Virginia	Upland hardwoods (red oak-white oak-chestnut oak-yellow poplar)	0.8-3.2	0.3-1.3	Time-area count	Uhlig (1955)
North Carolina	Upland hardwoods (oak-hickory-pine)	$\bar{x}$ = 1.2 (0.5-3.5)	$\bar{x}$ = 0.5 (0.2-1.4)	Schnabel method (livetrap-tag-retrap)	Barkalow et al. (1970)
Ohio	Upland hardwoods (oak-hickory)	$\bar{x}$ = 1.9* (1.0-3.2)	$\bar{x}$ = 0.8 (0.4-1.3)	Lincoln index (live-trap-tag-hunt)	Nixon et al. (1975)
	Woodlot Habitats				
Maryland	Upland hardwoods (red oak-beech-yellow poplar)	12.4	5.0	Schnabel method livetrap-mark-sight)	Flyger (1955)
Virginia	Upland hardwoods (oak-hickory)	14.1 11.1	5.7** 4.5†	Minimal time-specific estimates (livetrap-retrap-records)	Mosby (1969)

* Includes gray and fox squirrels. Gray squirrels comprised approximately 90% of the population.
** Unhunted control.
† Hunted.

in response to bumper crops of mast, and they have been observed to plummet to population levels only 15% to 25% of the previous fall density in response to mast crop failures (Nixon and McClain 1969, Barkalow et al. 1970, Nixon et al. 1975).

Sex and Age Ratios

Gray squirrel populations exhibit essentially balanced sex ratios for nestlings and adults (Chapman 1938, Uhlig 1955, Mosby 1969, Nixon et al. 1975). The shift to a slightly higher percentage of males in some instances may be more apparent than real and has been attributed to the higher activity level of males, which increases their exposure to sampling by traps, hunters, road kills, etc. (Brown and Yeager 1945, Packard 1956, Flyger and Cooper 1967). Reported percentages of the population composed of juveniles range from a low of 24% (Mosby 1969) to highs of 65% to 75% (Goodrum 1961). As a general rule of thumb for both fox and gray squirrels, stable populations are composed of approximately 60% juveniles; percentages significantly less than 60% probably indicate declining populations, whereas percentages of juveniles greater than 60% indicate population increases (Allen 1943, Uhlig 1955).

Home Range and Movements

A gray squirrel population is characterized by a highly stable linearly ranked social hierarchy (A dominates B, B dominates C, etc.) composed of nonterritorial individuals of both sexes having overlapping home ranges (Flyger 1955, Pack et al. 1967). Males tend to be dominant over females, and dominance and home range size tend to increase with age (Pack et al. 1967). The average home range size varies from 0.5 to 10 ha (approximately 1.2 to 24.7 acres) (Bakken 1959, Flyger 1960, Doebel and McGinnes 1974, Cordes and Barkalow 1972, Donohoe and Beal 1972, Bland 1977), and the normal daily cruising radius averages approximately 50 m (164 ft) (Doebel and McGinnes 1974). Daily activity is concentrated into two peaks--early morning and late afternoon (Goodrum 1940, Uhlig 1955).

Cordes and Barkalow (1972) found that dispersal movements for subadults normally occur as they approach sexual maturity at 8 to 11 months of age. These authors reported an average dispersal distance of 174 m (190 yd) for both sexes combined (males, $\bar{X}$ = 228 m [250 yd]; females, $\bar{X}$ = 119 m [130 yd]) with maximum distances of 2.7 to 3.2 km (1.7 to 2.0 miles) or greater. After

completing this initial dispersal, gray squirrels usually establish and maintain stable home ranges (Cordes and Barkalow 1972).

Although not migratory, gray squirrels have been reported to emigrate. These emigrations are one-way movements in which the majority of the squirrel population of an area travels in one general direction. Apparently these movements continue until they are finally dissipated by mortality factors (accidents, disease, exhaustion, predation, etc.). Most reported emigrations have been generally associated with above-average population densities and regional mast crop failures (Seton 1920, Sharp 1959, Nixon and McClain 1969).

Breeding Biology

Breeding periods. Gray squirrels are promiscuous and typically engage in "mating chases" which have been reported to involve from 3 to 34 squirrels for periods ranging from 1/2 hour to an entire day (Uhlig 1955, Bakken 1959, Goodrum 1961). Two distinct breeding periods occur each year. The winter-spring period has a mating activity peak in January, a parturition peak in late February and early March, and a weaning period in May. Mating activity for the spring-summer period peaks in June, parturition peaks in July, and weaning peaks from mid-September to mid-October (Fig. 5). Although there are some regional differences, the timing of breeding periods remains fairly constant throughout the entire range (Kirkpatrick et al. 1976).

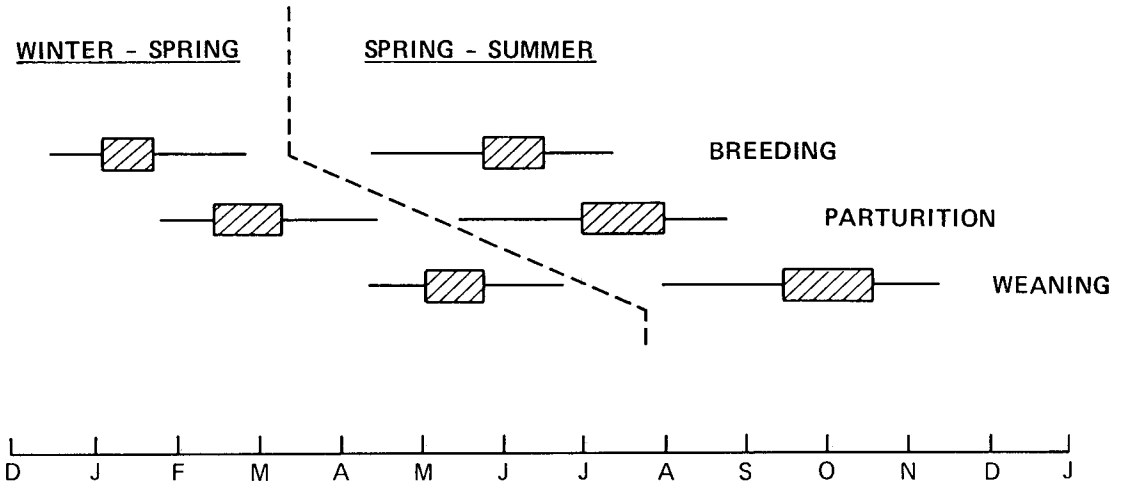


Figure 5. Breeding chronology of the eastern gray squirrel; weaning period of 11 weeks assumed (adapted from Nixon and McClain 1975)

Initial breeding age and longevity. Gray squirrels normally produce their first litter at approximately 1 year of age, and the production of litters by females less than 10 months old is rare (Smith and Barkalow 1967). Smith (1967) cited by Nixon and McClain (1975) found that 3% of subadult females (*O*10 months), 64% of yearling females (10 to 14 months), and 94% of adult females (*J*14 months) had at least 1 litter per year following a good mast year. Nixon and McClain (1975) reported similar results with 2% of subadult females (5 to 9 months), 56% of yearling females (10 to 14 months), and 95% of adult females breeding in response to a good mast crop.

Although gray squirrels have been found to be reproductively active at advanced ages (females, approximately 8 to 12-1/2 years; males, approximately 6-1/2 to 9 years) (Barkalow and Soots 1975), very few individuals live that long. Most squirrels have a mean life expectancy at birth of only 1 to 2 years (Mosby 1969, Barkalow et al. 1970).

Gestation. Gray squirrels have a gestation period of approximately 44 days (Goodrum 1940, Brown and Yeager 1945, Uhlig 1955). After becoming pregnant, females construct a nest which is usually located in the general area of their own birth (Cordes and Barkalow 1972). Most winter-spring litters are born in tree cavities, while most spring-summer litters are born in leaf nests (F. S. Barkalow, pers. commun., 1981).

Litter size and number. Adult females generally have larger litters than do yearling females, and spring-summer litters are generally larger than winter-spring litters (Table 3). Redmond (1953) reported that adult females in Mississippi had an average of 1.6 litters/year. In West Virginia, Uhlig (1955) found that 20% to 30% of the adult females had 2 litters/year during normal years; during good years, this figure increased to 40%. In Ohio, averages of 27.3% and 2.4% of the adult females had 2 litters/year during favorable and unfavorable food years, respectively (Nixon and McClain 1975). Nixon and McClain (1975) found the percentage of females breeding during the winter-spring and spring-summer periods to be nearly equal at approximately 61% and 66%, respectively.

Weaning. The young, born blind and hairless, begin to wean at approximately 7 weeks of age, but they do not switch to a complete diet of solid food until they are 10 to 12 weeks old (Uhlig 1955). The young are cared for solely by the female, and during late pregnancy and after parturition the female defends her nest tree against both sexes and all ages (Uhlig 1955,

Bakken 1959). The young become independent of their mothers and disperse at approximately 15 weeks of age (Bakken 1959).

Table 3. Gray squirrel litter sizes

Litter Size			
Winter-Spring	Spring-Summer	State	Source
2.36	2.69	Kentucky	Hibbard (1935)
2.7*	--	Texas	Goodrum (1940)
2.74	2.43	Illinois	Brown and Yeager (1945)
2.52*	--	West Virginia	Uhlig (1955)
2.15	3.29	Maryland	Flyger and Cooper (1967)
2.43**	2.51**	Ohio	Nixon and McClain (1975)
2.70	3.49†	Ohio	Nixon and McClain (1975)

* Reported as an average figure for both breeding periods.
** Yearling females (10 to 14 months of age).
† Adult females (15+ months of age).

Reproductive success. During any particular year, breeding may be significantly influenced by the size of the hard mast crop of the preceding fall. Breeding by subadult females (<10 months) has been reported only in response to above-average to excellent mast crops (Uhlig 1955, Smith and Barkalow 1967, Nixon and McClain 1975), whereas breeding failures have been reported in Ohio (Nixon and McClain 1969) and in North Carolina (Barkalow et al. 1970) in response to mast crop failures. During 2 springs following poor mast crops, only 5% of the females livetrapped were lactating; this was in contrast to 38% lactating during 2 springs following good mast years (Smith and Barkalow 1967).

Mortality

Although most major gray squirrel population declines occur primarily as a result of mast crop failures (Nixon and McClain 1969, Barkalow et al. 1970, Nixon et al. 1975), several other factors can contribute to the mortality rate. Reported mortality rates (adults and young) range from 42.4% (Mosby 1969) and 63.5% (Barkalow et al. 1970) for unhunted populations to approximately 80% for a heavily hunted population (Nixon et al. 1975). While

the adult mortality rate is relatively low at 50% per year, most of the mortality is concentrated in the nestling, juvenile, and subadult age classes; 75% of the young born during any year normally die within 12 months (Barkalow et al. 1970).

First-year mortality is apparently concentrated in the summer-born litter (Barkalow et al. 1970). Nixon et al. (1975) also found that summer-born litters suffered significantly higher mortality rates (68.1%) than did spring-born litters (15.9%). Barkalow et al. (1970) postulated that spring-born individuals fared better for several reasons: smaller litter sizes, greater use of dens for nesting, possibly fewer predators (especially climbing snakes), lower exposure to predators, fewer nest parasites, and the presence of an ample and varied food supply when the young leave the nest. Thus, in most years, it appears that most individuals of the summer-born litter are probably surplus animals which must disperse to other areas or die (Nixon et al. 1975).

Diseases and parasites. The effects of diseases and parasites are often difficult to assess, but they may be more important than is commonly realized. Ingles (1947), cited by Uhlig (1955), reported the virtual elimination of a population of western gray squirrels (*S. griseus*) from a 2400-acre park in California as a direct result of scabies mange (*Sarcoptes* spp.). Clark (1959) and Parker and Holliman (1971) listed approximately 80 endoparasites and ectoparasites associated with the gray squirrel. The squirrel botfly (*Cuterebra emasculator*), chiggers, fleas, and ticks are commonly reported as serious parasites (Goodrum 1940, Baker 1944, Redmond 1953); from the standpoint of hunter attitudes and wasted game (Jacobson et al. 1979), the most significant of these is probably the botfly larva.

Predators. A number of animals prey on gray squirrels. Major predators include the bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), barred owl (*Strix varia*), great horned owl (*Bubo virginianus*), red-shouldered hawk (*Buteo lineatus*), Cooper's hawk (*Accipiter cooperii*), red-tailed hawk (*Buteo jamaicensis*), broad-winged hawk (*Buteo platypterus*), rattlesnakes (*Crotalus* spp.), and climbing snakes such as rat snakes (*Elaphe* spp.) (Goodrum 1940, Progulske 1955, Uhlig 1955, Goodrum 1961, Barkalow and Soots 1965b). The overall effects of predation, however, are considered minor (Uhlig 1955) and do not appear to limit populations.

HABITAT REQUIREMENTS

Habitat Components

The eastern gray squirrel typically inhabits extensive hardwood stands dominated by mature, mast-producing species with closed or nearly closed canopies (Brown and Yeager 1945, Goodrum 1961, Nixon et al. 1978, Korschgen 1981). Small woodlots of old-growth oaks and hickories (Flyger 1960, Mosby 1969) and mixed hardwood-pine stands (Goodrum 1961) are also used, and gray squirrels are found in both bottomland and upland situations (Goodrum 1961). Pure pine stands and young hardwood stands less than 15 to 20 years old and not producing mast are generally avoided (Goodrum 1961, Nixon et al. 1980b). Stands of mature and overmature trees of a variety of mast-producing species apparently represent optimum conditions (Nixon et al. 1978).

Gray squirrels prefer timber stands with canopies dense enough to permit continuous travel through the tree crowns (Goodrum 1961); open stands such as post oak-blackjack oak stands and pecan groves generally are not used (Chesemore 1975). The density of the understory is also important, but the relationship is not clear. Most studies seem to indicate a preference for a dense understory and an abundant ground cover (Brown and Yeager 1945, Goodrum 1961, Nixon et al. 1978), but there is evidence to the contrary. In North Carolina, Barkalow (pers. commun., 1981) found that gray squirrels prefer open understories and generally avoid areas of dense understories of shrubs and vines where predators may hide. Dense ground mats of Japanese honeysuckle are almost totally avoided.

Food

Food items. Oak, hickory, and beech trees supply nuts, buds, and flowers, which constitute the major part of the diet for gray squirrels throughout most of their range. Table 4 shows the volume percentages of the 3 most important primary foods used monthly by gray squirrels in Missouri, as determined through the analysis of approximately 1000 stomach samples (Korschgen 1981). Although beech was not a significant part of the diet of Missouri squirrels, it is a major food in other areas (Table 5).

Although population levels are closely tied to the availability of hard mast (Nixon et al. 1975), supplemental foods are often heavily utilized when available (Baker 1944). In Ohio, Nixon et al. (1968) found that the flowers from yellow poplar trees comprised 14% of the gray squirrel's May diet, while

Table 4. Volume percentages of the 3 primary foods utilized each month by eastern gray squirrels in Missouri (from Korschgen 1981)

Food	% Volume	Food	% Volume	Food	% Volume
MARCH		APRIL		MAY	
Black oak acorns	19.8	Walnuts	20.1	Shagbark hickory	24.3
Black walnuts	16.3	White oak acorns and flowers	15.0	Silver maple seeds	10.6
White oak acorns	13.1	Shagbark hickory flowers and nuts	12.4	White oak acorns	9.0
JUNE		JULY		AUGUST	
Red mulberry fruit	45.3	Shagbark hickory nuts	40.7	Shagbark hickory nuts	62.5
Shagbark hickory-green nuts	13.4	Apple fruit	15.8	Shellbark hickory nuts	7.7
Walnut-green nuts	7.9	Shellbark hickory nuts	11.3	Bitternut hickory nuts	3.1
SEPTEMBER		OCTOBER		NOVEMBER	
Shagbark hickory nuts	22.0	Black oak acorns	34.2	Black walnuts	24.1
Black oak acorns	12.2	White oak acorns	9.8	Black oak acorns	22.3
White oak acorns	8.6	Pin oak acorns	7.1	White oak acorns	15.2
DECEMBER*		JANUARY		FEBRUARY	
White oak acorns	92.0	Black walnuts	48.1	Post oak acorns	30.3
Sorghum grain	8.0	White oak acorns	19.2	Black oak acorns	21.9
		Black oak acorns	11.5	White oak acorns	19.4

* Only 4 samples in December.

Table 5. Important food items of the eastern gray squirrel as determined by studies in Kentucky (Barber 1954), Ohio (Nixon et al. 1968), and Missouri (Korschgen 1981)

Food	Percent Occurrence		
	Kentucky	Ohio	Missouri
Hickory	27.7	37.1	46.8
Oak	22.1	19.2	33.2
Beech	14.4	21.8	0.5
Animal matter	-	15.1	12.8
Fungi	0.6	9.2	13.3
Black walnut	8.6	6.0	6.0
Yellow poplar	6.1	2.4	-
Red mulberry	3.7	-	4.5
Maple	3.9	1.3	2.2
Flowering dogwood	1.8	2.3	-
Blackgum	2.7	-	0.3
Corn	1.0	-	2.1

Table 6. Plant species commonly used by eastern gray squirrels as supplementary foods*

American hornbeam	Carolina silverbell	Palmetto
American plum	Carolina snailseed	Persimmon
Ash	Chinquapin	Pine
Baldcypress	Grape	Supplejack
Basswood	Greenbrier	Sweetgum
Blackberry	Hackberry	Sycamore
Black cherry	Hazelnut	Tupelo gum
Blueberry	Hophornbeam	Witchhazel
Buckeye	Magnolia	
Butternut	Osage orange	

* Based on observations reported by Goodrum (1940), Barber (1954), Uhlig (1955), Colin (1957), Davison (1964), and Nixon et al. (1968).

various fungi constituted 27% of the diet in June and July. Yellow poplar flowers also provided an abundant May and June food supply for gray squirrels in North Carolina (Cordes and Barkalow 1972). A list of commonly reported supplementary foods is provided in Table 6. Various animals, primarily insects, are also taken as food (Goodrum 1961, Nixon et al. 1968, Korschgen 1981); the presence of weevil larvae in acorns and other nuts do not prevent squirrels from eating the nuts (Korschgen 1981). Songbird eggs (Barber 1954), and frogs and lizards (Goodrum 1961) are occasionally eaten.

Gray squirrels have been observed to gnaw on bones, deer antlers, and turtle shells (Goodrum 1940, Uhlig 1955), presumably to obtain calcium and other minerals. Korschgen (1981) reported that some lactating females had eaten gravel, apparently to obtain minerals needed during the reproductive period.

Feeding behavior. Under normal conditions, gray squirrels have 2 feeding periods each day. The first period begins before daylight each morning and continues for 2 to 3 hours, and the second period starts in late afternoon and continues until dusk (Goodrum 1940). Inclement or unusual weather can change these general patterns to midday or all-day feeding activity during extended periods of drizzle or light rain (Goodrum 1940; Kriz 1959, cited by Perry et al. 1977) or a complete absence of feeding activity for a day or two during extremely cold, snowy weather (Sharp 1959).

Most gray squirrels eat only 1 or 2 (seldom 4 or more) food items during a particular feeding period (Goodrum 1940, Nixon et al. 1968, Korschgen 1981). Squirrels often concentrate at good food sources, and as many as 10 to 12 individuals have been observed feeding in a single tree (Bakken 1959, Goodrum 1961). As an integral part of the overall feeding activity, gray squirrels bury (cache) many nuts and acorns during the fall when these foods are abundant. Cached foods are dug up and eaten from winter through spring, thus effectively extending the available supply.

Energy requirements. Gray squirrels require approximately 0.7 kg (approximately 1.5 lb) of food (fresh weight) per week (Uhlig 1955, Goodrum 1961). Ludwick et al. (1969) found that adult gray squirrels could maintain their energy equilibrium at a daily dietary intake level of 167 kcal of metabolizable energy per $W^{0.75}$, where W = kg liveweight; none of the squirrels on a 0 intake level survived the 5-day feeding trial. For

additional energy information on the gray squirrel, see Ludwick et al. (1969) and Montgomery et al. (1975).

Water

Although gray squirrels can subsist for a few days on water they obtain by licking rain and dew from leaves and by eating snow or succulent foods (Christisen 1964, Barkalow and Shorten 1973), they are seldom found far from an open water source (Brown and Yeager 1945). It is doubtful that metabolic water alone would be sufficient to offset the fluid drain incurred by lactating females such that all individuals in litters of 4 to 6 young could survive. Thus, areas of optimum habitat should have permanent open water sources within the daily cruising radii of all gray squirrels present (Barkalow, pers. commun., 1981).

Cover

Gray squirrels use tree cavities and leaf nests for bedding, nesting, and escape cover. Dens and leaf nests are generally occupied by only 1 squirrel. However, aggregations of up to 7 squirrels of both sexes and different age classes have been observed to use the same shelter (Bakken 1959), and individual squirrels have been observed to use more than 1 den or leaf nest on successive days (Donohoe and Beal 1972).

Dens. Cavities that can be used for litter raising and winter shelter are known as dens (Sanderson 1975), and an ample supply (6 or more dens/ha; 2.4 or more/acre) must be available to support a gray squirrel population (Nixon et al. 1978). An effective den should have the following characteristics: the cavity should be dry; it should be large enough to accommodate a squirrel on its nest, approximately 15 to 25 cm (6 to 10 in.) inside diameter and approximately 40 to 50 cm (15.6 to 20 in.) deep (Baumgartner 1939, Gysel 1961); and it should have an entrance hole small enough, approximately 8 cm (3.2 in.) in diameter, to exclude raccoons (Nixon et al. 1980b). Cavities that do not meet the above requirements as den sites are only used as temporary escape cover.

Dens provide better shelter than leaf nests. In North Carolina, litters raised in wooden nest boxes had higher survival rates than did litters raised in leaf nests, and adults having access to both wooden nest boxes and dens had a longer average life than those having access to dens only (Barkalow and

Soots 1965a). In Maryland, Burger (1969) noted an increase in winter survival for young and adult squirrels on areas provided with rubber tire shelters.

Leaf nests. Leaf nests are constructed of leaves and leafy twigs and average approximately 30 to 35 cm (12 to 14 in.) in diameter with an interior of shredded leaves and strips of bark. The entrance is generally located next to the tree hole and is concealed by leaves. These nests are usually located in the crotch or fork of a limb next to the tree hole at an average height of 10.7 m (35 ft) above the ground. Grapes and other high climbing vines are also used as anchors (Colin 1957). On the average, the odds of finding a gray squirrel nest in a tree with a canopy-reaching vine are roughly 20 times higher than for another tree of the same species without a vine (Sanderson et al. 1980).

The dispersal of juveniles and the buildup of fleas in dens may prompt squirrels to build and utilize leaf nests. In West Virginia, Uhlig (1956) noted 2 peaks of leaf nest construction which occurred approximately 18 weeks after the peaks of the spring and summer parturition periods, respectively; he postulated that the post-nestling juveniles were responsible for most of the leaf nests built during these periods. Also, nursing females often move their litters from dens to leaf nests, possibly to escape the high flea populations normally found in dens in late spring and summer (Bakken 1959).

MANAGEMENT

The best gray squirrel habitats are old-growth, mixed oak-hickory forest stands (Nixon 1968, Mosby 1969), and the most effective management for squirrels is to promote the development and retention of these mature stands (Christisen 1964, Korschgen 1981). In instances where timber cutting is deemed unnecessary or inappropriate, the natural development of a mixed hardwood stand will normally result in good to excellent gray squirrel habitat. Other circumstances may warrant a more active approach to management; these include (1) modifying a commercial timber management program to benefit squirrels, or (2) implementing forest management practices to specifically achieve squirrel management objectives.

Management Objectives

The decision to manage a particular population for consumptive or nonconsumptive uses depends on the local or regional status of the animal, the

compatibility of the objective with the primary land use of a particular area, and appropriate state regulations. A reasonable goal for managing a population for hunting in an extensive area is 1.2 to 2.5 squirrels/ha (0.5 to 1.0/acre) (Nixon 1968, Sanderson 1975). A higher population level of 5 to 12 squirrels/ha (2 to 5/acre) may be obtainable where squirrels are managed for nonconsumptive recreation on smaller sites, such as along nature trails and in wildlife viewing areas.

The Management Unit

Large, extensive hardwood tracts are most desirable for gray squirrel management, but smaller stands can be managed as well. Woodlots as small as 2 to 4 ha (5 to 10 acres) with excellent habitat can support 2.5 to 12 squirrels/ha (1 to 5/acre) (Flyger 1959, Mosby 1969). Narrow hardwood stringers sandwiched between other habitat types can also be productive. Burger (1969) reported a population of approximately 2.5 squirrels/ha (1/acre) in a 30.6-ha (75.5-acre) lowland hardwood stand which varied in width from 15 to 122 m (50 to 400 ft) and extended for roughly 4.8 km (3 miles) around the perimeter of a peninsula of cleared cropland. Thus, as long as a stand is 15 to 30 m (50 to 100 ft) wide and 2 to 4 ha (5 to 10 acres) in extent, it can be utilized as a gray squirrel management area.

Management Practices

For an effective gray squirrel management program, the following major factors must be considered: (1) a large, dependable hard mast supply is essential; (2) a varied supply of auxiliary foods must be available to supplement the hard mast supply and to provide seasonal foods; (3) an ample supply of den cavities for bedding, nesting, and escape cover is critical; and (4) a permanent supply of free water is important (Christisen 1964). These requirements are discussed within the management practices presented below.

Hard mast. The hard mast production capability of a stand is the key that determines a stand's ability to support gray squirrels. Shaw (1971) assumed that a hard mast production rate of 112 kg/ha (100 lb/acre) would be sufficient to support 0.75 to 1.2 squirrels/ha (0.3 to 0.5/acre) when the needs of other game and nongame species were considered. Nixon et al. (1975) estimated that a higher rate of 145.7 kg of hard mast/ha (130 lb/acre) was the minimum production required to support densities of 2.5 squirrels/ha (1/acre) and, if possible, hard mast production should exceed 168 kg/ha (150 lb/acre).

Traps should be run early each morning (around 8 am) and late each afternoon (after 4 pm) (Sharp 1958c). All gray squirrels captured should be marked by dyeing their body fur and/or clipping their tail hair to allow identification from a distance (Flyger 1959). Flyger (1960) recommended using scissors to trim the hair on the distal portion of the tail for males and on the proximal portion of the tail for females; he also recommended dyeing the body fur in different patterns with the fur dye Nyanzol A.

Immediately following the completion of a trapping period, traps should be closed or removed, and observation counts should be conducted for 2 to 3 hours each day for approximately 2 weeks. Squirrels should be counted by still observers positioned sequentially at a series of randomly selected points within the trapping grid. At each point, the observer should tally the marked and unmarked squirrels seen during a 15- to 30-min period. Early morning and late afternoon counts will probably yield the most squirrels sighted, but midday counts should be tried as well, especially in the winter. The optimum time to conduct sampling is from February to April, as trapping success is generally high during this period (Sharp 1958c) and the effective population recruitment will be low, as most individuals of the spring litter will not have left the nest yet (Nixon and McClain 1975).

Flyger (1959) recommended using the Schnabel method for calculating population estimates from the trap-sight techniques. Input to the formula, modified for sight observations (Flyger 1959), is as follows:

$$P = \frac{\sum(AB)}{\sum C},$$

where

P = the estimated population

A = the total number of marked and unmarked squirrels observed in 1 day

B = the number of animals marked previously that are available to sight on the day of observation

C = the number of marked animals observed in 1 day

Trap-recapture techniques. Several methods for estimating the size of squirrel populations are based on a general trap-mark-recapture procedure. These include: (1) the Lincoln Index method utilizing hunting as the recapture procedure (Moran 1953, Nixon et al. 1967); (2) the Schnabel multiple census method (Flyger 1959, Barkalow and Soots 1965a, Nixon et al. 1967, Bouffard and Hein 1978); (3) the frequency of capture method using the maximum likelihood

estimation for the geometric distribution (Nixon et al. 1967); and (4) the time-specific minimal population estimate (Mosby 1969). For details on the use of these methods, the reader should consult the references cited above.

Time-area count. The time-area count has been widely used (Chapman 1938, Baker 1944, Uhlig 1955, Colin 1957); but when it has been tested against other techniques, it has generally underestimated the population. Flyger (1959) found that time-area counts accounted for only 7% to 17% of the gray squirrels determined to be present by trap-recapture and trap-sight techniques. Bouffard and Hein (1978) also found that the time-area count technique tended to seriously underestimate the population as determined by other methods. The chief disadvantages of the technique are the following: (1) not all members of a population are active at the same time; (2) not all active individuals are visible to the observer; and (3) counts made in different cover types, by different observers, or during different seasons may not be comparable (Flyger 1959).

Leaf nest counts. Leaf nest construction apparently is a behavioral trait exhibited primarily by dispersing juveniles 18 to 19 weeks old (Uhlig 1956), and the number of leaf nests found in an area in the late fall and early winter can be used as an index to population size. This index is approximate because: (1) it is often difficult to tell if a nest is being used (Colin 1957); (2) an individual squirrel may use more than 1 nest on successive days (Donohoe and Beal 1972); and (3) population estimates based on leaf nest counts may not be accurate if the number of adults is not known or cannot be estimated (Uhlig 1956). For index purposes, an average of 1.09 (Uhlig 1956) to 2 (Goodrum 1940) gray squirrels per leaf nest is generally used. However, if the percent of the population that is composed of adults is known or can be estimated, and if the number of leaf nests per 40.4 ha (100 acres) is known, one can make a rough estimate of the gray squirrel population size with the following formula:

$$N = \frac{(L/1.5)}{(1.0-A)}$$

where

N = the estimated population size

L = the number of leaf nests per 40.4 ha (100 acres)

A = the percent of the population that is composed of adults

or poor at producing acorns, and an otherwise acceptable tree may be a poor acorn producer (Sharp 1958b). Thus, stands to be thinned should be marked in the fall to ensure that the best mast producers are retained (Shaw 1971). For each productive tree, the number of feet in the crown diameter should be roughly twice the number of inches in the diameter of the trunk (Christisen 1964).

Small selection cuts (without cull tree removal) that create openings of 0.1 to 0.4 ha (0.25 to 1.0 acre) are less disruptive to squirrel populations than are clearcuts. During these selection cuts, a stocking rate of 15 to 20 oaks of 25.4+ cm (10+ in.) dbh and 15 to 20 similarly-sized hickories (6 to 8 trees/acre of each genera) should be retained to provide enough mast to maintain fall densities of 2 to 3 squirrels/ha (approximately 1/acre). Six to 8 trees/ha (approximately 2 to 3/acre) with suitable den cavities, including some large-diameter den trees (60+ cm dbh; 23.6+ in.), should be retained for shelter (Nixon et al. 1980a).

Clearcut stands should be kept small (*0*8 ha; *0*20 acres) and narrow (*0*160 m; *0*525 ft), and 40% to 60% of the management unit should be retained in stands with trees of mast-producing age (25 to 30 years old) (Shaw 1971, Nixon et al. 1980b). Management units should be regenerated in a pattern where young stands (20 to 25 years old) are not contiguous to each other (Shaw 1971). If clearcuts must be larger than 8 ha (20 acres), travel lanes 50 to 100 m (55 to 109 yd) wide of mature trees should be left uncut until the trees in the clearcuts are old enough to produce mast (Nixon et al. 1980b). Small uncut islands (0.2 to 0.4 ha; 0.5 to 1.0 acre) of mature trees left in clearcuts are generally ineffective because squirrels are reluctant to cross clearcut strips densely vegetated with ground cover (Nixon et al. 1980b). Nixon et al. (1975) suggested that 20 to 25 suppressed hickory poles (7.6 to 15.2 cm dbh; 3 to 6 in. dbh)/ha (8 to 10/acre) be left standing in clearcuts. Although some of these trees will die, some should live and reach seed-bearing size, thus improving the habitat for squirrels as the stand matures. A number of healthy understory trees that produce supplementary squirrel foods should also be retained in clearcuts; a minimum basal area of 0.4 to 0.7 sq m/ha (approximately 2 to 3 sq ft/acre) is recommended (Nixon et al. 1980b).

CENSUS AND SAMPLING

Planning recommendations and management decisions for gray squirrel populations should be based on the best population estimates and habitat data available. Accurate population estimates are used to (1) identify management needs, (2) prescribe appropriate management practices, and (3) determine the effectiveness and efficiency of management. Critical habitat factors should also be monitored to identify limiting factors and to develop habitat indices that can be correlated with population trends.

Population Estimates

Several methods have been developed to estimate gray squirrel numbers, but accurate, reliable estimates are hard to obtain. Mark-recapture methods are most commonly used, but they are not always practical and are subject to error if their model assumptions are not met. Results from observational and trap-success methods often depend on factors other than population density. Thus, the selection of a method or combination of methods depends on the characteristics of the method, study objectives, field conditions, and resources available (Bouffard and Hein 1978).

Based on a review of the literature, the trap-sight method proposed by Flyger (1959) is recommended as the best method currently available. Flyger's method is discussed at length below; a brief synopsis of other major techniques is also provided.

Trap-sight techniques. The trap-sight method proposed by Flyger (1959) appears to give relatively accurate, unbiased population estimates. This method avoids the problems created by differential trap response behavior characteristics of most gray squirrel populations studies, and it is not limited to the hunting season for obtaining recapture samples. The general procedures for this method are discussed below.

The study area should be gridded at approximately 60-m (197-ft) intervals and livetraps placed at the trapper's discretion within a 0.08-ha (0.2 acre) plot surrounding each intersection. This will give a trap density of approximately 1 trap/0.4 ha (1/acre). Traps should be locked open and prebaited with cracked English walnuts 4 to 6 times over a 2-week period. At the end of the prebaiting period, the traps should be set and run for approximately 10 days to 2 weeks (Nixon et al. 1975).

Traps should be run early each morning (around 8 am) and late each afternoon (after 4 pm) (Sharp 1958c). All gray squirrels captured should be marked by dyeing their body fur and/or clipping their tail hair to allow identification from a distance (Flyger 1959). Flyger (1960) recommended using scissors to trim the hair on the distal portion of the tail for males and on the proximal portion of the tail for females; he also recommended dyeing the body fur in different patterns with the fur dye Nyanzol A.

Immediately following the completion of a trapping period, traps should be closed or removed, and observation counts should be conducted for 2 to 3 hours each day for approximately 2 weeks. Squirrels should be counted by still observers positioned sequentially at a series of randomly selected points within the trapping grid. At each point, the observer should tally the marked and unmarked squirrels seen during a 15- to 30-min period. Early morning and late afternoon counts will probably yield the most squirrels sighted, but midday counts should be tried as well, especially in the winter. The optimum time to conduct sampling is from February to April, as trapping success is generally high during this period (Sharp 1958c) and the effective population recruitment will be low, as most individuals of the spring litter will not have left the nest yet (Nixon and McClain 1975).

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Trap-recapture techniques. Several methods for estimating the size of squirrel populations are based on a general trap-mark-recapture procedure. These include: (1) the Lincoln Index method utilizing hunting as the recapture procedure (Moran 1953, Nixon et al. 1967); (2) the Schnabel multiple census method (Flyger 1959, Barkalow and Soots 1965a, Nixon et al. 1967, Bouffard and Hein 1978); (3) the frequency of capture method using the maximum likelihood

estimation for the geometric distribution (Nixon et al. 1967); and (4) the time-specific minimal population estimate (Mosby 1969). For details on the use of these methods, the reader should consult the references cited above.

Time-area count. The time-area count has been widely used (Chapman 1938, Baker 1944, Uhlig 1955, Colin 1957); but when it has been tested against other techniques, it has generally underestimated the population. Flyger (1959) found that time-area counts accounted for only 7% to 17% of the gray squirrels determined to be present by trap-recapture and trap-sight techniques. Bouffard and Hein (1978) also found that the time-area count technique tended to seriously underestimate the population as determined by other methods. The chief disadvantages of the technique are the following: (1) not all members of a population are active at the same time; (2) not all active individuals are visible to the observer; and (3) counts made in different cover types, by different observers, or during different seasons may not be comparable (Flyger 1959).

Leaf nest counts. Leaf nest construction apparently is a behavioral trait exhibited primarily by dispersing juveniles 18 to 19 weeks old (Uhlig 1956), and the number of leaf nests found in an area in the late fall and early winter can be used as an index to population size. This index is approximate because: (1) it is often difficult to tell if a nest is being used (Colin 1957); (2) an individual squirrel may use more than 1 nest on successive days (Donohoe and Beal 1972); and (3) population estimates based on leaf nest counts may not be accurate if the number of adults is not known or cannot be estimated (Uhlig 1956). For index purposes, an average of 1.09 (Uhlig 1956) to 2 (Goodrum 1940) gray squirrels per leaf nest is generally used. However, if the percent of the population that is composed of adults is known or can be estimated, and if the number of leaf nests per 40.4 ha (100 acres) is known, one can make a rough estimate of the gray squirrel population size with the following formula:

$$N = \frac{(L/1.5)}{(1.0-A)}$$

where

N = the estimated population size

L = the number of leaf nests per 40.4 ha (100 acres)

A = the percent of the population that is composed of adults

Habitat Variables

Gray squirrels are forest-dwelling species, and active gray squirrel management implies some form of forest management. The following basic forestry data and specific gray squirrel habitat information should be available to the wildlife manager: (1) management unit size; (2) hard mast production potential (i.e., area, species composition, stocking level or canopy coverage, and age class or diameter distribution data) for each forest stand; (3) number of nesting and escape dens per unit area; and (4) location and distribution of permanent water sources. Most of this information can be gathered using standard timber cruising techniques. Den and leaf nest counts can be incorporated into timber cruises, and water availability can be determined from maps or aerial photographs supplemented by ground samples.

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APPENDIX A: COMMON AND SCIENTIFIC NAMES
OF PLANTS MENTIONED IN TEXT*

Common Name	Scientific Name
American hornbeam (ironwood)	*Carpinus caroliniana*
American plum	*Prunus americana*
Apple	*Malus pumila*
Ash	*Fraxinus* spp.
Baldcypress	*Taxodium distichum*
Basswood	*Tilia* spp.
Beech	*Fagus grandifolia*
Bitter pecan	*Carya aquatica*
Blackberry	*Rubus* spp.
Black cherry	*Prunus serotina*
Blackgum	*Nyssa sylvatica*
Black walnut	*Juglans nigra*
Blueberry	*Vaccinium* spp.
Buckeye	*Aesculus* spp.
Butternut	*Juglans cinerea*
Carolina silverbell	*Halesia* spp.
Carolina snailseed	*Cocculus carolinus*
Chinquapin	*Castanea pumila*
Corn	*Zea mays*
Elm	*Ulmus* spp.
Flowering dogwood	*Cornus florida*
Grape	*Vitis* spp.
Greenbrier	*Smilax* spp.
Hackberry	*Celtis* spp.
Hazelnut	*Corylus americana*
Hickory	*Carya* spp.
Bitternut hickory	*C. cordiformis*
Shagbark hickory	*C. ovata*
Shellbark hickory	*C. laciniosa*
Hophornbeam	*Ostrya virginiana*
Japanese honeysuckle	*Lonicera japonica*

(Continued)

* Scientific names follow Radford et al. (1968).

APPENDIX A (Concluded)

Common Name	Scientific Name
Magnolia	*Magnolia grandiflora*
Maple	*Acer* spp.
Silver maple	*A. saccharinum*
Oak	*Quercus* spp.
Black oak	*Q. velutina*
Blackjack oak	*Q. marilandica*
Chestnut oak	*Q. prinus*
Laurel oak	*Q. laurifolia*
Northern red oak	*Q. rubra*
Overcup oak	*Q. lyrata*
Pin oak	*Q. palustris*
Post oak	*Q. stellata*
Shumard oak	*Q. shumardii*
Southern red oak	*Q. falcata*
Water oak	*Q. nigra*
White oak	*Q. alba*
Willow oak	*Q. phellos*
Osage orange	*Maclura pomifera*
Palmetto	*Sabal* spp.
Pawpaw	*Asimina triloba*
Pecan	*Carya illinoensis*
Persimmon	*Diospyros virginiana*
Pine	*Pinus* spp.
Loblolly pine	*P. taeda*
Red mulberry	*Morus rubra*
Sassafras	*Sassafras albidum*
Sorghum	*Sorghum vulgare*
Supplejack	*Berchemia scandens*
Sweetgum	*Liquidambar styraciflua*
Sycamore	*Platanus occidentalis*
Tupelo gum	*Nyssa aquatica*
Witchhazel	*Hamamelis virginiana*
Yellow poplar	*Liriodendron tulipifera*