ECOLOGY OF FOX AND GRAY SQUIRRELS (*SCIURUS NIGER* AND *SCIURUS CAROLINENSIS*) IN OKLAHOMA

By

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PREFACE

This study of the ecology of fox and gray squirrels in east-central Oklahoma was financed by the U. S. Fish and Wildlife Service through the Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, Stillwater, and the Oklahoma Department of Wildlife Conservation. It was administered under the direction of Dr. John A. Morrison, Leader, Oklahoma Cooperative Wildlife Research Unit.

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Last, but certainly not least, are my fellow students and friends who participated in the "great annual squirrel hunts": Joe Allen, Mike Slimak, Wally Gorham, Steve Tobler, Roye Frye, Phil Garret, Tom Logan, Tom Eubanks, Jim Carpenter, Jim Lewis, and Jerry Sturdy. Charley Segelquist and Don Savage served as sounding boards for many of my "ideas" over numerous cups of coffee, and their logic and incisive wit helped clarify my thinking many times during the study. Drs. Robert Brown and David Grubbs served similar functions here at California State University, Fresno.

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CHAPTER I

INTRODUCTION

The hunting of fox and gray squirrels (*Sciurus niger* and *S. carolinensis*) ranks second in popularity only to quail hunting among Oklahoma's hunters (Ellis 1972). The loss of woodlands, particularly riverbottom areas, and increasing demands for more recreational hunting underscores the need for intensive management of these animals. However, not having sufficient information on the present status, distribution, and biological requirements of these squirrels in Oklahoma hampers effective management of them.

This study was begun to provide information on the ecological requirements, current status, and needs of squirrel populations in Oklahoma. Data on tree squirrels were collected from August 1968 through May 1972 along the drainage of the Deep Fork of the North Canadian River, known locally as the Deep Fork or Deep Fork River, between the towns of Okmulgee and Chandler (Fig. 1). Specifically I attempted:

(1) to construct an historical picture of previous squirrel abundance in Oklahoma and the ecological conditions that supported these populations;

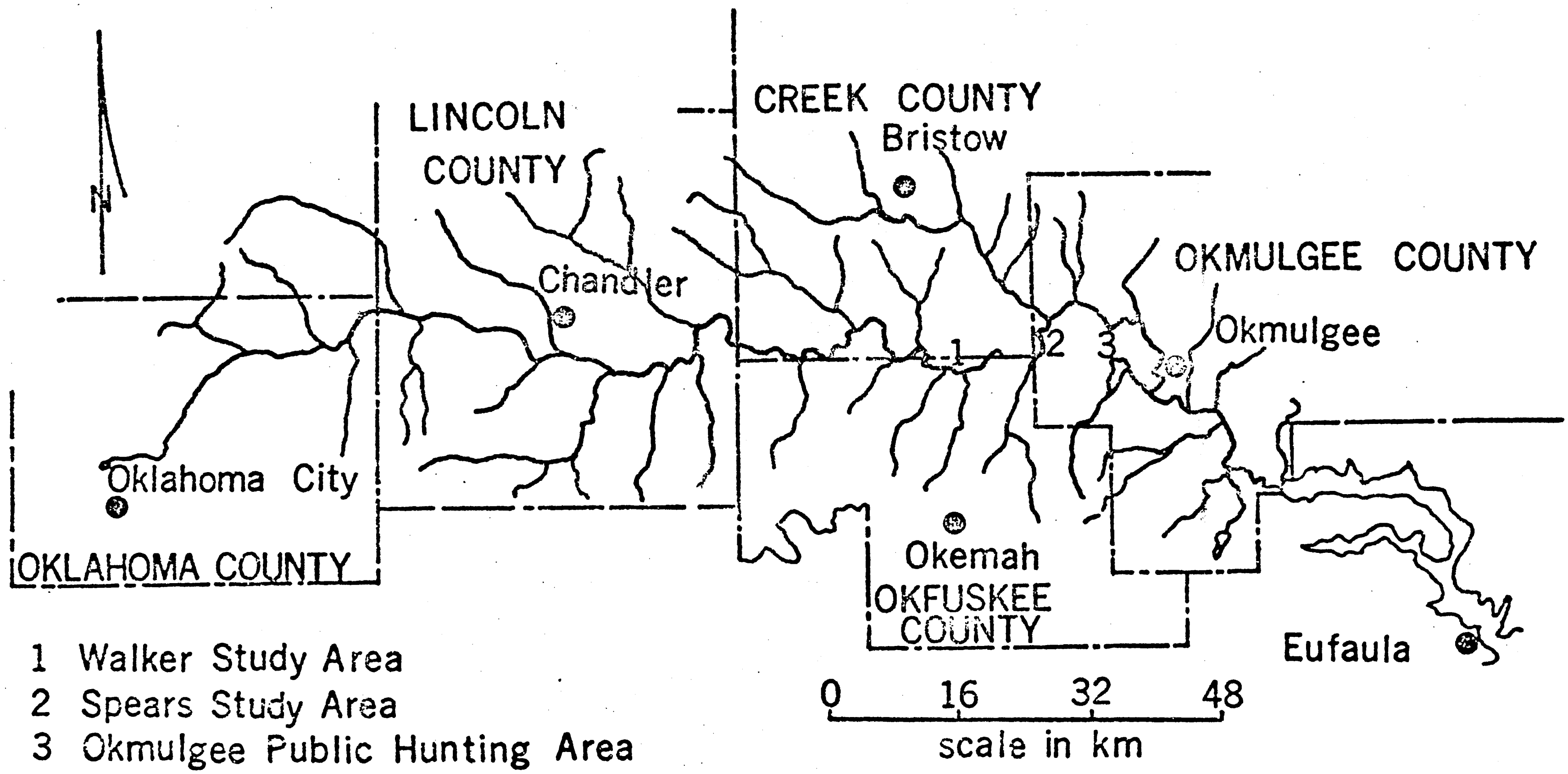

Figure 1. The Deep Fork of the North Canadian River Drainage System Showing the Location of Squirrel Study Areas, 1968-1972.

(2) to determine the present distribution and relative population densities of fox and gray squirrels in pecan groves, bottomland, and upland forests along the Deep Fork;

(3) to describe qualitatively and quantitatively the environmental conditions that affect squirrel densities in these areas;

(4) to discuss the population dynamics of these species with particular emphasis on reproductive biology, survival of offspring, and related mortality factors; and

(5) to examine the biological needs and preferences of fox and gray squirrels along the Deep Fork and relate these requirements to specific land management practices.

Few studies have been done specifically on squirrel ecology in Oklahoma. Duck and Fletcher (1944) determined the current status of these animals and attempted to estimate population densities in different habitat types. A study on the ecology and economics of the fox squirrel near Stillwater, Payne County, was conducted from 1950 to 1952 by Parker (1954). No other major studies dealing with the ecology of tree squirrels in Oklahoma have been published. Additional information on squirrel distribution and ecology is available in works by Jackson and Warfel (1933), Blair (1938,1939), and Blair and Hubbell (1938). Considerable work on tree squirrels has been done elsewhere and these reports provide information for comparison to data collected during this study.

Financial support for this project was provided by the U. S. Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation. It was administered under the direction of Dr. John A. Morrison, Leader, Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, Stillwater.

CHAPTER II

GEOGRAPHIC DISTRIBUTION AND HABITATS OF FOX AND GRAY SQUIRRELS IN OKLAHOMA

Introduction

Little published information exists on either the historical or current distribution of fox and gray squirrels in Oklahoma. Because of changes in land use and the resulting ecological effects that accompany these changes, a re-evaluation of squirrel distribution in Oklahoma was necessary. The existing range maps show that both the fox and the gray squirrel reach their westernmost limit in Oklahoma (Hall and Kelson 1959, MacClintock 1970). Information on squirrel distribution in Oklahoma was collected from August 1968 through August 1973.

Methods

The historical occurrence of squirrels in Oklahoma was determined by reviewing existing reports and diaries of early explorers and army expeditions. These provided insight into ecological conditions and habits of the prominent wildlife species of the period. Interviews with long-term residents and members of state and federal agencies, especially personnel of the Oklahoma Department of Wildlife Conservation, added information on past and present squirrel distribution. Inquiries were sent to 106 museums in the United States, selected from a list of collections containing mammals from North America compiled by Anderson, et al. (1963), requesting information on any squirrels they had from Oklahoma in their collections. All 33 colleges and universities in Oklahoma were also contacted regarding squirrel materials from Oklahoma held in their respective collections. I collected voucher specimens of squirrels from several counties, principally: Creek, Okfuskee, and Okmulgee Counties.

Results

The geographic ranges of fox and gray squirrels are shown on distribution maps (Figs. 2 and 3). Each distribution map shows the outlines of the counties and contains heavy black lines marking the approximate boundaries of the faunal regions as established by Duck and Fletcher (1943). Points of collection of specimens in museum collections are shown by solid circles. If no precise collection location for the specimen was given, its location was placed in the center of the county. A summary of this material and of additional records of occurrence, such as published records, sightings, or personal correspondence dealing with squirrel distribution in Oklahoma, is presented in Tables I and II.

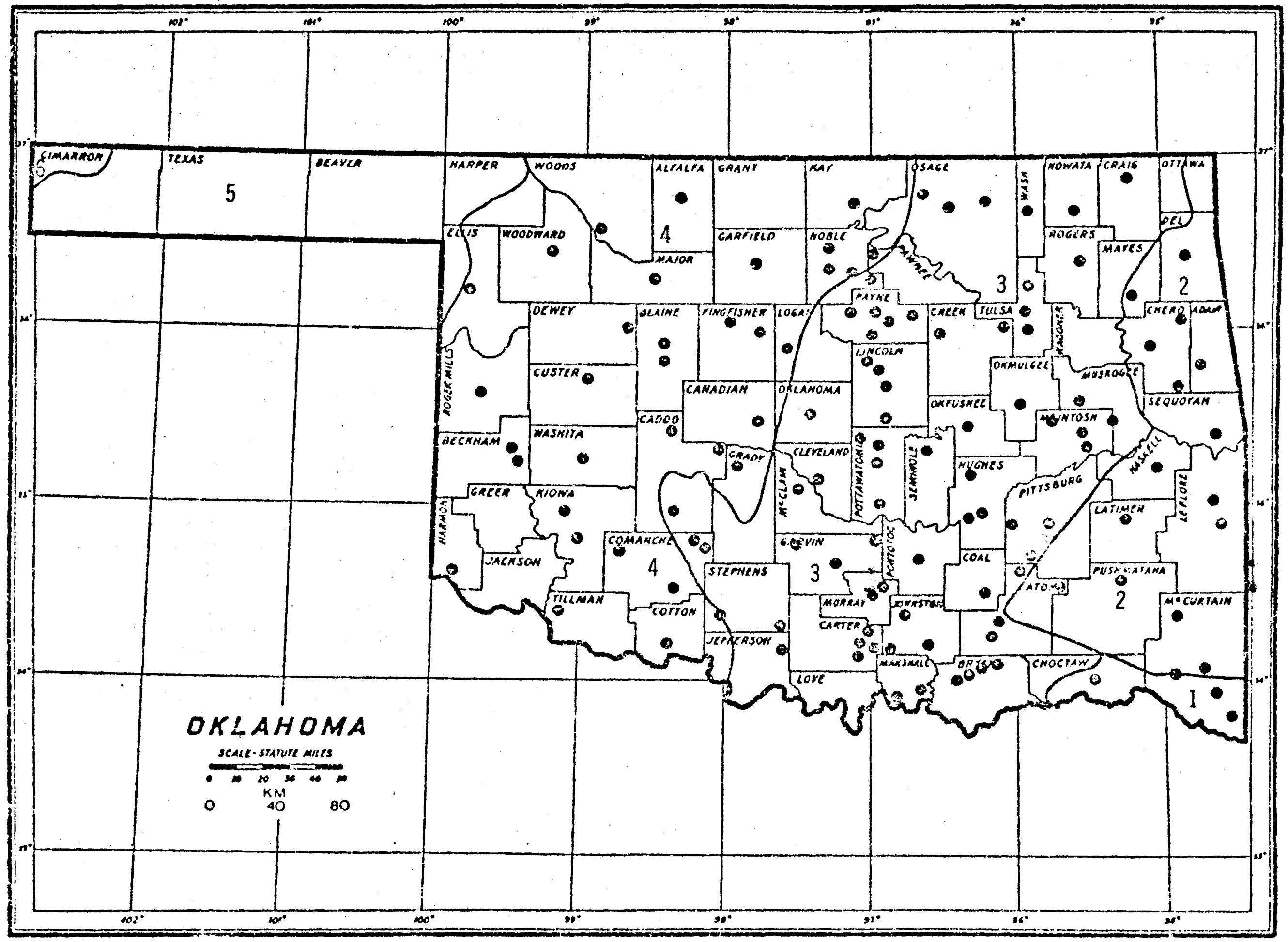

Figure 2. Distribution of Fox Squirrels (Sciurus Niger) in Oklahoma. Faunal Regions: (1) Coastal Plain; (2) Interior Highlands; (3) Oak Woodlands; (4) Grassland; (5) High Plains; (6) Mesa De Maya.

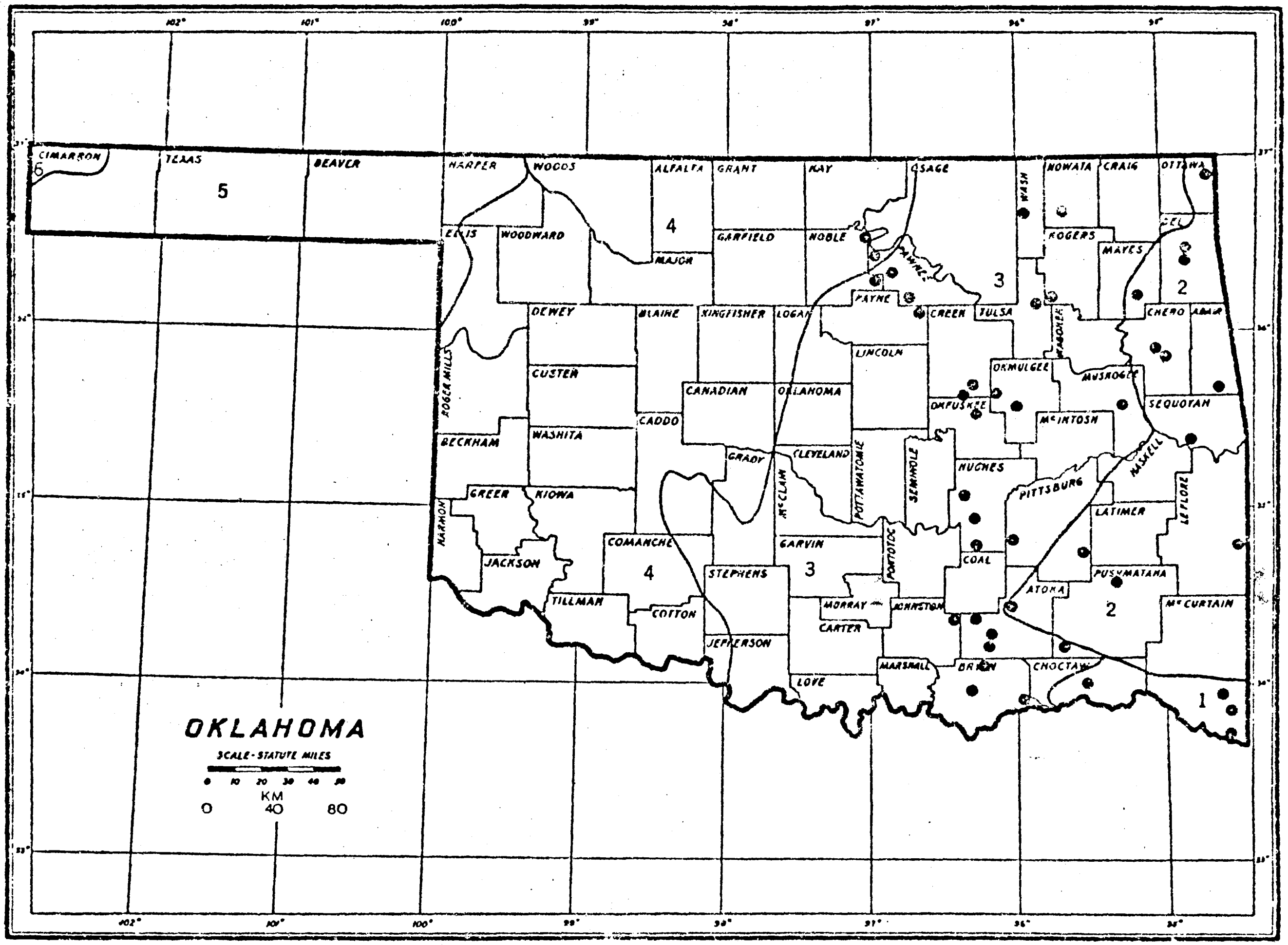

Figure 3. Distribution of Gray Squirrels (Sciurus carolinensis) in Oklahoma. Faunal Regions: (1) Coastal Plain; (2) Interior Highlands; (3) Oak Woodlands; (4) Grassland; (5) High Plains; (6) Mesa De Maya.

Records of occurrence for squirrels have been assembled from each of the collections queried and are indicated in Tables I and II by the following abbreviations:

CM	Carnegie Museum, Pittsburgh, Pennsylvania.
ECSC	East Central State College, Ada, Oklahoma.
FMNH	Field Museum of Natural History, Chicago, Illinois.
KSCP	Kansas State College, Pittsburg, Kansas.
KU	Museum of Natural History, University of Kansas, Lawrence.
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.
MU	Midwestern University, Wichita Falls, Texas.
OBU	Oklahoma Baptist University, Shawnee.
OSU	The Museum, Oklahoma State University, Stillwater.
OUMZ	University of Oklahoma Museum, Division of Zoology, Norman.
UF	University of Florida, Gainesville.
UI	Museum of Natural History, University of Illinois, Urbana.
UM	James Ford Bell Museum of Natural History, University of Minnesota, Minneapolis.
UMMZ	Museum of Zoology, The University of Michigan, Ann Arbor.
UTMM	Texas Memorial Museum, University of Texas, Austin.
SESC	Southeastern State College, Durant, Oklahoma.
SWSC	Southwestern State College, Weatherford, Oklahoma.
WMWR	Wichita Mountains National Wildlife Refuge, Cache, Oklahoma.

TABLE I

DISTRIBUTION RECORDS OF FOX SQUIRRELS IN OKLAHOMA

Location		Source
Adair County		
(1)	11.2 km west of Stillwell, 26 Dec. 1934	KU-10972
(2)	7.2 km west of Stillwell (Sec. 1, T5N, R24E), 25 April 1965	OUMZ-1178
(3)	2.4 km west of Chewey, 28 March 1967	OUMZ-2417, OUMZ-2418
Alfalfa County		
(1)	fox squirrels have been collected north of the Cherokee Plain near the Salt Fork River in the spring of 1931	Jackson and Warfel (1933:69)
Atoka County		
(1)	0.8 km east of Daisy, 4 Dec. 1960	SESC-2
(2)	8 km south of Wardville, 28 Dec. 1965	ECSC-M-135
(3)	3.2 km north of Caney at Old Boggy Bridge, 9 Nov. 1969	SESC-11, SESC-12
(4)	4.8 km east of Tushka, 18 Dec. 1971	SESC-50
Beckham County		
(1)	14.5 km south of Elk City, 30 Dec. 1960	OSU-7004
(2)	6.4 km west of Sayre, 27 Nov. 1965	OSU-7013
(3)	near Sayre, 30 Dec. 1965	SWSC-M-26

TABLE I (Continued)

Location	Source
(4) very few scattered fox squirrels present in this area, 1971	Exendine (personal communication)
Blaine County	
(1) no specific location given, 4 July 1901	OUMZ-5937
(2) no specific location given, 12 Sept. 1932	SWSC-M-29
(3) Roman Nose State Park, 11 Jan. 1948	OSU-496
(4) Roman Nose State Park, 5 Jan. 1952	OSU-1739, OSU-1741
(5) never very abundant, best habitat for fox squirrel occurs in the southern portion of the county west of Geary and north of the South Canadian River and along the North Canadian River, 1971	Derdeyn (personal communication)
Bryan County	
(1) 9.7 km west of Colbert, no date of collection given	UTMM-1655
(2) 3.2 km south of Caddo, 29 Dec. 1960	SESC-3
(3) 1.6 km east of Durant, 30 Dec. 1960	SESC-4
(4) 0.4 km north of Willow Springs, 10 Oct. 1963	SESC-8
(5) Shearer Hall, Southeastern State College, Durant, 23 Oct. 1969	SESC-9
(6) T5S, R9W, Sec. 2, 28 Oct. 1969	SESC-10

TABLE I (Continued)

	Location	Source
(7)	0.4 km north of Durant on Chuckwa Creek, 20 Nov. 1969	SESC-13
(8)	above low water dam, near Armstrong, 28 Nov. 1969	SESC-15
(9)	Durant, 1 Jan. 1970	SESC-23
(10)	3.2 km north of Armstrong, 30 m from Blue River Dam, 2 Jan. 1970	SESC-24
(11)	6.4 km south of Curant, 10 Oct. 1970	SESC-26
(12)	8.0 km north, 9.7 km east of Caddo, 31 Oct. 1971	SESC-54
(13)	8.0 km west and 3.2 km south of Durant, 27 Nov. 1971	SESC-34
(14)	8.0 km north, 9.7 km east of Caddo, 27 Nov. 1971	SESC-37
(15)	3.2 km east of Durant, 30 Nov. 1971	SESC-55
(16)	1.6 km north, 3.2 km east of Durant, 6 Dec. 1971	SESC-42
(17)	1.6 km north, 4.8 km west of Durant, 8 Dec. 1971	SESC-43, SESC-44
(18)	4.8 km south, 2.4 km east of Durant, 11 Dec. 1971	SESC-45
(19)	0.4 km north of Southeastern State College, Durant on Chuckwa Creek, 12 Dec. 1971	SESC-48, SESC-49
(20)	good fox squirrel population in oak forest along Red River and its tributaries from Durant eastward, 1971	McCain (personal communication)

TABLE I (Continued)

Location		Source
Caddo County		
(1)	Kiowa Agency, 27.4 km southeast of Ford Cobb, collected by Dr. E. Palmer, deposited in Smithsonian Institution, Jan. 1874; earliest squirrel specimen from Oklahoma	MCZ-?
(2)	Red Rock Canyon, 1965	OUMZ-1262, OUMZ-1263
(3)	6.4 km west of Cogar, 7 August 1968	OUMZ-4284
(4)	Ft. Cobb Public Hunting Area has a population of fox squirrel in oak habitat, 1971	Chesemore (personal observation)
(5)	occasional occurrence in post oak-blackjack oak areas or along river and creek bottoms, 1971	Iams (personal communication)
Canadian County		
(1)	near Yukon, Fall 1919	KU-4245
(2)	near Yukon, 2 Nov. 1919	KU-4188
(3)	occasional occurrence in post oak-blackjack oak areas or along river and creek bottoms, 1971	Iams (personal communication)
Carter County		
(1)	4 km west of Gene Autry, 21, 24, and 29 Dec. 1969	SESC-19, SESC-20, SESC-21, SESC-22
(2)	2.4 km east, 7.2 km north of Lone Grove, 19 Nov. 1971	SESC-31, SESC-32
(3)	2.4 km east, 7.2 km north of Lone Grove, 27 Nov. 1971	SESC-35

TABLE I (Continued)

Location	Source
(4) 9.7 km west, 6.4 km north of Ardmore, 27 Nov. 1971	SESC-36
(5) 0.8 km west, 7.2 km north of Lone Grove, 4 Dec. 1971	SESC-38, SESC-39
(6) 12.9 km north of Dickson, 12 Dec. 1971	SESC-47
(7) 6.4 km east and 12.9 km north of Ardmore, 27 Dec. 1971	SESC-51
Cherokee County	
(1) near Scraper, 14 July 1936	UMMZ-75986
(2) 1.6 km north and 6.4 km east of Wellington, 16 Nov. 1963	OSU-7008
(3) 8.0 km northeast of Hulbert, 26 Nov. 1964	OSU-7016
(4) 9.7 km south of Cookson, 26 Nov. 1969	OSU-8357
(5) 4.8 km southwest of Cookson, 16 Oct. 1972	OSU-9315
Choctaw County	
(1) 4.8 km east and 2.4 km south of Hugo, 29 Dec. 1959	OSU-4182
(2) near Sandy Branch, 3 Jan. 1964	OSU-8051, OSU-8052
(3) 1.6 km south of Hugo, north Goodland Road, 26 Nov. 1969	SESC-14
(4) 5.6 km north of Hugo, 14 Nov. 1971	SESC-29, SESC-30

TABLE I (Continued)

Location	Source
Cleveland County	
(1) collected at Noble, 1899	FMNH-6973; Elliot (1899:291)
(2) 2.4 km southwest of Norman, 4 Feb. 1934	OUMZ-5940
(3) 3.2 km south of Norman, 15 Apr. 1934	OUMZ-5938, OUMZ-5939
(4) in Norman, 20 Feb. 1959, 13 Oct. 1961, 10 Mar. 1965, 5 June 1969, 17 May. 1968, 10 June 1969	OUMZ-324, OUMZ-268, OUMZ-1140, OUMZ-6966, OUMZ-3612, OUMZ-6967
(5) in Sec. 35, T 8N, R1E, 6 Oct. 1961	OUMZ-203
(6) in Norman, Sept. 1967	OBU-78
(7) 6.4 km east and 3.2 km north of Norman, 15 April 1968	OUMZ-3611
(8) 8.0 km east of Noble, 28 Dec. 1968	OUMZ-7019, OUMZ-7020, OUMZ-7021, OUMZ-7022, OUMZ-7023, OUMZ-7024
(9) fox squirrel population declining in this general area; good numbers still found on Lexington Game Management Area, 1971	Ingersoll (personal communication)
Coal County	
(1) in Wichita National Forest, 18 July 1931	OUMZ-5941
(2) Panther Creek, Wichita Mountains Wildlife Refuge, 3 Feb. 1938	WMWR-40
(3) Quanah, Wichita Mountains Wildlife Refuge, 30 Nov. 1940	WMWR-68

TABLE I (Continued)

Location	Source
(4) Pecan Springs, Wichita Mountains Wildlife Refuge, 30 Nov. 1940	WMWR-75
(5) Headquarters, Wichita Mountains Wildlife Refuge, 2 May 1943	WMWR-126
(6) Wichita Mountains Wildlife Refuge, 23 April 1967	MU-5787
(7) 6.4 km north of Sterling, 22 Oct. 1960, 25 Dec. 1962, 23 Dec. 1964	OSU-5604, OSU-7017, OSU-8028
(8) 3.2 km north and 0.4 km east of Fletcher, 27 Dec. 1966	OSU-6560
(9) 9.7 km south of Lawton, 23 Dec. 1969	OSU-8879
(10) occasional occurrence in post oak-blackjack oak areas or along river and creek bottoms, 1971	Iams (personal communication)
Cotton County	
(1) 16.1 km north of the Red River, 5 April 1963	OSU-5113
(2) Hooper Farm, 31 Dec. 1964	OSU-7022
Craig County	
(1) 1.6 km south and 9.7 km west of Oklahoma-Kansas border, north of Welch, 24 Sept. 1971	OSU-9174
Creek County	
(1) Sapulpa, 31 Dec. 1930	KU-3306
(2) 12.1 km northeast of Sapulpa, 9 Oct. 1966	OSU-6478

TABLE I (Continued)

Location	Source
(3) 6.4 km north of Drumwright, 6 Dec. 1968	OSU-8293
Custer County	
(1) 30.6 km west of Thomas, 31 Oct. 1965	OSU-6122
(2) Deer Creek Woods, 28 Nov. 1968	SWSC-M-30
Delaware County	
(1) 4.0 km west of Eucha, 26 March 1967	OUMZ-2416
Dewey County	
(1) 8.0 km west of Canton, 9-11 Sept. 1933	KU-9457, KU-9458
(2) 8.0 km north and 8.0 km west of Canton, 23 July 1934	KU-10059, KU-10060
(3) 16.1 km northwest of Canton, 24 July 1934	KU-10058
(4) 8.0 km west of Canton, 27 Dec. 1937	KU-12478
(5) 1.6 km west of Thomas Gas Plant, 3 Oct. 1965	OSU-8638
(6) Canton Public Hunting Area contains huntable numbers of fox squirrels	Anon. (1969:7)
Ellis County	
(1) Wilson Ranch, 17 August 1942 by H. G. Hanson	UM-1927
(2) very few fox squirrels in the county, 1971	McCaslan (personal communication)

TABLE I (Continued)

Location	Source
(3) huntable fox squirrel population on the Ellis County Public Hunting Area, 1971	Miller (personal communication)
Garfield County	
(1) Boggy Creek east of Phillips University, Fall 1920	KU-4190
(2) the southeast portion of Garfield County has fair fox squirrel numbers, 1971	Derdeyn (personal communication)
Garvin County	
(1) 4.8 km northeast of Stratford, 21 Dec. 1965	ECSC-M-103
(2) 3.2 km south of Pauls Valley, 2 Jan. 1966	ECSC-M-121
(3) 3.2 km west of Maysville, 15 Oct. 1967	ECSC-M-268
Grady County	
(1) Barley Cemetery, Barley, 22 Dec. 1961	OUMZ-461
(2) 4.8 km west and 4.8 km north of Minco, 10 Sept. 1967	OSU-6576
(3) 12.9 km west and 4.8 km north of Minco, 27 Dec. 1967	OSU-6902
(4) occasional occurrence in post oak-blackjack oak areas or along river and creek bottoms, 1971	Iams (personal communication)
Harmon County	
(1) 16.1 km south and 0.8 km east of Gould, 26 Dec. 1967	OSU-6899

TABLE I (Continued)

Location	Source
(2) in Harmon County this species is found along stream valleys, shelter-belts and in isolated wooded areas. All records are in the mosquito plains and sage areas. 1 specimen (OAM) 16.1 km S, 0.8 km E of Gould. Sight records: 16.1 km N, 0.8 km W of Hollis; 7.2 km N of Hollis, no specific dates given for the sightings	Martin and Preston (1970)
<u>Harper County</u>	
(1) 3.2 km west of May, Nov. 1949	OSU-1531
(2) 4.8 km west of May, 27 Nov. 1949	OSU-1533
<u>Haskell County</u>	
(1) 8.8 km north and 0.8 km west of Stigler, 24 Nov. 1966	OSU-7002
<u>Hughes County</u>	
(1) 4.8 km south of Atwood, 26 Nov. 1961	SESC-5
(2) 5.6 km south of Wetumka, 22 Oct. 1965	ECSC-M-115
(3) 11.3 km southwest of Wetumka, 14 Nov. 1965	ECSC-M-446
(4) 6.4 km east of Calvin, 20 Dec. 1970	ECSC-M-446
(5) Sec. 18, T8S, R13, 8 Nov. 1971	SESC-28
<u>Jefferson County</u>	
(1) 3.2 km east, 1.6 km north of Ringling, 26 Nov. 1961	SESC-6

TABLE I (Continued)

Location	Source
(2) 4.8 km northeast of Ringling, 23 Dec. 1961	SESC-7
(3) occasional occurrence in post oak-blackjack oak areas or along river and creek bottoms, 1971	Iams (personal communication)
<u>Johnston County</u>	
(1) 4.0 km northeast of Mannsville, no date given on specimen tag	OSU-7012
(2) 4.4 km northwest of Mannsville, 29 Dec. 1947	OSU-494
(3) 6.4 km north of Mill Creek and 1.6 km east of Highway 7, 1 Jan. 1967	ECSC-M-235, ECSC-M-236
(4) 6.4 km east of Tishomingo, 8 Jan. 1967	OSU-6477
(5) in 1970 had a high population of fox squirrels along the Lower Blue River (Sec. 1S-4S-8E), 1971	Herd (personal communication)
<u>Kay County</u>	
(1) 1.6 km north and 8.0 km east of Uncas, 30 Dec. 1953	OSU-2379
(2) 14.5 km southwest of Ponca City, 15 Oct. 1966	OSU-6479
<u>Kingfisher County</u>	
(1) 16.1 km west from Hennessey on Highway 51, 3 Nov. 1958	OSU-3958
(2) 3.2 km west of Hennessey, 8 Oct. 1966	OSU-6476
(3) 22.5 km west of Crescent, 14 Oct. 1967	OSU-6901

TABLE I (Continued)

Location		Source
(4)	9.7 km southwest of Hennessey, 20 Oct. 1967	OSU-6907
(5)	between Kingfisher and Guthrie, 29 Nov. 1968	OSU-8225
(6)	fair number of squirrels in the area along the north side of the Cimarron River in Kingfisher County, 1971	Derdeyn (personal communication)
Kiowa County		
(1)	Roosevelt, no specific date given	Blair (1939:113)
(2)	6.4 km south of Wagonwheel near Hobart, 26 Oct. 1965	SWSC-M-31
Latimer County		
(1)	7.2 km north of Wilburton, 18 July 1934	OUMZ-5948
(2)	4.0 km northeast of Wilburton, 19 July 1934	OUMZ-5943
(3)	along Fourche Maline River north of Wilburton, 16 Nov. 1952	OSU-2499
LeFlore County		
(1)	2.4 km northeast of Zoe, 5 July 1934	OUMZ-5947
(2)	1.6 km west of Hontubby, 27 Dec. 1966	OSU-6561
(3)	3.2 km upstream on Poteau River from iron bridge, northeast of Poteau on Highway 59, 12 Dec. 1969	SESC-18
(4)	16.1 km southeast of Heavener, 26 Nov. 1971	SESC-33

TABLE I (Continued)

Location		Source
(5)	16.1 km southeast of Heavener, no date given	SESC-53
(6)	Ouachita Game Management Area has fox squirrels on the ridges, 1971	Johnston (personal communication)
<u>Lincoln County</u>		
(1)	1.6 km south of Chandler, 14 Oct. 1950	OSU-1541
(2)	4.8 km north of Carney on Highway 177, 5 Dec. 1966	OSU-1541
(3)	1.6 km west of Tryon, 31 Dec. 1966	OSU-6473
(4)	8.0 km north and 9.7 km east of Meeker, 7 Nov. 1970	
<u>Logan County</u>		
(1)	4.8 km south and 4.8 km west of Marshall, 11 Oct. 1951, 15 Oct. 1961	OSU-1740, OSU-1742
(2)	in Sec. 2, T18N, R14W, 24 Dec. 1961	OUMZ-349
<u>Love County</u>		
(1)	fox squirrels occur on the Hickory Creek Public Hunting Area and in other parts of the county where tree habitat is adequate, 1971	Thompson (personal communication)
<u>Major County</u>		
(1)	individuals were seen at Cleo Springs, no specific dates given	Jackson and Warfel (1933:69)
(2)	on Graver Creek, 17 June 1936	UMMZ-75985

TABLE I (Continued)

Location		Source
(3)	14.5 km southwest of Togo, no specific date given	Blair (1939:113)
(4)	Vicker I Cave area, 1970	Chesemore (personal observation)
(5)	along the north side of the Cimarron River best for fox squirrels, 1971	Derdeyn (personal communication)
Marshall County		
(1)	on University of Oklahoma Biological Station, 27 July 1950	OUMZ-122
(2)	0.8 km northeast of the University of Oklahoma Biological Station, 18 July 1953	OUMZ-427
(3)	at University of Oklahoma Biological Station, Lake Texoma, 19 June 1955	OUMZ-448
(4)	1.6 km east from Willis, 1965	OUMZ-1307
Mayes County		
(1)	Locust Grove, no specific date given	Blair (1939:113)
(2)	3.2 km south of Big Cabin, 29 Oct. 1970	OSU-8809
McClain County		
(1)	14.5 km west of Norman, 13 Dec. 1952	KSCP-51-B
McCurtain County		
(1)	3.2 km north of Broken Bow, 17 June 1925	OUMZ-5945, OUMZ-5946

TABLE I (Continued)

Location		Source
(2)	16.1 km southeast of Broken Bow, 20 June 1925	OUMZ-5944
(3)	27.4 km north and 11.3 km west of Broken Bow, 25 Nov. 1959	OSU-4185
(4)	24.1 km north of Wright City and 0.8 km west of Glover River, 28 Nov. 1969	SESC-16
(5)	abundance of fox squirrels in the Broken Bow area, 1969	Jones (personal communication)
(6)	high populations of fox squirrels are found at higher elevations where there are abundant stands of hardwoods, 1971	James (personal communication)
(7)	4.8 km east of Battiest on Coon Creek, 26 April 1970	SESC-25
<u>McIntosh County</u>		
(1)	1.6 km west and north of Hitchita, 22 Aug. 1967	OSU-6577
(2)	3.2 km west of Warner, 23 May 1968	OSU-8393
(3)	within the city limits of Eufaula, 10 Dec. 1969	SESC-17
(4)	Stidham, no specific date given	SESC-52
<u>Murray County</u>		
(1)	12.9 km west of Mill Creek, 17 Oct. 1970	OSU-8795
(2)	8.0 km south of Sulphur, 11 Dec. 1971	SESC-46

TABLE I (Continued)

Location	Source
Muskogee County	
(1) 4.8 km east of Wainwright, 29 Oct. 1933	OUMZ-5936
Noble County	
(1) 20.9 km north of Stillwater, 20 Nov. 1949	OSU-1534
(2) 3.2 km north of Morrison, 14 Oct. 1961	OSU-5111
(3) 11.3 km north and 3.2 km east of Perry, 27 Dec. 1963	OSU-6173
(4) 3.2 km west of Morrison, 30 Nov. 1969	OSU-8929, OSU-9048
(5) 1.6 km north and 8.0 km east of Morrison, 18 Sept. 1970	OSU-8694, OSU-8686
(6) 8.8 km west and 0.8 km south of Red Rock, 14 Oct. 1972	OSU-9336
Nowata County	
(1) 8.0 km east of Nowata, 31 Dec. 1953	OSU-2494
Okfuskee County	
(1) 3.2 km east of Mason, 5 July 1969	OSU-8875
(2) 4.0 km east of Mason, 14 July 1960	OSU-8874
Oklahoma County	
(1) 8.0 km north and 3.2 km west of Oklahoma City, 29 Nov. 1959	OSU-4184
(2) north of Jones, 11 Nov. 1967	OSU-6921

TABLE I (Continued)

Location	Source
Okmulgee County	
(1) 8.0 km south of Okmulgee, 22 Oct. 1960	OSU-4578
(2) no location, April 1966	ECSC-M-197, ECSC-M-198, ECSC-M-199
Osage County	
(1) 20.9 km east of Pawhuska, 1 Oct. 1961	OSU-5110
(2) 8.0 km south of Pawhuska, 25 Nov. 1966	OSU-6480
(3) fox squirrels are abundant along Sand Creek east of Pawhuska, 1971	Zachary (personal communication)
(4) 3.2 km south of Shidler, 30 Nov. 1972	OSU-9342
Pawnee County	
(1) 14.5 km east of Red Rock on Greasy Creek, 29 Nov. 1951	OSU-1735
Payne County	
(1) 3.2 km west of Stillwater, 12 July 1925	OSU-152, OSU-153, OSU-156
(2) no specific location, 22 July 1925	UMMZ-80491
(3) 3.2 km south of Stillwater, 10 Feb. 1937	OSU-302
(4) 13.7 km southeast of Stillwater on tributary of Little Stillwater Creek, 20 Nov. 1947	OSU-489
(5) below the dam at Lake Carl Blackwell, 23 Nov. 1947	OSU-490

TABLE I (Continued)

	Location	Source
(6)	on Little Stillwater Creek, 28 Nov. 1947	OSU-491
(7)	2.8 km south of Highway 51 on Little Stillwater Creek, 28 Nov. 1947	OSU-492, OSU-493
(8)	4.8 km south of Stillwater, 2 Jan. 1948	OSU-495
(9)	4.8 km east and 6.4 km south of Stillwater, 19 Oct. 1948	OSU-761
(10)	3.2 km west of Stillwater, 29 Oct. 1948	OSU-758
(11)	4.8 km west and 3.2 km south of Stillwater, 15 Nov. 1948	OSU-829
(12)	6.4 km west and 4.8 km south of Stillwater, 28 Nov. 1948	OSU-830, OSU-762
(13)	14.5 km south of Stillwater, 23 Jan. 1949	OSU-759
(14)	2.4 km west of Stillwater, 3 Dec. 1949	OSU-1532
(15)	6.4 km west of Stillwater, 16 Dec. 1949, 18 Dec. 1949	OSU-1529, OSU-1530
(16)	southeast of Stillwater, 28 Oct. 1950	OSU-1542
(17)	on the Oklahoma State University dairy farm, 18 Sept. 1952	OSU-2497
(18)	4.8 km west of Stillwater, 28 Sept. 1952	OSU-2500
(19)	6.4 km west and 0.8 km north of Stillwater, 9 Oct. 1952	OSU-2389
(20)	0.8 km north of Oklahoma State University Campus, 7 Nov. 1952	OSU-2490

TABLE I (Continued)

	Location	Source
(21)	9.7 km north and 8.8 km west of Stillwater, 23 Nov. 1952	OSU-2498
(22)	1.6 km north of Stillwater, 9 Jan. 1953	OSU-2496
(23)	4.8 km north of Stillwater, 2 Dec. 1953	OSU-2492
(24)	1.6 km west and 0.8 km south of Stillwater, 17 Dec. 1953	OSU-2495
(25)	1.6 km west and 4.8 km south of Stillwater, 17 Dec. 1953	OSU-2491
(26)	1.6 km west of Stillwater, 28 Sept. 1955	OSU-3735
(27)	4.8 km west and 1.6 km south of Perkin's Corner, 18 Oct. 1956	OSU-3733
(28)	8.0 km east of Stillwater, 9 Nov. 1956	OSU-3734
(29)	0.4 km east of the junction of Highways 133 and 40 near Perkins, 16 Sept. 1958	OSU-3957
(30)	12.1 km east and 3.2 km south of Stillwater, 18 Dec. 1958	OSU-4542
(31)	east side of Boomer Lake, 25 April 1963	OSU-5112
(32)	4.8 km east and 1.6 km south of Stillwater, 15 Oct. 1963	OSU-7019
(33)	Lake Carl Blackwell, 10 Nov. 1963	OSU-5668
(34)	4.0 km west of Perkins, 16 Nov. 1963	OSU-9068
(35)	Agronomy grove, Oklahoma State University, Stillwater, 2 Dec. 1963	OSU-5783

TABLE I (Continued)

	Location	Source
(36)	24.1 km east and 32.2 km north of Stillwater, 1 Sept. 1964	OSU-6071
(37)	3.2 km north and 14.5 km east of Stillwater, 2 Oct. 1964	OSU-6072
(38)	20.9 km east and 4.8 km north of Stillwater, 2 Oct. 1964	OSU-7011
(39)	south of Stillwater, 23 Dec. 1964	OSU-7031
(40)	9.7 km north and 4.8 km west of Stillwater, 15 Jan. 1966	OSU-7003
(41)	2.0 km north of Stillwater, 2 Oct. 1966	OSU-7015
(42)	6.4 km south and 1.6 km west of Stillwater, 2 Oct. 1966	OSU-7014
(43)	6.4 km south and 3.2 km west of Stillwater, 30 Oct. 1966	OSU-7035
(44)	16.1 km west and 1.6 km north of Stillwater, 13 Oct. 1967, 26 Nov. 1967	OSU-8528, OSU-8529
(45)	0.8 km west of Stillwater along Stillwater Creek, 22 Oct. 1967	OSU-8530
(46)	4.8 km east and 3.2 km south of Stillwater, 19 Nov. 1967	OSU-8527
(47)	0.4 km south of Stillwater Golf Course, 21 Nov. 1967	OSU-8526, OSU-8528
(48)	9.7 km west of Stillwater, 26 Dec. 1968	OSU-8121
(49)	west of Highway 33, 30 Dec. 1968	OSU-8122

TABLE I (Continued)

	Location	Source
(50)	12.9 km southeast of Stillwater, 15 Nov. 1969	OSU-8876
(51)	1.6 km west and 1.6 km north of Stillwater, 15 Nov. 1969	OSU-9084
(52)	4.8 km west of Stillwater, 14 Dec. 1969	OSU-8928
(53)	1.6 km north and 4.8 km west of Stillwater, 16 Dec. 1969	OSU-8877
(54)	3.2 km east of Stillwater, 8 Nov. 1970	OSU-8709
(55)	12.9 km southeast of Stillwater, 15 Nov. 1970	OSU-8878
(56)	west of Stillwater, 18 Nov. 1970	OSU-9079
Pittsburg County		
(1)	no specific location given, 20 Oct. 1959	OSU-4186
(2)	6.4 km west of Kiowa, 9 Jan. 1966	ECSC-M-97
(3)	3.2 km east of Stuart, 5 Dec. 1971	SESC-40
(4)	8.0 km south of Pittsburg, 5 Dec. 1971	SESC-41
Pontotoc County		
(1)	no location given, 25 Nov. 1961	ECSC-M-274
(2)	14th Street in Ada, 31 Nov. 1964	ECSC-M-35
(3)	north of Ada, 2 Jan. 1966	ECSC-M-99

TABLE I (Continued)

Location	Source
(4) 9.7 km north of Ada, 20 Oct. 1969	ECSC-M-361
<u>Pottawatomie County</u>	
(1) on the Little River 11.3 km southeast of Tecumseh, 21 Dec. 1919	KU-4189
(2) no specific location given, 18 May 1939	OBU-?
(3) 2.4 km west of Tecumseh, 27 May 1970	OBU-?
(4) 3.2 km south and 2.0 km east of Pearson, 20 Sept. 1970	OSU-8770, OSU-8733
(5) 6.4 km west of Shawnee, 12 March 1971	OBU-?
(6) 14.5 km west of Shawnee, 27 Nov. 1967	ECSC-M-267
<u>Pushmataha County</u>	
(1) 11.3 km northeast of Clayton, 10 Oct. 1964	ECSC-M-36
(2) 11.3 km north of Clayton, 28 Dec. 1964	ECSC-M-37
(3) 3.2 km west of Clayton, 15 June 1969	OSU-8873, OSU-8880
<u>Roger Mills County</u>	
(1) 4.8 km west of Cheyenne, 12 May 1937	CM-14752
(2) Garnett, no date	Blair (1938:499)
(3) 4.8 km west of Cheyenne	Blair (1939:113)
(4) near Crawford, 28 Nov. 1965	SWSC-M-32

TABLE I (Continued)

Location	Source
(5) good population of squirrels on the Black Kettle Public Hunting Area	Anon. (1969:4)
<u>Rogers County</u>	
(1) collected fox squirrels along the Bushyhead Fork of the Verdigris River, 1850	Woodhouse (1852:8)
(2) 16.1 km east of Claremore, 29 Dec. 1959	OSU-4183
<u>Seminole County</u>	
(1) near Seminole, 26 Dec. 1950	OSU-1535
<u>Sequoyah County</u>	
(1) 4.0 km east of Akins, 19 Dec. 1959	OUMZ-42
(2) 3.2 km south of Muldrow, 27 Nov. 1968	ECSC-M-333
<u>Stephens County</u>	
(1) 14.5 km north and 1.6 km east of Ringling, 26 Dec. 1967	OSU-6900
(2) 2.0 km west and 2.0 km south of Comanche, 22 March 1969	OSU-8039
(3) occasional occurrence in blackjack oak-post oak areas or along river and creek bottoms, 1971	Iams (personal communication)
<u>Tillman County</u>	
(1) 6.4 km north and 0.4 km east of Tipton, 25 Dec. 1963	OSU-6121

Table I (Continued)

Location	Source
Tulsa County	
(1) near Garnett, 22 July 1935, 27 July 1935	UMMZ-75688, UMMZ-75689
(2) in Mohawk Park, Tulsa, 28 Nov. 1948	OSU-760
(3) 2.4 km north of Sperry, 29 Nov. 1952	OSU-3323, OSU-3351
(4) 3.2 km west of Tulsa, 22 Dec. 1959	OUMZ-386
(5) 8.0 km west of Bixby, 5 May 1963	OSU-7010
Wagner County	
(1) collected fox squirrels along Flat Rock Creek, 1850	Woodhouse (1852:4)
Washington County	
(1) 1.6 km south of the Caney River in Bartlesville, 1 Jan. 1965	OSU-7007
(2) 4.8 km south of Bartlesville, 26 May 1967	OSU-6575
Washita County	
(1) no specific location given, 20 Dec. 1965	SWSC-M-28
Woods County	
(1) 4.8 km southwest of Waynoka, 7 July 1930	OUMZ-5942
(2) specimens were taken near Waynoka and near Edith	Jackson and Warfel (1933)
(3) Waynoka, no date	Blair (1939:113)

TABLE I (Continued)

	Location	Source
(4)	Long Creek, south side of the Cimarron River, 1950, had a high population of fox squirrels	Duck (1951:3)
(5)	3.2 km north and 2.4 km west of Alva, 15 Nov. 1953	OSU-2493
Woodward County		
(1)	in Boiling Spring State Park, east of Woodward, 25 July 1950	OUMZ-444
(2)	0.8 km east of Mooreland, 2 Nov. 1952	OSU-2501
(3)	5.6 km west of Mooreland, 2 Nov. 1963	OSU-7018
(4)	no known fox squirrel concentrations in this area, scattered in shelterbelt or creek bottoms, 1971	McCaslan (personal communication)
(5)	a huntable population of fox squirrels exists near Mooreland, 1971	Miller (personal communication)

TABLE II

DISTRIBUTION RECORDS OF GRAY SQUIRRELS IN OKLAHOMA

Location		Source
Adair County		
(1)	24.1 km south-southwest of Stillwell, 28 Dec. 1966	OSU-6474
Atoka County		
(1)	14.5 km west of Atoka, 26 Dec. 1947	KU-76487
(2)	North Boggy River, Aug. 1941	Duck and Fletcher (1944:106)
(3)	3.2 km east of Stringtown, 3 Jan. 1960	SESC-1
(4)	1.6 km east of Daisy, 4 Dec. 1960	SESC-2
(5)	4.8 km west of Caney, 10 Dec. 1969	SESC-8
(6)	4.8 km east of Tushka, 16 Nov. 1971	SESC-14
Bryan County		
(1)	16.1 km southeast of Bennington	UTMM-1656
(2)	below Blue River dam, north of Armstrong, 27 Oct. 1969	SESC-5
(3)	1.6 km north of Armstrong, Blue River dam, 3 Nov. 1969	SESC-6
(4)	8.0 km north, 9.7 km east of Caddo, 31 Oct. 1971	SESC-12, SESC-13
Cherokee County		
(1)	no specific location on skin, 24 Nov. 1961	OSU-5603

TABLE II (Continued)

Location	Source
(2) Scraper, no specific date given	Blair (1939:112)
(3) 1.6 km southeast of Cookson refuge	Tobler (personal communication)
Choctaw County	
(1) 5.6 km east, 2.4 km south of Hugo, 27 Dec. 1959	OSU-4180
Creek County	
(1) gray squirrels are common along the Deep Fork of the North Canadian River and its major tributaries such as the Little Deep Fork upstream to Edna and Sand Creek, 1968 to 1972	Chesemore (personal observations)
Delaware County	
(1) 40.2 km north of Ketchum, 24 Nov. 1960	OSU-4577
(2) no specific location on specimen, 29 Dec. 1961	OUMZ-350
(3) 7.2 km southeast of Jay, 300 m elevation, 27 March 1967	OUMZ-2415
(4) gray squirrels are common on the hardwood ridges of the Spavinaw Hills Refuge, 1971	Chesemore (personal observation)
Hughes County	
(1) 9.7 km southeast of Holdenville, 4 July 1961	KU-119481
(2) 6.4 km south of Gerty, 6 July 1967	ECSC-M-240
(3) 4.8 km west of Calvin, 6 Oct. 1970	ECSC-M-413

TABLE II (Continued)

Location	Source
Johnston County	
(1) 8.0 km east, 2.4 km north of Wapanucka, 26 Nov. 1969	SESC-7
(2) high population of gray squirrels found in the watershed of the lower Blue River (Sec. 1S to 4S to 8E) in southeastern area of the county, 1971	Herd (personal communication)
Kay County	
(1) best squirrel population found along the Arkansas, Chikaskia and Salt Fork Rivers	Anon. (1969)
LeFlore County	
(1) gray squirrels normally frequent the large mountains and riverbottoms where dense hardwood timber stands still occur, 1971	Johnson (personal communication)
(2) 16.1 km southeast of Heavener, 24 Nov. 1971	SESC-15
(3) 6.4 km east of Hontubby, 28 Nov. 1971	SESC-16, SESC-17
Love County	
(1) at one time there was a good population of grays in western Love County and a small population in southeastern areas along the Red River, all of this habitat has now been bulldozed, 1971	Thompson (personal communication)

TABLE II (Continued)

Location	Source
Mayes County	
(1) 0.8 km north of low water dam on Grand River, 27 Dec. 1956	OSU-3954
(2) 8.0 km south of Locust Grove, 22 Oct. 1972	OSU-9318
(3) Locust Grove, no date	Blair (1939:112)
McCurtain County	
(1) 24.1 km southeast of Broken Bow, 14 Aug. 1934	OUMZ-5954, OUMZ-5955
(2) Sec. 29, T6, R22 along creek, 1 Oct. 1969	SESC-4
(3) 8.0 km southeast of Broken Bow, 2 Jan. 1970	SESC-10
(4) 16.1 km south of Tom on bank of the Red River, 25 Oct. 1970	OSU-8752
(5) gray squirrels occur throughout the county; higher populations of grays along bottom lands where mixed hardwoods are abundant; the Little River, Glover River, Mountain Fork River, and all large creek bottoms have high gray squirrel populations, 1971	James (personal communication) Jones (personal communication) McCain (personal communication)
Murray County	
(1) Dougherty, no specific date given	Hall and Kelson (1959:370)
Muskogee County	
(1) 4.8 km east of Wainwright, 18 Nov. 1953	OUMZ-5956

TABLE II (Continued)

Location	Source
<u>Noble County</u>	
(1) 0.4 km south of junction of Red Rock Creek and the Arkansas River, 7 Nov. 1958	OSU-3956
(2) gray squirrels inhabit Black Bear Creek about 24.1 km northeast of Stillwater; once found across the entire county along Bear Creek to the Garfield County line; also found along Red Rock Creek west to Highway 77, 1971	Honeyman (personal communication)
(3) 12.9 km northeast of Red Rock near the Arkansas River, 7 Nov. 1958	OSU-3955
(4) 4.8 km east, 1.6 km north of Morrison, 1 Nov. 1959	OSU-4181
(5) 1.6 km east of junction of Red Rock Creek and Arkansas River, 7 Oct. 1957	OSU-3759
(6) 0.4 km north of junction of Red Rock Creek and the Arkansas River, 17 Oct. 1958	OSU-3587
<u>Nowata County</u>	
(1) 9.7 km east of Nowata, 13 April 1963	OSU-5114
<u>Okfuskee County</u>	
(1) gray squirrels are common along the Deep Fork of the North Canadian River and its larger tributaries such as Nuyaka and Brier Creek, 1971	Chesemore (personal observation)

TABLE II (Continued)

Location	Source
Okmulgee County	
(1) no location, June 1966	ECSC-M-183
(2) gray squirrels are common in the bottoms along the Deep Fork of the North Canadian River and some of its major tributaries such as Salt Creek, 1971	Chesemore (personal observation)
Osage County	
(1) pockets of gray squirrels are present on Salt Creek near Fairfax, 1968	Wazinski (personal communication)
(2) there seems to be an abundance of gray squirrels along Sand Creek east of Pawhuska, 1971	Zachary (personal communication)
Ottawa County	
(1) 19.3 km east of Miami, 8 May 1966	KSCP-651-B
Pawnee County	
(1) 9.7 km northeast of Morrison, 22 Nov. 1946	OSU-411, OSU-412
(2) 4.8 km east of Morrison, 4 Oct. 1951	OSU-1716, OSU-1717
(3) 14.5 km east of Red Rock on Greasy Creek, 28 Nov. 1951	OSU-1737
(4) gray squirrels occur along the Arkansas River to the town of Cleveland; also found on Rock Creek in northwestern Pawnee County, on Coal Creek, and on Black Bear and Crystal Creeks, 1971	Honeyman (personal communication)

TABLE II (Continued)

Location	Source
Payne County	
(1) gray squirrels reportedly inhabited portions of Stillwater Creek 50 years ago, prior to the cutting of many of the hickory trees, but apparently are absent from this watercourse at the present time, 1950	Parker (1950)
(2) 24.1 km east of Stillwater, 7 Oct. 1966	OSU-6475
(3) one gray squirrel was seen in SE 1/4 of Sec. 5, R3E, T17N, 30 Oct. 1970 by a wildlife survey crew	Eubanks (personal communication)
(4) one gray squirrel was seen by Jerry Blossom in southeastern portion of the county, Sec. 24, R4E, T19N, Sept. 1971	Eubanks (personal communication)
(5) small populations of gray squirrels are scattered along the Cimarron River to Highway 35; also found on Council and Salt Creeks in the eastern portion of Payne County, 1971	Honeyman (personal communication)
Pittsburg County	
(1) 3.2 km south of Hartshorne, 21 Sept. 1952	OSU-2502
(2) 12.9 km southeast of Stuart, 21 Dec. 1966	SESC-3
(3) 3.2 km east of Stuart, 31 Oct. 1971	SESC-11
Pushmataha County	
(1) near Clayton, 8 Dec. 1951	OSU-1738

TABLE II (Continued)

Location		Source
(2)	3.2 km northeast of Cloudy, 18 March 1953	OUMZ-5953
(3)	1.6 km west and 6.4 km north of Antlers, 30 Dec. 1965	ECSC-M-110
(4)	1.6 km southeast of Clayton, 15 June 1969	OSU-8882
(5)	3.2 km west of Clayton, 15 June 1969	OSU-8881
(6)	high gray squirrel populations occur along the Kiamichi River bottoms between Clayton and Antlers, 1971	Baker (personal communication)
Rogers County		
(1)	collected gray squirrels along the Bushyhead Fork of the Verdigris River, 1850	Woodhouse (1852:8)
(2)	Garnett, no specific date given	Blair (1938:498-499)
Sequoyah County		
(1)	near Tenkiller Dam, 4 Jan. 1970	OSU-8358
Tulsa County		
(1)	within city of Tulsa, no date	UI-24051
(2)	at town of Garnett, 24 July 1935	UMMZ-75692, UMMZ-75693
(3)	at town of Garnett, 5 Sept. 1935	OSU-350
(4)	within Mohawk Park in Tulsa, 5 Sept. 1935	UF-1404

TABLE II (Continued)

Location	Source
<u>Wagner County</u>	
(1) collected gray squirrels along Flat Rock Creek, 1850	Woodhouse (1852:4)
<u>Washington County</u>	
(1) along Caney River in Bartlesville, 6 Jan. 1964	OSU-6075
(2) 1.6 km south of the Caney River, Bartlesville, 1 Jan. 1965	OSU-6123, OSU-6127

Discussion

Gray squirrels are poorly represented in collections, but fox squirrels are relatively common in museums and probably adequately represent the present distribution of *Sciurus niger* in Oklahoma. Snider (1917:201) lists fox and gray squirrels as common in Oklahoma but gives no specific details. Blair (1939) summarizes the early work on mammals on their distribution and discusses squirrel distribution in relation to habitat type in Oklahoma.

Previous Collections and Reports

Information about explorers and early biological collections can be found summarized in Morris and McReynolds (1965) and Webb (1970). Although the early explorers crossing Oklahoma collected some biological materials, few tree squirrels evidently were included in their collections. Even travelers who went through what still remains as some of the best squirrel habitat in east-central Oklahoma, the Deep Fork of the North Canadian River, while discussing many other species of wildlife did not mention squirrels specifically in their writings.

Captain Nathan Boone, the youngest son of Daniel Boone, traversed the Deep Fork area on 28 and 29 July 1843, crossing the river 1.6 to 3.2 km northwest of the present location of the town of Eufaula (Boone 1929). Washington Irving and his party camped near Paden 3 November 1832 and travelled along the Deep Fork to camp near Okfuskee 4 November 1832. They then made a difficult crossing of the Deep Fork River on 5 November 1832 at some 4.8 to 6.4 km upstream from the present location of the city of Okmulgee, perhaps close to the present southeastern boundary of the Okmulgee Public Hunting Area. To quote Irving (1955):

> The rich wood bottom in which we were encamped abounded with wild turkeys of which a considerable number were killed.

On 6 November 1832 they moved eastward into the open grasslands on their way to Fort Smith and mentioned seeing many "prairie hens" but no squirrels were reported seen (Irving 1955).

Examination of some of the early records of the 1880's and 1890's from the Nuyaka Mission in east-central Oklahoma near the Deep Fork shows that wildlife, particularly white-tailed deer (Odocoileus virginianus) and wild turkey (Meleagris gallopavo) were sold by local hunters regularly to the Mission. No mention was found of squirrels being utilized by the Mission.

The earliest squirrel specimen available is that of a fox squirrel collected by Dr. E. Palmer 27.4 km south of Fort Cobb at the Wichita Agency and deposited in the Smithsonian Institution's mammal collection in Washington, D.C., in 1874. Since 1900, squirrel materials from Oklahoma have been deposited sporadically in museum collections throughout the country, but only since the 1930's have many counties been represented by specimens. Of some 300 museum specimens of fox squirrels reported, 64 percent of these have been added to museum collections since 1960; of the 55 specimens of gray squirrels reported in collections, 66 percent have been collected since 1960 and 89 percent since 1950.

Distribution and Abundance of Fox Squirrels in Oklahoma

Fox squirrels were formerly found throughout Oklahoma wherever there was timber enough to support them and usually they were considered plentiful (Duck and Fletcher 1944). Blair (1939:113) reported that fox squirrels were widely distributed in all of the Eastern Deciduous Forest subdivisions of Oklahoma: the Mississippi, Ouachita, Ozark, Cherokee Prairie, and Osage Savanna; and in the Mixed-Grass Plains and Wichita Mountains portions of the Great Plains Grasslands. This species extended westward along wooded stream valleys nearly across the Mixed-Grass Plains District (Blair 1939:113). There are no records of fox squirrels from the panhandle portion of Oklahoma nor from its Black Mesa area, although in Texas fox squirrels have been found near Stinnett (Blair 1954) and in Kansas in Meade County (Hall 1955). The fox squirrel now occurs along all streams even in western Kansas except along the Cimarron River in the extreme southwestern part of the state (Packard 1956:6).

I did not find any evidence of fox squirrels along the tributaries of the Cimarron River in Cimarron County in November 1968 although the stand of cottonwood (Populus deltoides) in the area appeared large enough to support some fox squirrels. Packard (1956) attributed a lack of fox squirrels along the Cimarron in Kansas to the scarcity of trees and a lack of suitable foods. An eventual range extension of fox squirrels to at least midpanhandle in Oklahoma seems possible based on these occurrences in Texas and Kansas.

Today, sparse populations of fox squirrels occur intermittently along the western border of its range where stream gallery forests, shelterbelts, and farm woodlots exist. This species is most abundant in central and east-central Oklahoma in the transition zone between the prairie and oak woodlands. Fox squirrels also occur throughout the forests of northeastern, eastern and southeastern Oklahoma in the transition zone between the prairie and oak woodlands. Fox squirrels probably have expanded their range in Oklahoma in recent times, aided by the opening up of the eastern woodlands for grazing and agriculture and by afforestation in western Oklahoma. These changes in land use create more habitat suitable for fox squirrels.

Fox squirrels occupy a wide range of habitats in Oklahoma, showing an ability to survive almost anyplace in which there are a few trees. In northeastern, eastern, and southeastern Oklahoma, they predominate in the upland hardwood forests and also occur regularly in the dense timber along stream bottoms. In east-central Oklahoma they utilize the open pecan orchards, post oak-blackjack oak and upland oak-hickory forests, and are common in the bottomland forests along the larger rivers such as the Deep Fork. The stream gallery forests of central Oklahoma often support high fox squirrel populations.

Distribution and Abundance of Gray Squirrels in Oklahoma

The gray squirrel once was abundant in the Mississippi, Ozark, Cherokee Prairie, and Osage biotic districts of the Eastern Deciduous Forest of Oklahoma (Blair 1939:113). They apparently did not extend westward beyond the Osage Savanna district into the Great Plains Grasslands. Gray squirrels were formerly found along all major streams in east-central Oklahoma having dense bottomland forests and sometimes in the post oak-blackjack oak timber type. From all records on its distribution, it appears that a line drawn north and south through Oklahoma City would mark the former western boundary of this squirrel's distribution in Oklahoma (Duck and Fletcher 1944).

Gray squirrels today occur in Oklahoma only east of the 97th meridian. They once extended into westernmost Love County and perhaps into western Payne County, but no specimens exist to document this past distribution. Suitable habitat for gray squirrels in these areas has now been destroyed. These squirrels are common and often abundant in east-central Oklahoma along the major rivers and their larger tributaries. Such a distribution pattern occurs along the Deep Fork River in Creek, Okfuskee, and Okmulgee Counties and on some of its larger tributaries such as Little Deep Fork, Salt, and Nuyaka Creeks. In northeastern, eastern, and southeastern Oklahoma sizeable populations of gray squirrels occur in the river bottoms and on ridges still covered with dense forests.

Gray squirrels are more restricted in their habitat preference in Oklahoma than is the more adaptive fox squirrel. In eastern Oklahoma, gray squirrels are found primarily in the dense bottomland forests and in the heavily timbered hardwood uplands. In east-central Oklahoma, the gray squirrel utilizes neither the post oak-blackjack oak uplands nor the open pecan orchards, which are prime habitats for the fox squirrel. Gray squirrels may be present in oak-hickory woodlands or at the edges of open pecan orchards if a brushy area and travel lanes from the bottomland forest to these brushy areas exist. They are most abundant in the remaining bottomland forests bordering the large rivers. In northeastern, eastern, and southeastern Oklahoma, gray squirrels are found on heavily-timbered hardwood ridges and in the oak-hickory-pine forests bordering the rivers of the area.

It appears that the distribution of gray squirrels in Oklahoma will continue to be reduced. There is continual conversion of bottomland forests to open pecan orchards and grassland, clearing the stream gallery forests along tributary streams to increase agricultural lands, flooding of bottomland areas due to dam construction and flood activities, and channelizing of streams, such as occurred on the Deep Fork in Lincoln County in east-central Oklahoma. The extent of these changes is discussed in Chapter III. All of these activities are destroying suitable gray squirrel habitat. The apparent inability of the gray squirrel to utilize other existing woodlands therefore makes it likely that there will be a decrease in its abundance and distribution in Oklahoma.

Causes of Squirrel Distribution Patterns

Hall and Kelson (1959) note the effect of grasslands in limiting the eastward expansion of tree squirrels. Continental distribution patterns are determined in general by climatic considerations, in this case by rainfall or annual precipitation becoming insufficient to support tree growth. Local conditions, such as moist soils, allowing the stream gallery forest to extend westward in Oklahoma, result in the westward extension of the fox squirrel as well.

Certain mammals extend beyond the area of their expected vegetation type, the result of ecological features associated with the stream systems of Oklahoma. In the relatively deep, relatively moist alluvial soils of the stream flood plain, the eastern forest extends westward into the mixed-grass plain district of the Great Plains Grasslands (Blair 1939). These relatively narrow strips of forest area in an area predominantly grassland are the highways by which some of the eastern forest animals extend westward beyond the eastern forest districts (Blair 1939:95).

Man's settlement of Oklahoma and his planting of shelterbelts and farm woodlots has created more habitat for fox squirrels in western Oklahoma and has helped them extend their distribution westward in Oklahoma.

Conversely, man is also rapidly destroying suitable squirrel habitat. Aerial application of herbicides to destroy woodlands to create more pasture for domestic stock, intensive management of pecan orchards after clearing out all other bottomland tree species from the orchard, and converting mixed hardwood forests into monocultures of pines for timber production are rapidly destroying squirrel habitat in Oklahoma. Destroying windbreaks established during the dustbowl days of the early 1930's in western Oklahoma to increase usable crop acreage is also destroying some of the only woodland available to fox squirrels in the area. Channelizing streams or constructing dams that flood bottomland areas is effectively destroying much of the available habitat for gray squirrels in eastern Oklahoma.

The spatial distribution of fox and gray squirrels within remaining woodland habitats has not been adequately explained. At least in east-central Oklahoma along the Deep Fork of the North Canadian River, fox squirrels do not follow the stereotyped opinion of being found only in open woodlands and at the forest-prairie edge. Fox squirrels are found in all wooded habitats in the area, even in the densest bottomland forests where they coexist with gray squirrels.

The absence of gray squirrels from the post oak-blackjack oak uplands and open pecan orchards may be due to competitive exclusion and/or behavioral traits of the gray squirrel. Both habitat types support large numbers of fox squirrels. Interspecific competition between these two species should be studied.

CHAPTER III

THE WATERSHED OF THE DEEP FORK OF THE NORTH CANADIAN RIVER

Introduction

The Deep Fork drainage includes some of the best wildlife habitat in east-central Oklahoma and supports one of the highest tree squirrel populations in the state (Fig. 1). White-tailed deer flourish in the remaining bottomland forests along the Deep Fork. Waterfowl, particularly wood ducks (*Aix sponsa*) and mallards (*Anas platyrhynchos*) utilize this area throughout the year, and wood ducks regularly nest along it in Okmulgee County. Bobwhite quail (*Colinus virginianus*) are common in the fields along the river and even a few turkeys still remain in the woodlands bordering the Deep Fork near Okmulgee. The area is noted for its raccoon (*Procyon lotor*) hunting; and swamp rabbits (*Sylvilagus aquaticus*), extirpated from much of their former range in Oklahoma, are still regularly seen in the bottomland forests along the Deep Fork in Okmulgee, Creek, and Okfuskee Counties.

The Deep Fork of the North Canadian River is admirably suited to development for recreational activities, particularly those connected with hunting, fishing, and other wildlife-orientated uses such as nature study, wildlife photography, and bird watching. The Oklahoma Department of Wildlife Conservation has proposed that 23,310 ha along this river be developed into a multi-purpose recreational area. This proposed area, about 4.8 km wide and 48.3 km long, would be located along the river between State Highways 18 and 48. A 2,832 ha park, a 4,047 ha waterfowl refuge and a 16,431 ha public hunting area would be included in this development. Based on his projections, Ellis (personal communication) concluded that the area would be used extensively by the half-million people in and around Oklahoma City who live only an hour's drive from this proposed area. Appreciable use by people from Tulsa, Shawnee, Stillwater, Cushing and Sapulpa as well as by tourists was also expected. This area has a greater need for additional recreational areas than does anywhere else in Oklahoma (Copelin 1969, Ellis 1969).

U. S. Senator Henry Bellmon has noted the recreational potential of the Deep Fork and stated that it contains some of the best scenic, recreation, and wildlife value available in many states (Anon. 1971).

Other uses for the Deep Fork have also been projected. One proposal, known as the Central Oklahoma Project (COP), was first drafted by the U. S. Army Corps of Engineers in 1964. The plan recommended construction of a navigation channel to the Oklahoma City area from the Arkansas River via the Deep Fork to Arcadia. The canal, if constructed, besides its transportation values, would also help control flooding, silting, and overflow problems in the Deep Fork Valley (Central Oklahoma Project 1964). Construction of this canal would adversely affect wildlife resources on an estimated 16,592 ha along the Deep Fork (Anon. 1971). The feasibility of this project was again studied by federal agencies and in 1975 it was decided that channelization of the Deep Fork River was not economically feasible.

Methods and Materials

Information on the watershed of the Deep Fork was compiled principally by an intensive search through voluminous, but scattered, literature and unpublished administrative reports. Informal meetings with U. S. Army Corps of Engineer personnel, participation in formal public meetings, and panel discussions dealing with the Deep Fork crystalized my ideas on potential uses of this river basin. Discussions with long-time residents of areas along the Deep Fork and information gleaned from Oklahoma Department of Wildlife Conservation personnel provided data on specific areas of the watershed. I travelled along much of the river, mainly in Okmulgee, Creek, Okfuskee, and Lincoln Counties, and flew its length from Lincoln County to eastern Okmulgee County. Analysis of current literature provided indications on the future development along the Deep Fork and its possible effects on the ecology of the river system.

Aerial photographs, available at the Agricultural Stabilization and Conservation Service (ASCS) offices and the Library, Oklahoma State University, Stillwater, were studied to determine gross changes in habitat types that had occurred in Sections 29, 30, 31, and 32 (T14N, R11E) on land bordering the Deep Fork in Okmulgee County. Comparison of aerial photographs taken along the Deep Fork from 1949 to 1970 were used to provide a quantitative index to agricultural usage and to forest cover converted to pecan orchards. Acreage of these respective types was determined by measuring this area on each aerial photograph with a compensating polar planimeter. These sections were studied because of the availability of aerial photographs and because these sections encompassed the major intensive study area of the squirrel project.

Results and Discussion

Hydrology and Physiography of the Deep Fork Drainage

The Deep Fork of the North Canadian River, known commonly as the Deep Fork, begins about 8.0 km east of Lake Hefner in Oklahoma County (Sec. 34, T13N, R3W) and flows eastward through central Oklahoma some 370 km to its confluence with the North Canadian River at River Km 23.2 in Eufaula Reservoir (Table III).

With the construction of Eufaula Reservoir in 1956 to 1964, the easternmost segment of the Deep Fork has been drowned by the waters of Eufaula Reservoir. It inundates approximately 35.4 km of the Deep Fork at conservation pool level and about 54.7 km of it at flood pool level.

It is a sluggish, slowly moving, winding stream (Fig. 4). The stream has a weighted slope of 1.82 m per 1.6 km in its upper reaches and 0.3 m per 1.6 km near its mouth; with an average gradient of approximately 0.6 m per 1.6 km. The Deep Fork is sluggish and usually turbid. Low flows on the Deep Fork have occurred for extended periods, whereas short periods of no flow have occurred during prolonged dry seasons. During the past 30 years, flows of the River near Beggs ranged from zero in 1939, 1954, and 1956 to 1,892 m^3/sec. on 11 May 1943. From records available from 1939 to 1968, an average flow of 22.7 m^3/sec. has been maintained by the River at Beggs (Oklahoma Water Resources Board 1972).

The hilly terrain of the Deep Fork watershed is conducive to quick runoff, and it results in frequent flooding along the river. Flooding of major proportions occurs once every five years, of moderate proportions once every 1.5 years, and of minor proportions about two times a year. Near Beggs, the Deep Fork has flooded on an average of twice a year during 25 years of record. Peak

TABLE III

MAJOR TRIBUTARIES OF THE DEEP FORK OF THE NORTH CANADIAN RIVER, IN EAST-CENTRAL OKLAHOMA[a]

Tributary	Area Drained in Km^2	Confluence with Deep Fork at River Km
Bear Creek	290.1	317.9
Captain Creek	165.8	313.4
Quapaw Creek	393.7	284.8
Dry Creek	461.0	266.3
Salt Creek	290.1	224.5
Little Deep Fork River	683.8	157.8

[a]Data compiled from Volume 4 of Central Oklahoma Project (1964).

Figure 4. Aerial View of the Walker Study Area, Okfuskee County. This Virgin Bottomland Forest Was Clear-Cut Beginning in November 1969. Photo Taken January 1970.

discharges have been comparatively briefer and the duration of flooding less in the upper reaches of the Deep Fork than in the main stem below the mouth of the Little Deep Fork River at River Km 157.8. The estimated channel capacity of the Deep Fork near Luther averages 56.6 m^3/sec. and increases to 113.3 m^3/sec. near its confluence with the North Canadian River (Central Oklahoma Project 1964). According to historical flood information, the highest flood on the main stem of the Deep Fork occurred in October 1908. It produced an estimated peak discharge of about 2,832 m^3/sec. at a height of about 3.4 m above bankfull near Dewar.

The flood plain along the Deep Fork, comprising about 27,034 ha, varies in width from 0.8 km at the Arcadia Dam site (River Km 344) to about 4.8 km wide in the lower reaches of the river. Each year flooding in this flood plain does an estimated 690,000 dollars of damage to this land (Central Oklahoma Project 1964).

Flood control for municipal demands in the upper reaches of the Deep Fork, primarily for water storage and providing water for water quality control in the Deep Fork, are serious problems. The upper area of the Deep Fork is subject to urban development from expansion by the cities of Oklahoma City and Edmond. Other major cities within the zone of influence of the Deep Fork River include: Okmulgee, Henryetta, and Bristow. The overflow area below Arcadia Dam site is used primarily for producing diversified crops and raising livestock. Producing oil and gas wells are located in all reaches of the Deep Fork drainage.

The lower reaches of the river are mainly rural in nature. The frequency of flooding has limited housing development in the lower Deep Fork flood plain. Pasture for livestock and pecan orchards are common in the flood plain of the eastern segment of the Deep Fork, and patches of relatively natural portions of native vegetation still occur in isolated areas.

Drainage and land reclamation are problems in the Deep Fork Valley. Existing improvements in the Deep Fork Basin, other than programs by the Soil Conservation Service, include channel improvement work along the Deep Fork in Lincoln and Oklahoma Counties. These improvements were made from 1910 to 1923. The main improved channel is about 80.5 km long; ending at River Km 262.3 at the eastern boundary of Lincoln County (Fig. 5). The improved channel is in good condition in its upper reaches and apparently does reduce the frequency and duration of flooding in these areas. However, the lower reaches of the channel have been severely silted, which has resulted in the formation of extensive swampy conditions over a large area of the flood plain in the eastern portion of Lincoln County.

Geology and Soils of the Deep Fork Drainage

The Deep Fork lies mainly within the physiographic region known as the Osage Plains section of the Central

Figure 5. Channelized Portion of the Deep Fork of the North Canadian River in Western Lincoln County. No Tree Cover Remains Along These Banks to Support Tree Squirrels. June 1969.

Lowlands (Johnson 1972). The five counties through which the Deep Fork flows lie within two physical regions: the Eastern Sandstone Cuesta Plains and the Central Redbed Plains.

The Central Redbed Plains consist of gently rolling hills and broad, flat plains formed on flat-lying red shales and sandstones of Permian age. The eastern half of this province is developed mainly on sandstones and has a greater relief, generally between 7.6 to 30.5 m, while the western half is mostly on shales and has lower relief, commonly between 3.1 to 15.2 m. The Deep Fork's route through Lincoln and Oklahoma Counties crosses this geological formation.

The Eastern Sandstone Cuesta Plains consist of gently dipping Pennsylvanian sandstones forming cuestas that overlook broad shale plains. Rocks dip westward away from the Ozarks, and the area is part of the Prairie Plains Homocline. Relief is generally from 15.2 to 61.0 m. The eastern reaches of the Deep Fork cross this geological type in Creek, Okfuskee, and Okmulgee Counties.

A soil association consists of names of the soil series which dominate and typify the landscape, although other important soil series may occur in each association. Five soil associations occur throughout the Deep Fork drainage: Darnell-Stephenville; Renfrow-Zaneis-Vernon; Parsons-Dennis-Bates; Port-Pulaski-Konawa; and Verdigris-

Osage-Konawa (Buckhannan, et al. 1952, Sparwasser, et al. 1968, Williams and Bartolina 1970).

The Darnell-Stephenville association occurs throughout the drainage and dominates the soil types on the gently sloping to strongly sloping hillsides and ridge tops along the river. These light-colored soils support the wooded uplands as typified by the post oak-blackjack oak forests found on these ridges in the drainage.

The Renfrow-Zaneis-Vernon association characterizes the uplands and ridgetops along the western half of the Deep Fork drainage, extending eastward to the edge of Creek and Okfuskee Counties. These are loamy soils found over clay or shale rocks on the prairie uplands.

From Creek and Okfuskee Counties eastward the Renfrow-Zaneis-Vernon association is replaced by the Parsons-Dennis-Bates association on the prairie uplands. This association's soils are dark-colored, deep, and moderately fertile, and are among the most productive of the upland soils.

The floodplain and terraces bordering the Deep Fork of the North Canadian River are characterized by two soil associations. The Port-Pulaski-Konawa association is found from the western border of Okmulgee County eastward while westward the Verdigris-Osage-Konawa association dominates the soils of the river bottom. Before extensive clearing by man for agricultural development, these soils supported dense bottomland forests.

Climatology of the Deep Fork Drainage

The climate of the Deep Fork drainage is generally mild with an average annual temperature of about 16.5^{o}C maintained in the drainage. Spring and fall months are characterized by warm days and cool nights. The summers are long and hot, nights are warm, and violent thunderstorms and occasional tornadoes occur within the drainage during late spring and early summer. The winters are short and mild with occasional snowfall and subfreezing temperatures occurring infrequently throughout the area. A summary of weather conditions from five weather stations within the drainage is presented in Table IV. Seasonal changes occur gradually but daily variation in climatological factors can be abrupt and unpredictable.

The Deep Fork basin lies in the southern part of the Great Plains. Predominating air masses in late December, January, and February are of the continental polar air associated with northerly winds from Canada. During the rest of the year, air masses are maritime tropical air and southerly winds that originate in the Caribbean Sea and the Gulf of Mexico.

The normal rainfall over the Deep Fork basin is about 76 cm a year at Oklahoma City and increases steadily eastward to about 106.7 cm annually in eastern Okmulgee County. There is seasonal variation in the rainfall: spring, the wettest season, provides about 33 percent of

TABLE IV

CLIMATOLOGICAL MEANS AND EXTREMES, DEEP FORK DRAINAGE[a]

City	Total Annual Precipitation (cm)	Temperature: Daily Maximum (C)	Temperature: Daily Minimum (C)	Temperature: Monthly (C)	Temperature: Record High (C)	Temperature: Record Low (C)
Okmulgee	99.16	22.7	9.3	16.0	45.1	-28.6
Okemah	98.32	22.3	10.0	16.1	45.6	-23.1
Bristow	94.13	22.4	9.1	15.8	45.6	-24.8
Chandler	86.58	22.7	9.4	16.0	47.3	-28.6
Oklahoma City	78.28	21.2	10.0	15.6	44.6	-27.0

[a]Data summarized from Oklahoma Water Resources Board.

the annual precipitation; summer, 27 percent; fall, 25 percent; and winter the remaining 15 percent. May is generally the wettest month with approximately 15 percent of the annual precipitation occurring during this time. September is historically the second wettest month of the year along the Deep Fork.

Vegetation

Variation in soil types and climate along the drainage of the Deep Fork has produced a mosaic of vegetation types and floristic diversity. Four major vegetation types dominate the plant associations in the Deep Fork drainage: bottomland forests, post oak-blackjack oak forest, oak-hickory forest, and the tall-grass prairie type. The oak-hickory forest occurs only sporadically in the eastern-most reaches of the drainage whereas the tall-grass prairie occurs only in the western portion. All other types occur throughout the drainage basin.

The floral diversity of the Deep Fork drainage is poorly known. Botanical work in Oklahoma has been reviewed by Kelting and Penfound (1953) and Milby and Penfound (1967), but few papers deal specifically with the Deep Fork area. Early explorers have provided a general picture of the major vegetation types of Oklahoma. Edwin James, Thomas Nuttall, and Washington Irving explored portions of eastern and central Oklahoma in the mid and late 1800's (Nuttall 1837, Thwaites 1905, Irving 1955), and Josiah Gregg (1944) recorded his impressions of the state during travels across it in the 1820's and 1830's. Sitgreaves and Woodruff (Woodhouse 1852) surveyed the northern boundary of the Creek Indian Country in 1849 and 1850 and provided a detailed account of the vegetation types they encountered along the North and South Canadian Rivers.

The animal and plant communities of Oklahoma have been described in a number of ways (Blair and Hubbell 1938, Clements and Shelford 1939, Carpenter 1940, Dice 1952) while Bruner (1931), Weaver and Clements (1938), and Oosting (1956) have classified only the vegetation into different categories. Duck and Fletcher (1943,1944) have compiled the only comprehensive vegetation map of the state. Sternitzke and Van Sickle (1968) described the forests of eastern Oklahoma. Recently, the upland forests in the western portion of the Deep Fork drainage have been studied by Rice and Penfound (1959) and Rice (1965) has described the composition of bottomland forests present in the western portion of the drainage.

Basically, the vegetation of the Deep Fork drainage can be separated into two broad classes: forest and grassland. Another category of miscellaneous types includes specialized habitats limited to local areas, such as sand dunes, and severely disturbed areas such as roadsides or abandoned, eroded fields.

Three types of forest vegetation occur within the Deep Fork drainage: the oak-hickory type of the eastern deciduous forest complex; the upland oak forest, dominated by the post oak-blackjack oak stands; and the bottomland forests, occurring only on alluvial soils of the flood plains and terraces bordering these streams (Duck and Fletcher 1944).

The oak-hickory forest occurs only sporadically in the eastern-most reaches of the drainage and is synonymous with the Ozark Biotic District of Blair and Hubbell (1938).

The upland oak forest, found west of the deciduous forest zone, includes that known as the "Cross Timbers" (Dyksterhuis 1948) and the oak-hickory savanna (Bruner 1931). Upland oak forest, composed predominantly of post oak (Quercus stellata) and blackjack oak (Quercus marilandica) occupies the rolling to hilly uplands of the drainage where sandy soils have developed. Post oak makes up about 60 percent of the forest stand while 30 percent is blackjack oak (Dyksterhuis 1948). The percentage of blackjack oak in the stand increases as drier sites are occupied.

Before settlement, the post oak-blackjack oak woodland consisted of an eastern parkland of scattered clumps of oak timber which was bordered on the west by a relatively narrow, continuous belt of timber (Blinn 1958). Blinn (1958) feels that wildfire kept the Cross Timbers between the Canadian and Red Rivers in an open savanna and prevented the development of the dense woodland form that presently exists.

Penfound (1967) has reviewed grassland classification and his nomenclature is followed here. Tall-grass prairie, often known as the true prairie, occurs interspersed with the forest edge throughout the drainage until it meets with the southern mixed-grass prairie in western Oklahoma, beginning in mid Lincoln County. Big bluestem (Andropogon gerardi), little bluestem (Schizachyrium scoparius), indian grass (Sorghastrum nutans) and switchgrass (Panicum virgatum) are the characteristic species of tall-grass prairie in the eastern portion of the Deep Fork drainage. The distinction of the boundary between tall- and mixed-grass prairies in the drainage is difficult because man's activities have altered most of these types beyond recognition. True tall-grass prairie has a continuous, one-layer stand of tall grasses while mixed-grass prairie has two distinct layers; an upper one composed of dominant mid-grass species and a lower layer of short-grass dominants (Allen 1968). Smith (1940) found the typical mixed-grass prairie community to be composed of 30 percent short-grass species, 60 percent mixed-grass species, and 10 percent tall-grass species. Little bluestem and sideoats grama (Bouteloua curtipendula) form the characteristic upper layer in the mixed-grass prairie whereas buffalo-grass (Buchloe dactyloides) and blue grama (Bouteloua gracilis) form the lower layer. In the mixed-grass habitat, tall-grass species are limited to the wetter areas on deeper, better-developed soils.

Often a sharp boundary occurs between the bottomland forest and its neighboring grassland vegetation. The bottomland forests along the Deep Fork are dominated by white (American) elm (Ulmus americana), hackberry (Celtis occidentalis), pecan (Carya illinoensis), and green ash (Fraxinus pennsylvanica). Tree species diversity and density increase as one travels eastward along the Deep Fork (Rice 1965). Much of the forest cover bordering the Deep Fork has been removed and replaced with pecan orchards, fields of agricultural crops, or pasture for domestic stock (Figs. 6, 7, and 8).

Settlement of the Deep Fork Drainage

The region that is now Oklahoma was claimed at various times by Spain, France, and England during the period of colonial struggle and territorial dispute that marked the 1600's and 1700's (Morris and McReynolds 1965). Most of the region was acquired by the United States under terms of the Lousiana Purchase in 1803, but the exact boundaries between the Purchase and Spanish territory to the southwest were not definitely established until the Adams-Onis Treaty of 1819. The boundaries included the Red River and the 100th meridian, and formed the southern and western limits, respectively, of Arkansas Territory,

Figure 6. The Clearing of Forest and Drainage Work Has Created Agricultural Lands in Much of the Formerly Bottomland Forest Along the Deep Fork. Near Chandler in Lincoln County, April 1971.

Figure 7. Extensive Clearing of Forest Lands Along the Deep Fork Is Markedly Reducing Its Forest Cover. Okfuskee County, 5 km West of Highway 48. January 1970.

Figure 8. After Clearing, Over-grazing by Domestic Stock Completes the Transition from Forest to Pasture in East-Central Oklahoma. Payne County Near Carney, September 1971.

which was created in 1819. The creation of Kansas Territory fixed the northern border of Arkansas Territory as the 37th Parallel.

The western part of Arkansas Territory, which included most of what is now Oklahoma, was designated an Indian Territory by the United States, under an act passed 30 June 1834, for possession by the Five Civilized Tribes: Choctaws, Cherokees, Chickasaw, Creek, and Seminole, which were removed from their homelands east of the Mississippi River. The Creeks officially ceded all their lands east of the Mississippi in 1832, and in 1833 the boundaries of the Creek lands in Oklahoma were established. Its northern border began 40.2 km north of the Arkansas River and extended due west to the 100th meridian; the southern boundary was the Canadian River; and its eastern limit an irregular boundary negotiated with the Cherokees.

The eastern portion of the Deep Fork drainage was included in the Creek Nation lands. The deep soil of the Deep Fork bottoms and the abundance of wildlife in the area attracted settlers here in the mid 1800's. The Federal census of 1890 recorded 500 people in Eufaula and 136 living in Okmulgee. The western portion of the Deep Fork drainage occupied unassigned lands which were first opened for settlement by whites on 22 April 1869.

Sac and Fox, Iowa, and Kickapoo Indians occupied the lands immediately west of the Creek Nation until enactment of the Organic Act of 2 May 1890 when Congress gave the territory west of the Five Civilized tribes a formal government. Formation of counties in Oklahoma occurred at the time of statehood on 16 November 1907. County boundaries within the Deep Fork drainage have remained constant since their origin in 1907.

Nuyaka Mission is an important historical landmark near the Deep Fork. It was founded by the Presbyterian Board and the Creek Nation in 1882 through the work of Alice Robertson. Nuyaka Town, nearby, was the seat of the Loyal Creek faction in the Green Peach War, led by Isparhecker, later Chief of the Creek Nation.

Sparwasser, et al. (1968) have summarized the historical development of Okmulgee County. In the first half of the 19th century, agriculture was brought to Okmulgee County by the first settlers: Creek Indians. These Indians did not own land individually but built on, improved, and cultivated any unused tribal land. Generally, they cultivated only enough land to produce corn and other produce for their own needs. A few Indians cultivated large acreages of corn and other produce for sale to the U. S. Army and to the few established trading posts in the area. Later, other settlers came, attracted by surplus Indian land and the boom caused by the discovery of oil in 1907. The boom reached its climax in the 1920's and since then the oil industry has been a major and continuing influence in Okmulgee County.

There have always been a few large ranches in Okmulgee County; but until about 1940, most farms were between 16.2 and 24.3 ha in size. Most farmers were tenants who grew most of the food for their families as well as feed for their livestock. They grew corn (*Zea mays*), oats (*Avena sativa*), hay and, as a cash crop, cotton (*Gossypium hirsutum*); and they raised a few cows (*Bos taurus*), hogs (*Sus scrofa*), and chickens (*Gallus domesticus*). They sold garden produce, dairy products, and poultry and other meat not used by the family, as well as the grain and hay not needed for their stock. By 1960, the farm population in Okmulgee County was only about a third of what it had been in 1950, there was less than one-half as many farms, and the average acreage of each farm had more than doubled.

At present, more land is used for raising beef cattle than for growing crops. Nearly half of the county is not suitable for cultivation and is used mostly as native grass range, tame pasture, and hay crop production. Pecans, mostly harvested from native trees, are an important cash crop in Okmulgee County.

Creek County was part of the Indian Territory, which included most of what now is eastern Oklahoma (Oakes, et al. 1959). The Creek and Cherokee tribes lived in the area. Hunting and fishing were their chief means of subsistence, although some agriculture was also practiced before 1860. After about 1865, a few white squatters began grazing cattle in the area, usually by agreement with the Indians. In 1889, the Indian land was divided and allotted to individuals. After 1904, some of the land was purchased by white settlers so that by the time Oklahoma was admitted as a state in 1907, Creek County had been organized and was becoming well settled by whites. The early settlers came mostly from the southeastern states and nearby states. In 1910 Creek County had a population of 26,223, but only 2,914 of these inhabitants actually lived on farms in the area. Cattle production was the principal farming activity although some cotton and corn crops were also grown. Since 1950, Creek County's rural population has continually declined and a slight increase in its urban population has occurred.

Today, the principal industry in Creek County is the production of crude petroleum and natural gas. Livestock raising is the most common type of farming in the county. Grain, cotton, vegetables and other crops are raised with the general shift from crop farming to livestock occurring here as in other counties along the Deep Fork.

The land constituting Okfuskee County was claimed by the Osage Indians at the time of the Lousiana Purchase (Buckhannan, et al. 1952). It was ceded to the Creek Nation by the United States government in exchange for their lands in Georgia after which the government of the Creek Nation was established in Okmulgee in 1838. A few white settlers ranched in Okfuskee County as early as

1870, but the land was not formally opened to white settlement until after 1903. At that time the Indians were given individual allotments, and beginning in 1904 they were allowed to sell all but 16.2 ha of this allotment. This resulted in the creation of a number of small farms within the county. White settlement began in the 1870's and 1880's with the establishment of cattle ranches on the prairie areas. The Indians obtained most of their food by hunting and fishing; agriculture was incidental to their subsistence hunting in the area.

Lincoln County was formed from the lands of the Sac and Fox and Iowa Indian Reservations, which were opened to white settlers in 1891 (Williams and Bartolina 1970). The economy of the area is mainly agricultural; livestock raising is the main enterprise. Small grains, alfalfa (*Medicago sativa*), and grain sorghum (*Sorghum vulgare*) are cultivated crops commonly produced in Lincoln County. Recently, the agricultural trend in the county is to form larger farms and ranches from the smaller units with the conversion of cropland to tame pasture to increase livestock production in the area. The conversion of timbered land to tame pasture or native range is widespread throughout the county. Currently, about 17 percent of the county is bottomland forest, 39 percent is upland prairie, and 44 percent is partly wooded land in the Cross Timbers area.

Homesteaders who came from the northern states settled in the area that is now Oklahoma County after the area was opened to settlement in 1889 (Fisher and Chelf 1969). Farming was the main occupation and is still one of the principal sources of income within the county. Main farm enterprises today include the growing of small grains, mainly winter wheat (*Triticum aestivum*), and livestock raising, primarily cattle. Most of the farmland in the eastern part of the county is in pastures of tame and native grasses. The western part of the county marks the eastern border of the main wheat-growing area of Oklahoma. The concentration of human population in and around Oklahoma City dominates land use patterns from Luther westward.

Current Trends in Land Use Along the Deep Fork Drainage

The average size of farms along the Deep Fork is increasing and in 1964 they averaged 114.4 ha each (Table V). Of the non-urban land uses along the river, only 29 percent of the land area remains forested (Table VI). About 71 percent of the area of the five counties bordering the Deep Fork of the North Canadian River is used for agricultural purposes.

As shown by Table VII, in 1967 only 10 percent of the 275,261 ha of forest land in the five counties bordering the Deep Fork were of commercial quality. Of the total

TABLE V

AGRICULTURAL LAND USES IN 1964 IN COUNTIES ALONG THE DEEP FORK[a]

County	Percent in Farm Land	Average Size of Farm in Ha		Agricultural Land Uses (ha)					
		1959	1964	Cropland Harvested	Cropland Pastured	Cropland Not Used	Woodland Pastured	Woodland Not Pastured	Idle Lands
Okmulgee	74.0	99.9	113.3	19,635	9,379	9,700	17,652	841	2,445
Creek	70.2	128.2	127.8	11,340	14,564	5,930	59,542	2,667	3,060
Okfuskee	73.4	120.0	138.1	12,635	10,506	5,234	24,550	2,616	1,444
Lincoln	79.7	108.1	106.2	22,955	7,036	4,564	32,715	2,015	1,395
Oklahoma	52.2	74.1	86.5	20,841	6,114	2,493	14,336	1,932	586
Totals		106.1[b]	114.4[b]	87,406	47,599	27,920	148,796	10,070	8,929

[a]Data extracted from Census of Agriculture 1964. Table 1. Statistics for Counties, pp. 276-283.

[b]Unweighted average farm size in acres.

TABLE VI

TOTAL NON-URBAN LAND USES, 1966, IN COUNTIES ALONG THE DEEP FORK

County	Total (ha)	Cropland (ha)	Pasture (ha)	Range (ha)	Forest (ha)	Other Land Types (ha)
Okmulgee	172,445	37,764	38,232	46,842	46,696	2,911
Creek	230,192	30,079	36,741	71,314	89,837	2,221
Okfuskee	158,062	26,234	28,971	67,620	33,475	1,762
Lincoln	242,241	34,941	29,818	111,850	63,286	2,346
Oklahoma	134,202	36,719	10,238	42,326	41,967	2,952
Total	937,142	165,737	144,000	339,951	275,261	12,193

TABLE VII

COMMERCIAL, NON-COMMERCIAL, AND GRAZING FOREST LANDS, 1967, IN COUNTIES ALONG THE DEEP FORK[a]

County	Type of Forest Land (ha) Commercial	+ Non-commercial	Total Forest Land (ha)	Total Forest Land Percent	Commercial Grazing (ha)	Non-commercial Grazing (ha)	Total Forest Land Grazed (ha)
Okmulgee	8,660	38,037	46,696	17.0	4,565	37,832	42,397
Creek	9,057	80,780	89,837	32.6	9,057	80,780	89,837
Okfuskee	4,782	28,693	33,475	12.2	4,698	28,609	33,307
Lincoln	1,134	62,151	63,286	23.0	-0-	62,151	62,151
Oklahoma	4,151	37,816	41,967	15.2	277	34,127	34,404
Total	27,784	247,477	275,261		18,597	243,499	262,096

[a]Data extracted from Oklahoma Conservation Needs Inventory, U. S. Department of Agriculture, Soil Conservation Service Report, March 1970.

forest land, 95 percent of it was grazed by domestic livestock in 1967. Creek County contained the most forest land, 32.6 percent of that found in the five counties; Okfuskee County contained the least with only 12.2 percent of the total forest land.

Of the total human population of these counties along the Deep Fork in 1970, only 6.9 percent was considered to be rural, and the remainder was urban dwellers (Table VIII). However, the population of Oklahoma County provides a disproportionate amount of the total population of the area, 87.9 percent, of which 99.7 percent is classed as urban. The other counties along the Deep Fork vary in rural population from 81.6 percent in Lincoln County to 32.3 percent in Okmulgee County. With the exception of Oklahoma County, which gained population between 1960 and 1970, all of the other counties along the Deep Fork lost both total population and rural population during this period.

The Oklahoma Department of Wildlife Conservation began in 1969 to inventory land use in all counties, updating the work of Duck and Fletcher (1943,1944). Information compiled from these reports on land-use categories in counties along the Deep Fork of the North Canadian River is presented in Table IX. This survey used aerial photographs supplied by the Agricultural Stabilization and Conservation Service (ASCS) and included the entire area of each county. The acreage of each

TABLE VIII

HUMAN POPULATION NUMBERS PRESENT IN COUNTIES ALONG THE DEEP FORK, 1920-1970[a]

	Year					
County	1920	1930	1940	1950	1960	1970[b]
Okmulgee						
total	47,429	48,911	43,567	40,167	33,469	30,987
urban	23,319	24,791	22,956	26,304	22,502	20,986
rural	24,110	24,120	20,611	13,863	10,967	10,001
Creek						
total	33,489	31,781	31,212	15,415	13,562	12,372
urban	3,460	6,619	6,050	5,400	4,795	4,582
rural	30,029	25,162	25,162	10,015	8,767	7,790
Okfuskee						
total	25,051	25,647	26,279	16,948	11,706	10,466
urban	---	2,717	3,811	3,454	2,836	2,771
rural	25,051	22,930	22,468	13,494	8,870	7,695
Lincoln						
total	28,913	29,268	25,668	19,310	16,440	16,422
urban	2,226	2,717	2,738	2,724	2,524	3,026
rural	26,687	26,551	22,930	16,586	13,916	13,396

[a]Data extracted from Preliminary Report, June 1970, Bureau of the Census. PC(PI)-38.

[b]Subject to revisions of final census report.

TABLE VIII (continued)

County	1920	1930	1940	1950	1960	1970[b]
Oklahoma						
total	111,184	215,026	237,371	316,305	436,639	511,022
urban	91,295	188,965	211,016	281,177	425,507	509,646
rural	19,889	26,061	26,355	35,128	11,132	1,376

TABLE IX

LAND-USE CATEGORIES IN COUNTIES ALONG THE DEEP FORK IN 1971[a]

Land-use Category	County										Total	
	Okmulgee		Creek		Okfuskee		Lincoln		Oklahoma			
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Area	%
Pasture	114,073	63.5	159,901	34.8	102,584	63.0	203,808	55.1	47,870	25.7	628,236	53.78
Post oak-Blackjack Oak	37,838	21.1	144,881	57.8	42,654	26.2	89,146	35.6	35,792	19.2	350,312	29.98
Oak-hickory	3,758	2.1	--	--	2,303	1.4	--	--	--	--	6,061	0.51
Bottomland Forest	16,335	9.1	6,673	2.7	8,353	5.1	788	.3	935	.5	33,085	2.83
Cultivated	2,588	1.4	1,820	.7	3,592	2.2	15,070	6.0	22,680	12.2	45,749	3.91
Wetlands	--	--	--	--	--	--	3,045	1.2	12	--	3,057	0.26
Lake	813	0.5	3,539	1.4	537	.3	463	.2	1,637	.9	6,989	0.59
River	--	--	388	.2	611	.4	105	--	341	.2	1,445	0.12

[a]Data supplied from unpublished reports and field data by Thomas Eubanks, Research Biologist, Oklahoma Department of Wildlife Conservation, Wildlife Research Center, Stillwater, Oklahoma.

TABLE IX (continued)

Land-use Category	County										Total	
	Okmulgee		Creek		Okfuskee		Lincoln		Oklahoma			
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Area	%
Urban-industrial	2,952	1.6	4,145	1.7	1,093	.7	2,372	.9	76,086	40.8	86,648	7.41
Highways	1,189	0.7	1,764	.7	1,115	.7	1,540	.6	957	.5	6,565	0.56
Totals	179,546	--	323,111	--	162,842	--	316,337	--	186,311	--	1,168,147	--

land-use category on the aerial photograph was determined by use of a compensating polar planimeter. These data provide the most accurate assessment of land uses in these five counties that is currently available.

Of the land area of the five counties, 37.8 percent was estimated to be forested: 34 percent was post oak-blackjack oak forest; 0.6 percent oak-hickory; and 3.2 percent bottomland forest. Fifty-two percent of the land area of these five counties was used for agricultural production, mainly as pasture.

Changes in land-use patterns in Sections 29, 30, 31, and 32, Okmulgee County (T14N, R11E) followed the same general trend noted for other areas along the river. Using the 1896 surveyors map as a base (Fig. 9), woodland decreased 21.5 percent in the area from 1896 to 1949 in these four sections with a corresponding increase in agricultural use of 21.3 percent (Table X).

From 1949 to 1970, a slight increase in total woodland occurred as the post oak-blackjack oak association expanded into former grassland and cultivated areas. The control of wildfire in the area may have induced this expansion. Similar increases in woodland acreage after the control of fire in grassland areas have been noted elsewhere (Weaver 1968).

Since 1970, extensive changes in land-use have occurred within these four sections (Table XI). Clearing of existing woodlands, principally the post oak-blackjack

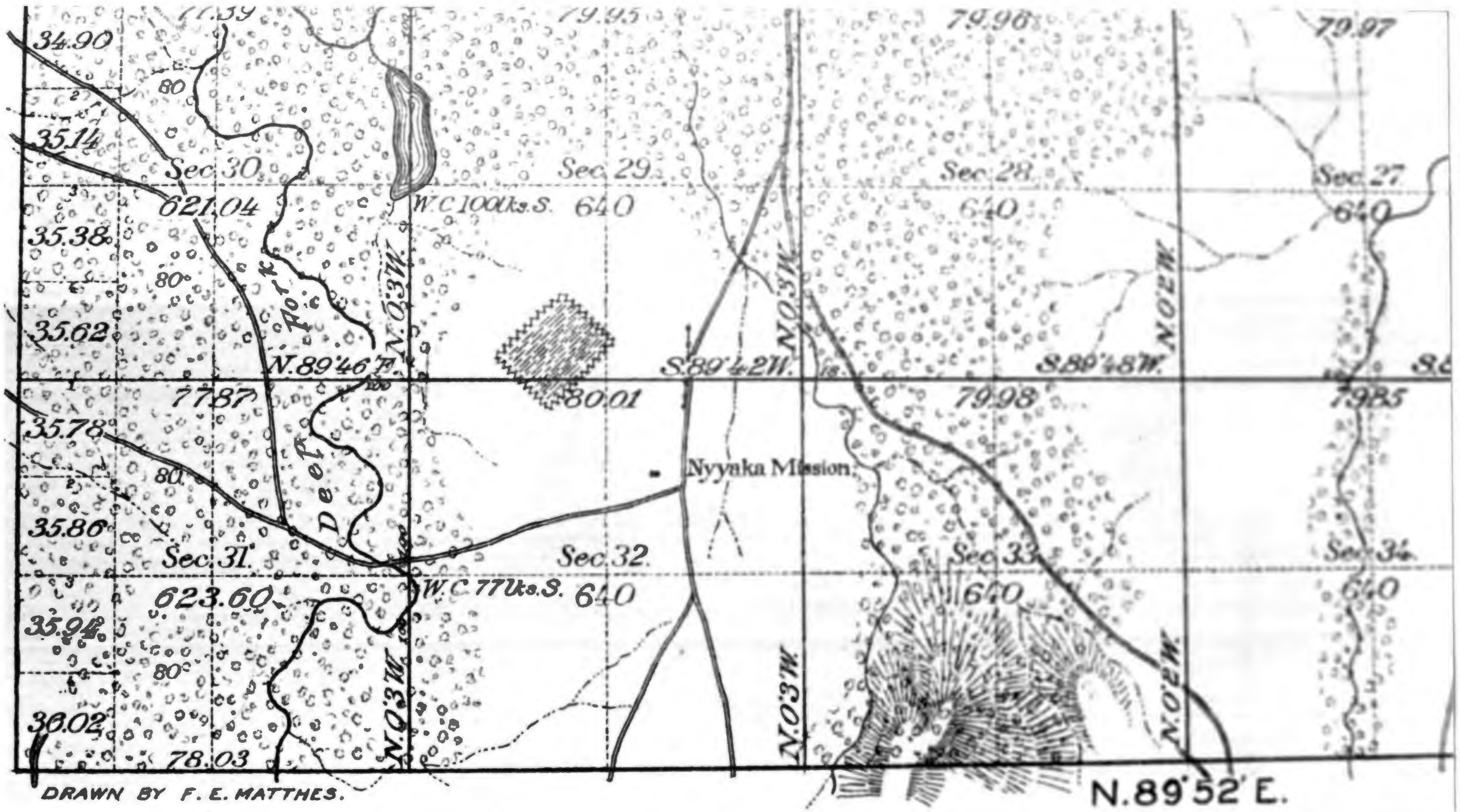

Figure 9. The Nuyaka Area as it First Appeared to Surveyors in 1897. The NE 1/4 and the S 1/2 of Sec. 30 and the E 1/2 of Sec. 31 Contain the Spears Study Area.

TABLE X

CHANGES IN LAND-USE ALONG THE DEEP FORK, SECTIONS 29, 30, 31, AND 32 (T14N, R11E), OKMULGEE COUNTY, OKLAHOMA, 1896 TO 1974

	Year									
	1896		1949		1956		1970		1974[a]	
Land-use	Percent	Ha	Percent	Ha	Percent	Ha	Percent	Ha	Percent	Ha
Woodland	67.7	692	46.2	472	48.1	492	50.8	519	43.2	442
Agricultural	31.1	318	52.4	517	50.6	517	48.0	490	55.6	568
Other	1.2	12	1.4	13	1.3	13	1.2	12	1.2	12

[a]Intensive clearing of woodlands known to have occurred in 1972 and 1973 within the four sections.

TABLE XI

LAND-USE ALONG THE DEEP FORK, OKMULGEE COUNTY, OKLAHOMA, SECTIONS 29, 30, 31, AND 32 (T14N, R11E), 1970

	Section Number								Total	
	29		30		31		32			
Land-use	Percent	Ha	Percent	Ha	Percent	Ha	Percent	Ha	Percent	Ha
Woodland	35.7	92.0	82.5	209.0	74.6	187.0	11.9	31.0	50.8	519.0
Bottomland Forest	4.2	11.0	43.4	110.0	47.2	118.0	--	--	23.4	239.0
Post oak-Blackjack Oak Forest	15.9	41.0	12.0	30.0	3.9	10.0	11.9	31.0	11.0	112.0
Pecan Orchard	15.3	40.0	27.1	69.0	23.5	59.0	--	--	16.4	167.0
Agricultural	63.6	164.0	16.7	42.0	22.7	56.0	88.3	226.0	48.0	490.0
Cultivated	14.4	37.0	--	--	16.2	40.0	0.5	1.2	7.7	79.0
Pasture	49.2	127.0	16.7	42.0	6.5	16.0	87.8	225.0	40.3	411.0
Other	0.5	1.2	0.8	2.0	2.6	6.8	0.9	4.8	1.2	30.0
River	0.2	0.4	0.7	1.6	1.0	2.4	--	--	0.4	4.5
Ponds	0.3	0.8	0.1	0.4	0.5	1.6	0.6	4.0	0.4	4.0
Roads	--	--	--	--	1.1	2.8	0.3	0.8	0.3	3.6

oak uplands, to provide additional pastureland, has resulted in a 7.6 percent decrease in the forest cover of the area since 1970. Considerable logging of the bottomland forest, about 56.6 ha in all, in Section 30 in 1972 and 1973, has changed the structure of the forest area. Most large oak and pecan trees have been selectively harvested from this area. Intensive management of the pecan orchards in this area has resulted in the thinning of the orchard and cutting out many of the old pecan trees that provided dens for many species of wildlife. The ground between the trees is being cleared, seeded, and mowed regularly to establish permanent pasture, further reducing the diversity of the area and consequently making it poorer in quality and quantity for wildlife species present in the area.

Future Management of the Deep Fork Bottomlands

The trend in land use and demands along the Deep Fork of the North Canadian River is clear: development of agribusiness combines that result in more intense agricultural management, clearing of existing post oak-blackjack oak on the uplands to create more pastureland for domestic stock, and conversion of bottomland forests either into pecan orchards or into cropland or pasture by logging off the timber (Figs. 10-16).

Figure 10. Application of Herbicides to the Post Oak-Blackjack Oak Forest Is an Effective Way of Converting Forest Land to Pastureland in East-Central Oklahoma. Creek County, 8 km N of Bristow, March 1971.

Figure 11. Mechanical Clearing of Forest Cover Often Follows the Application of Herbicides to These Areas. Creek County, 8 km N of Bristow, March 1971.

Figure 12. After Tree Removal, Improper Range Management Results in Woody Shrubs Rapidly Re-establishing Their Dominance on the Area. Creek County, 6 km N of Bristow, March 1971.

Figure 13. Careless Logging Practices Destroy Much of the Available Timber Resources Along the Deep Fork. Walker Study Area, January 1970.

Figure 14. Clearing of Timber from Natural Draimages Reduces Squirrel Habitat and Often Produces Serious Soil Erosion Problems. All Trees but Pecans Have Been Cut from This Site. Okfuskee County, 3 km S of the Deep Fork and 2 km E of Highway 48. March 1971.

Figure 15. Salt Water, Produced by Oil Extraction Commonly Creates Sterilized, Erosion-prone Areas in the Deep Fork Drainage. This Area Is 8 km East of the Entrance to the Okmulgee Public Hunting Area. June 1970.

Figure 16. Modern, Intensive Management of Pecan Orchards Leaves Little Suitable Habitat for Squirrels in These Coverted Bottomlands of East-Central Oklahoma. Hayden Pecan Orchard, 2 km S of Walker Study Area. April 1970.

In 1971, bottomland forest made up only 3.2 percent of the total forest cover in the counties bordering the Deep Fork; it now probably makes up less. It is this habitat that contains the most diverse wildlife aggregation and represents perhaps some of the finest squirrel habitat remaining in Oklahoma. The path of the Deep Fork between two population centers of Oklahoma, Oklahoma City and Tulsa, makes this drainage a logical choice to satisfy some of the recreational demands of these population centers. However, much of the land-use patterns developing or proposed for the Deep Fork destroy its very qualities of wildness that make it valuable for recreation.

To my knowledge, no virgin bottomland forest exists along the Deep Fork. The only 64.8 ha that I felt qualified as such along the river's entire 370 km length was clearcut in December 1969. It was the only area I was able to find along the river that had not been previously logged or burned recently and showed no evidence of grazing by domestic stock except on its outer fringes.

It seems reasonable to me that representative portions of the bottomland forest association be preserved as soon as possible for their recreational and scientific values. These bottoms represent a unique association of plants and animals that are found nowhere else except along rivers such as the Deep Fork in east-central Oklahoma. It becomes a national loss if, as now appears likely, the fate of all Oklahoma bottomland forest is to become either pasture or cropland, interspersed with manicured pecan orchards.

CHAPTER IV

CHARACTERISTICS OF HABITATS IN THE SPEARS STUDY AREA

Introduction

The Spears Study Area is located near the western border of Okmulgee County, about 24.1 km west of Okmulgee, Oklahoma (Fig. 1). The 160 ha area is dominated by open pecan orchards and is grazed regularly by domestic cattle and horses. The area is managed primarily for cattle and pecan production; no agricultural crops are produced on the site. Lowland areas near the Deep Fork of the North Canadian River are subject to periodic flooding. The area experienced two major floods per year during 1970 to 1972. The habitat types present on the area and their respective acreages are shown in Table XII. Changes in land-use patterns in this general area have been previously discussed in Chapter III.

Methods and Materials

Data on soil conditions within the Spears Study Area was collected from soil samples collected at randomly located points within the major vegetation types of the

TABLE XII

MAJOR HABITAT TYPES OF THE SPEAR'S STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Habitat Type	Area (ha)	Percent of Total Area
Pecan Orchard	92.7	57.8
Bottomland Forest	26.7	16.7
Post Oak-Blackjack Oak Forest	11.3	7.1
Pasture	20.6	12.9
Brush	6.5	4.0
Standing Water (9 ponds)	2.4	1.5
Total	160.2	100.0

area: pecan orchard, bottomland forest, and posk oak-blackjack oak forest. Soil samples were taken from the 0 to 15 cm and 45 to 61 cm levels. Chemical tests, performed by the Soil and Water Service Laboratory, Agronomy Department, Oklahoma State University, Stillwater, determined the pH, percent of organic matter, and available phosphorus, available potassium, and available nitrogen in the samples. Mechanical analysis of the soils was done by the Bouyoucos hydrometer method (Bouyoucos 1936). Mr. Roscoe M. Long, Soil Scientist with the U. S. Soil Conservation Service, visited the study area and provided the physical descriptions of the major soil types within the area. Rice (1965) has reported on soil conditions in the bottomlands west of the study area, and soil survey maps were also available to provide general guidance for collection of soils data from this area (Sparwasser, et al. 1968).

Vegetation was sampled using the point-centered-quarter method developed by Curtis and McIntosh (1951) with correction for measurement to the center of each stem rather than just to its closest edge (Ashby 1972). Location of randomly located sample points within each habitat type sampled was achieved in the following manner: from a randomly selected starting point, a random azimuth provided direction for the route of the point-centered-quarter line, and a randomly chosen distance along the line, from 1 to 50 paces from the previous point, marked the location of the next sample point. Proportional allocation of sample points within habitat types was used to maintain equal sampling intensities between habitat types so that statistical comparison of types was possible. The stratified-random-sampling analysis used follows that of Cochran (1963). Data were analyzed at California State University, Fresno, on a CDC 3150 computer. The program developed for this analysis is on file at The Computer Center, California State University, Fresno.

For this vegetation work, a tree was considered to be any woody plant having a total stem diameter at breast height, 1.4 m above the ground (dbh), greater than 7.6 cm. A shrub was considered to be any woody plant having a dbh less than 7.6 cm. Its diameter was measured with calipers 2.54 cm above the surface of the ground.

In each forest type, the randomly selected tree in the point-centered quarter was also classified as either a potential den tree or not. Trees were examined with the aid of binoculars and any above-ground cavity seen was sufficient to denote the tree as at least a potential den site for squirrel use. No attempt was made to categorize the den as suitable for either escape or rearing of young. Using the method of Snedecor and Cochran (1967:6), 95-percent confidence intervals were placed around these estimates of den frequencies.

The presence or absence of an apparently recent, active, leaf nest, referred to as "dreys" in Europe, was also noted during examination of the tree. A complete count of all leaf nests present on 41.7 ha of the study area was also conducted in March 1971 and March 1972. The abundance of leaf nests may serve as a general indication of squirrel numbers on an area (Uhlig 1955a).

Results and Discussion

Historical Development and Effects of Man

Discussions with the owners of the study area, Mr. and Mrs. William Spears, produced the following historical picture of development and changes that the area has undergone since the late 1930's. This area was sold in 1972 and although the new owners have caused extensive changes on the area, no information as to the exact extent of these changes is currently available. Figure 17 denotes the six general areas mentioned in this discussion. Until the current study, beginning in 1970, only a limited amount of squirrel hunting was allowed on the study area.

The procedure used in converting forest land into pecan orchard was to first poison all trees other than pecan with an arsenic-caustic soda mix. After dying, the limbs fell off the dead trees and these were collected and burned. Eventually, the stubs of the trees themselves toppled and also were burned. In the mid 1940's, mechanical power was first used on the area for clearing land; until

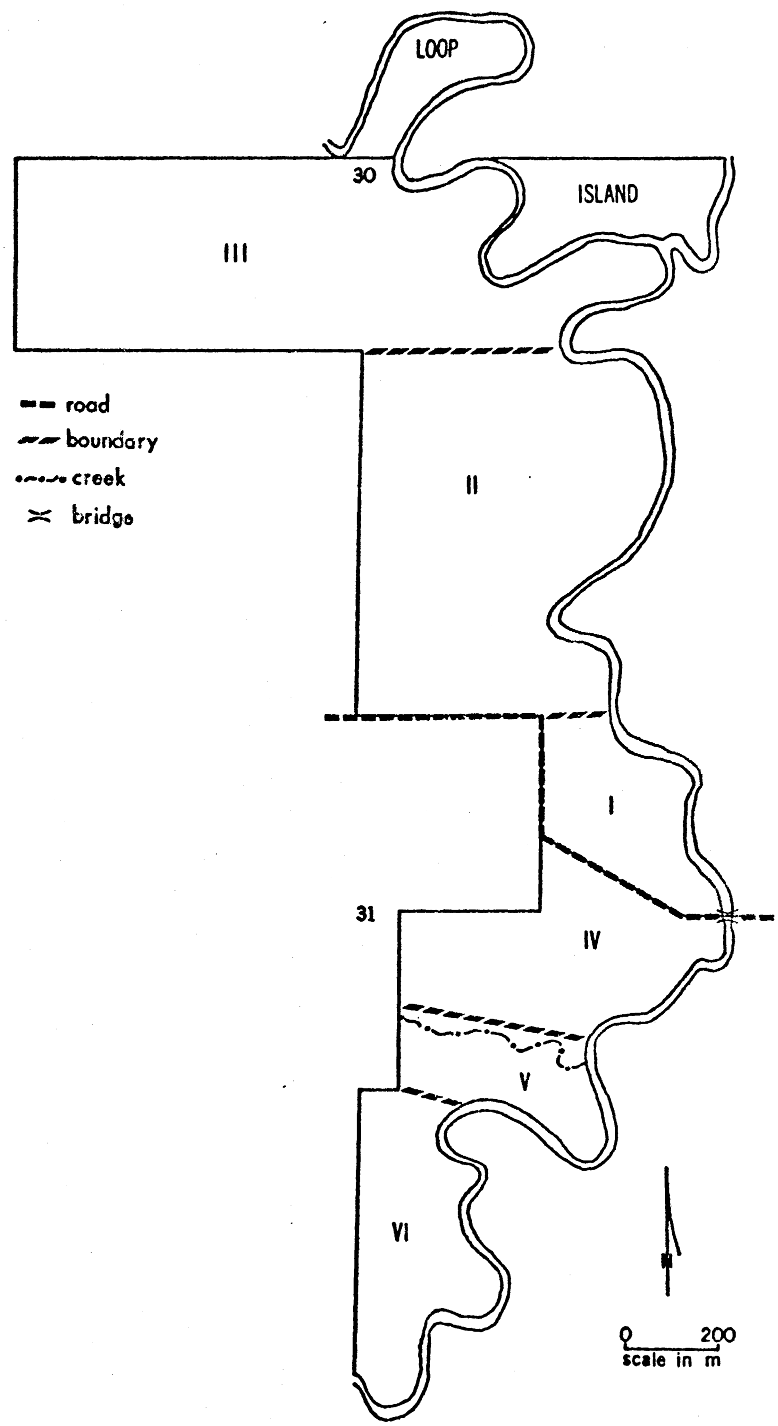

Figure 17. Administrative Areas of the Spears Study Area.

then only horse- and man-power were used to clear the area of forest cover.

The land west of Area I, now classified as pasture land, was first cleared of post oak-blackjack oak forest in the 1920's and converted to crop land. Little of the acreage south of the bridge in Area IV was cleared until the early 1930's when approximately 4.0 ha of it was cleared. Area I is subject to extensive flooding which occurs almost annually. The deadening of tree species other than pecan first occurred on Area I in 1937.

The first systematic clearing of land on the area began in 1940. In 1940, the Spear's purchased the Areas II and III and in 1942 deadened all trees except pecans having a dbh greater than 10 cm within these areas. The eastern portion of Area II became very brushy after this treatment, but the rest of Area II and III were under control for pecan management.

One of the worst floods in recent times occurred in 1941, washing the wooden planks off the bridge crossing the study area. It converted a large pond in Area II into the slough that today still occurs on the area.

In 1943, about 4.0 ha of brush were cleared from Area IV and all trees except pecans were deadened in Areas V and VI during the mid 1940's. In 1946-47, 4.0 to 6.0 ha of brush, consisting mostly of red haw (<u>Crataegus</u> sp.) were cleared from the northwestern quarter of Area

II. Any woody shrub with a dbh of less than 7.6 cm was removed from the area.

During the decade of the 1950's the most extensive changes in vegetation on the study area occurred. In 1950, the Spear's purchased the western half of Area III and logged off all the oak on it in 1952. In 1953, all weed trees on Area III were poisoned; and, by 1955, all clearing of unwanted vegetation had been completed on the area. In 1955, the dense brush on either side of the road crossing the study area, at that time too dense to allow one to see north into the pecan grove of Area I, was cleared. This brush consisted primarily of haw and privet (Forestiera acuminata). Area II was selectively logged in 1950 to 1955, removing large, old pecan trees not producing an adequate harvest of pecans.

Consolidation of many small land ownerships on the study area into one larger ranch resulted in cessation of agricultural crops being grown on the area. The Northwest corner of Area IV, now grown to brush (Fig. 18), was farmed for the last time in 1950. The cleared areas west of the post oak-blackjack oak forest on Area I, now classified as pasture, once produced cotton and corn, but since 1950 have been converted to grassland.

The post oak-blackjack oak forests on the Areas I, IV, and III represent relatively natural stands of this forest type as they have not been cleared or disturbed for 20 to

Figure 18. Farmland, Formerly Cleared of its Original Post Oak-Blackjack Oak Forest, Reverts Back to Brush a Few Years After Farming on It Ceases. Spears Study Area, March 1972.

25 years. The post oak-blackjack oak stand in Area II has been undisturbed for more than 30 years.

In 1955, Spears recleared the eastern one-half of Area II and also cleared the fringe area south of the bottomland island in Area III, but did not clear the center of the area. Another large flood occurred in 1955; Spears lost 20 head of cattle that were marooned on the island in Area III and swept from its highest point by the flood waters.

In 1957, the island portion in the northeastern part of Area III was logged, and all large oaks, mostly red oak (Quercus rubra), were selectively cut from the area. No pecan were logged from the Spear's portion of the island at this time.

In 1960, the area east of the post oak-blackjack oak woods in Area IV was cleared, brush in Area V near the river was removed, and intensive removal of brush in Area II, particularly the northwestern portion, occurred. Selective logging of large pecan trees throughout the study area occurred in 1967. Trees known to be poor bearers of pecans were cut and their butt logs sold for use as veneer.

During the winter of 1967-68 all large green ash (Fraxinus pennsylvanica) were cut out of the wet bottomland forest in Area VI. A limited amount of logging also occurred on the island area of Area III during the same winter with a few large pecan trees removed from it.

In summary, in the past 30 to 40 years the study area has been transformed from a forested area supporting several small farms and their associated field crops into a consolidated ranch managed exclusively for producing pecans and grazing domestic stock. However, the area has not been managed as intensively as ranching operations of this type customarily are in eastern Oklahoma. Consequently, in 1970-1972 the area still contained an abundance of wildlife and provided an excellent area on which to study the ecology of fox and gray squirrels.

Physiography and Geology of the Study Area

The Deep Fork provides the drainage for the area. Several small feeder streams periodically drain into the Deep Fork. The geologic formations are sedimentary in origin (Sparwasser, et al. 1968). Except for Recent Alluvium and Quaternary terrace deposits, these formations belong to the Pennsylvania system. These formations consist mostly of sandstone and shale. Elevations on the site vary from about 198 m at river bank to 229 m above sea level at the highest point of the study area in the northwestern portion of Area III.

The Recent Alluvium is much younger than the terrace deposits and is made up of debris washed from areas of these deposits and from the higher areas of the Pennsylvania formations. Since man's settlement of areas along the Deep

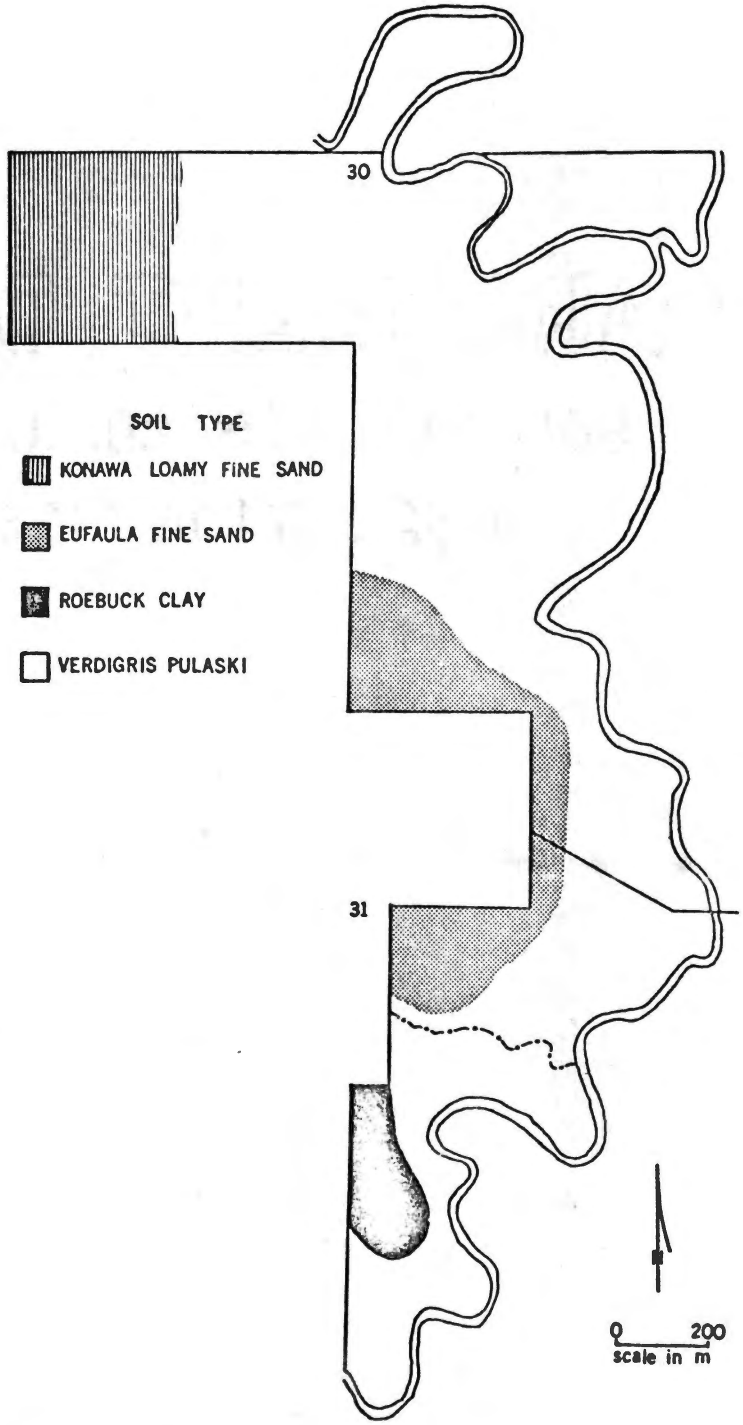

Figure 19. Soil Types in the Spears Study Area.

Fork accumulations of these sediments have increased considerably (Geiger and Gray 1965).

Soils of the Study Area

As shown by Figure 19, four major soil types occur on the area with most of it being dominated by Verdigris-Pulaski soils on areas covered by pecan orchard or bottomland forest near the Deep Fork. Roebuck clay occurs only on the higher portions of the study site near the river while Konawa loamy sand occurs on the uplands of the area. Both sandy soil types support post oak-blackjack oak forests typical of this area of east-central Oklahoma. Table XIII presents a detailed description of the three dominant soil types found on the study area. The results of chemical and textural analysis performed on soil samples collected from major habitat types on the study area are presented in Tables XIV and XV.

No significant difference in pH, percentage of organic material, or phosphorus was found between soil samples taken from the 0 to 15 cm depth and samples from the 46 to 61 cm levels in the bottomland and pecan orchard sites. No significant differences in these attributes were found between the concentrations of potassium estimated to be present in these two layers (t=7.38) and also a significant difference between the percentage of organic material present in the 0 to 15 cm and 46 to 61 cm layers of soil in the pecan orchard. Nitrogen levels for all samples

TABLE XIII

DESCRIPTION OF COMMON TYPES OF SOILS FOUND ON THE SPEARS STUDY AREA, TAKEN MARCH 1972[a]

Soil Profile: Number 1 (formerly cultivated field)
1.5 percent slope (moist colors)
Soil Type: Eufaula fine sand

Horizon description:

Ap — 0 to 18 cm; (10YR 4/2) dark grayish brown; loamy fine sand; massive; loose; pH 6.5; clear boundary 10 to 25 cm thick.

A_2 — 18 to 38 cm; (10YR 6/4) light yellowish brown; fine sand; massive; loose; few fine and medium faint brownish mottles; clear boundary 8 to 25 cm thick.

B_2t — 38 to 152 + cm; (10YR 7/5) yellow; loamy fine sand; bands 5 to 10 cm apart and 0.3 to 0.6 cm thick; (5YR 5/4) reddish brown; massive; loose, pH 6.4.

Remarks: Thickness of A horizon varies from 7 cm to as much as 38 cm. Color ranges from dark grayish brown, brown, or pale brown. Bands of heavier material varies from none to 1.3 cm in thickness.

Soil Profile: Number 2 (timbered uplands) 4.0 percent slope (moist colors)
Soil Type: Konawa loamy fine sand

Horizon description:

01 — 0 to 2.54 cm, partially decomposed forest litter.

A_1 — 2.5 to 15 cm; (10YR 4/4) dark grayish brown; loamy fine sand; weak fine grandular structure; very friable; pH 6.1; clear boundary 10 to 25 cm thick.

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[a]Soil profile descriptions provided by Mr. Roscoe M. Long, Soil Scientist, Soil Conservation Service, Muskogee, Oklahoma, from randomly selected soil pits dug within the Spears Study Area, 30 March 1972.

TABLE XIII (continued)

A_2	15 to 33 cm; (10YR 6/4) light yellowish brown; loamy fine sand; massive; loose; pH 5.6; abrupt boundary 13 to 20 cm thick.
B_2t	33 to 84 cm; (2.5YR 5/8) red; sandy clay loam; coarse; strong; subangular blocky structure; firm; pH 5.1; diffuse boundary 38 to 64 cm thick.
B_3	84 to 130 cm; (2.5YR 5/6) red; sandy loam; weak; moderate; subangular blocky structure; friable; gradual boundary 30 to 51 cm thick.
C	130 to 165 + cm; (5YR 5/6) yellowish red; fine sandy loam; weak fine blocky structure, breaking to massive; very friable.
Remarks:	Thickness of A_1 horizon ranges from 10 to 25 cm. Color varies from (7.5YR 4/2) dark brown to (7.5YR 6/4) light brown. Texture generally is a loamy fine sand, but in places may be a light fine sandy loam. A_2 horizon varies from 10 to 25 cm thick with textures of loamy fine sand to fine sand. The B_2t horizon is generally reddish with textures ranging from a heavy fine sandy loam to a clay loam in places. Depth to sandy material varies from 152 to 213 cm.

Soil Profile: Number 3 (pecan orchard-bottomland forest)
0 to 1.0 percent slope (moist colors)
Soil Type: Verdigris-Pulaski soils, frequently flooded

Horison description:

A_1	0 to 18 cm; (5YR 3/3) dark reddish brown; silty clay loam; strong, fine and medium subangular blocky structure; very firm; many worm casts; pH 6.1; clear boundary 13 to 46 cm thick.

TABLE XIII (continued)

C_1	18 to 43 cm; (5YR 5/4) reddish brown; heavy silt loam; weak fine and medium subangular blocky structure, breaking into massive; friable; pH 6.6; gradual boundary 43 to 183 cm thick.
C_2	43 to 183 cm; (7.5YR 5/4) brown; fine sandy loam; massive; loose; few fine faint (7.5YR 5/6) mottles; pH 7.1.
Remarks:	This is frequently flooded bottomland. Texture varies from a silty clay loam to a fine sandy loam. Depth to sandy material varies from 25 to 76 cm.

TABLE XIV

RESULTS OF CHEMICAL ANALYSIS OF RANDOMLY SELECTED SOIL SAMPLES FROM THE SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA

Habitat Type	n	Sample Depth (cm)	pH	Percent Organic Matter (1SE)	P Kg/Ha (1SE)	K Kg/Ha (1SE)
Bottomland	3	0-15	6.46	1.2 (.20)	29.9 (2.9)	441.9 (120.8)
forest	3	46-61	6.30	0.7 (.70)	24.0 (5.8)	113.5 (19.5)
Pecan orchard	3	0-15	6.20	2.53 (.45)	54.3 (45.7)	447.5 (74.2)
	3	46-61	6.06	0.56 (.11)	52.0 (58.2)	123.9 (92.9)
Post oak-						
blackjack oak	3	0-15	5.60	1.06 (.47)	24.0 (10.1)	179.0 (136.2)
forest	3	46-61	5.73	0.23 (.05)	21.0 (14.1)	28.9 (16.9)

TABLE XV

RESULTS OF MECHANICAL ANALYSIS OF RANDOMLY SELECTED SOIL SAMPLES FROM THE SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA

Habitat Type	n	Sample Depth (cm)	Sand Percent (1SE)	Silt Percent (1SE)	Clay Percent (1SE)
Bottomland forest	3	0-15	41.5 (11.7)	18.5 (0.0)	40.0 (11.8)
	3	46-61	46.7 (14.9)	22.3 (3.6)	24.3 (7.4)
Pecan orchard	3	0-15	31.5 (7.2)	17.7 (3.6)	50.4 (3.6)
	3	46-61	62.2 (7.8)	18.2 (3.5)	19.7 (4.5)
Post oak-blackjack oak forest	3	0-15	79.0 (9.8)	8.1 (1.5)	12.8 (8.3)
	3	46-61	86.8 (3.7)	7.5 (2.2)	5.7 (2.0)

taken on the Spears Study Area were estimated to be less than 4.5 kg per 0.4 ha.

Because of the disturbed nature of the pecan orchard portion of the study area, no correlation coefficients between soil factors and stand density were calculated. Rice (1965) found no apparent correlations between the type of plant community or the distribution of individual species and soil factors he analyzed in forests in north-central Oklahoma.

Vegetation of the Study Area

Four major habitat types occur on the study area: pasture-brush, post oak-blackjack oak forest, pecan orchard, and bottomland forest (Fig. 20). The bottomland forest type was divided into two types: a wet bottomland, found on Roebuck Clay, and the dry bottomland forest occurring on Verdigris-Pulaski soils.

Post Oak-Blackjack Oak Forest. Only 11.3 ha of post oak-blackjack oak forest type occurs on the study area in four areas. Most upland areas once supporting post oak-blackjack oak forest have now been converted to pastureland (Fig. 21). The post oak-blackjack oak forest stands were dense and had an overall density of 291 stems per 0.4 ha (Figs. 22, 23, and 24) and a mean distance of 3.71 m between trees. The combined estimated basal area

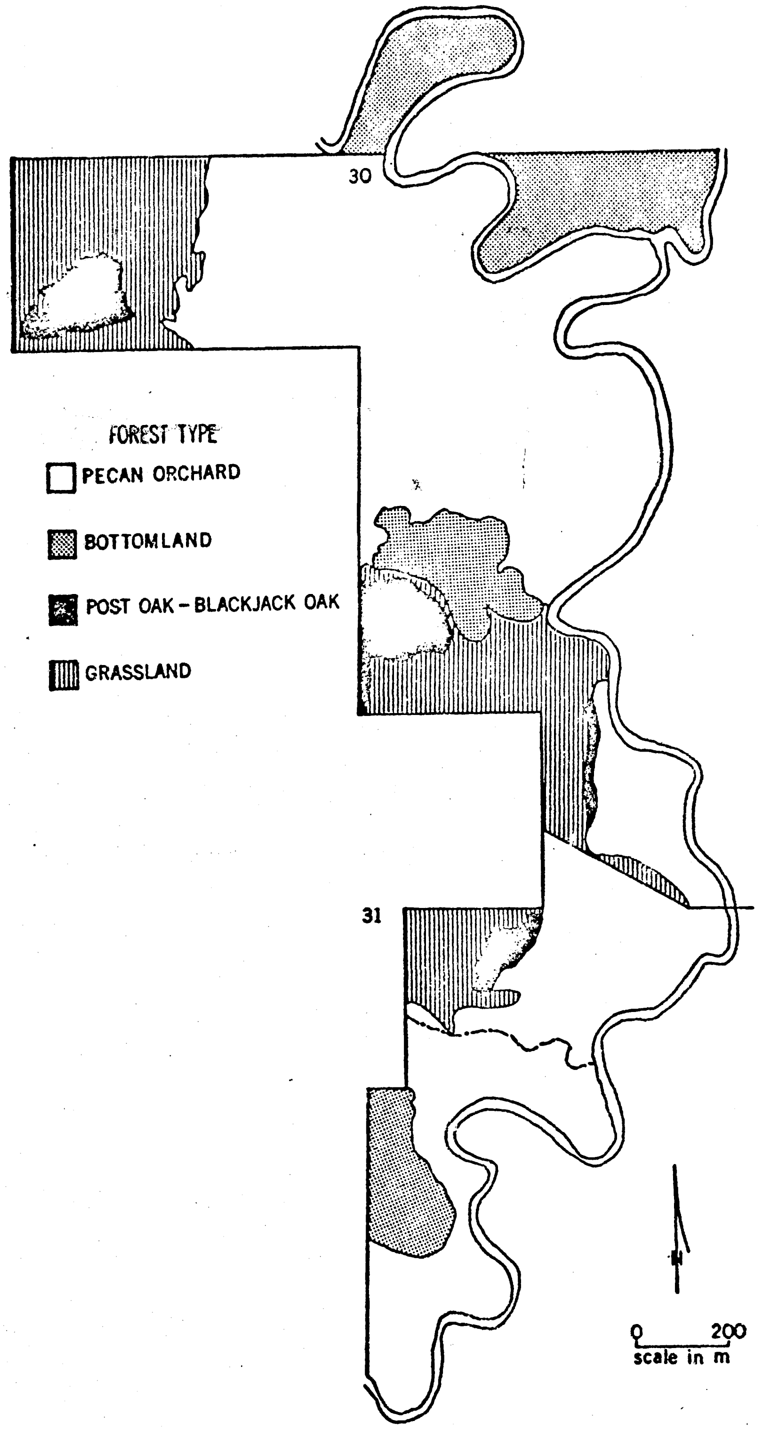

Figure 20. Vegetation Types in the Spears Study Area.

Figure 21. Most of the Upland Forest on the Spears Study Area Has Been Converted to Pasture. March 1972.

Figure 22. The Post Oak-Blackjack Oak Forest Consists of Small Trees in Dense Stands on Sandy Soils. Spears Study Area, March 1972.

Figure 23. Apparent Density of the Post Oak-Blackjack Oak Forest Depends on the Season of the Year. Spears Study Area, July 1972.

Figure 24. Clearing of the Post Oak-Blackjack Oak Stands Often Results in Serious Erosion Problems Such as Is Developing on This Site 3 km Southeast of the Spears Study Area. March 1971.

for trees on the site was 30.39 m^2 per ha. Average basal area per tree on the site was .04 m^2.

Post oak dominates this type of woodland. Blackjack and black oak (*Q. velutina*) also are important members of this tree community, as are white (American) elm and winged elm (*Ulmus alata*). Table XVI presents the results of the point-centered-quarter sampling on the post oak-blackjack oak sites.

The shrub component of this forest type consists of many species of shrubs but is dominated by post oak, elm, and hickory (*Carya* sp.) seedlings, dogwood (*Cornus drummondii*), and chittamwood (*Bumelia lanuginosa*). Density of shrubs per acre on the post oak-blackjack oak site was 1,941 stems per 0.4 ha with an estimated basal area of 1.47 m^2 per ha.

Bottomland Forest. Because of obvious differences in soil type, moisture conditions, and plant composition, two subtypes of bottomland forest were recognized on the study site: wet bottomland forest and dry bottomland forest.

Wet bottomland forest occupied 4.0 ha in Area VI on the study site (Fig. 25). It had an average tree density of 185.6 stems per 0.4 ha with a mean distance between trees of 4.66 m. Basal area on this forest type was 63.6 m^2 per ha with an average basal area per tree of 0.45 m^2.

Green ash and southern hackberry dominated the tree cover of this forest type (Table XVII). The shrub layer

TABLE XVI

VEGETATION ANALYSIS FOR POST OAK-BLACKJACK OAK FOREST STRATA, SPEARS STUDY AREA

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
Tree							
Post Oak	52	155.6	165.0	91.3	7.10	3.5	1.8
Black Oak	9	35.6	28.6	26.1	1.70	5.0	2.6
American Elm	11	33.0	34.9	30.4	0.90	3.8	1.9
Winged Elm	6	28.0	19.0	21.7	1.40	5.4	3.2
Blackjack Oak	5	19.4	15.9	21.7	0.50	5.8	3.9
Hickory	6	18.4	19.0	17.4	0.50	8.9	2.8
Chittamwood	2	3.9	6.4	8.7	0.10	3.6	3.0
Red Mulberry	1	2.0	3.2	4.4	0.01	1.4	---
Total	92	300.0	292.0	221.7	12.29	4.3	1.45 (1SE= .15)
Shrub							
Post Oak	16	56.6	337.6	34.8	0.4	1.3	0.8
American Elm	10	46.1	211.0	30.4	0.3	3.2	1.5
Dogwood	18	32.5	379.8	30.4	T[a]	1.2	0.7
Hickory	6	29.6	126.6	21.7	0.2	2.8	1.9
Chittamwood	6	26.8	126.6	21.7	0.2	1.8	1.2

[a]T indicates value of less than 0.1.

TABLE XVI (continued)

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
Blackjack Oak	3	21.0	63.3	13.0	0.2	1.6	0.4
Buckbrush	9	19.0	189.9	21.7	T	1.0	0.5
Vitis sp.	3	9.6	63.3	13.0	T	1.5	0.5
Poison ivy	4	7.9	84.4	8.7	T	1.8	2.5
Winged Elm	3	7.3	63.3	8.7	T	0.8	0.2
Amelanchier sp.	3	7.1	63.3	8.7	T	1.0	0.5
Privet	1	6.9	21.1	4.4	0.1	2.0	---
Smooth Sumac	3	6.8	63.3	4.4	T	0.9	0.3
Red Mulberry	1	5.7	21.1	4.4	T	2.0	---
Redbud	1	3.0	21.1	4.4	T	0.9	---
Moonseed	1	2.9	21.1	4.4	T	2.2	---
Rubus sp.	1	2.9	21.1	4.4	T	1.5	---
Ilex sp.	1	2.9	21.1	4.4	T	2.3	---
Smilax sp.	1	2.8	21.1	4.4	T	2.3	---
Virginia Creeper	1	2.8	21.1	4.4	T	0.8	---
Total	92	300.0				1.62	.73 (1SE= .07)

Figure 25. The Wet Bottomland Forest Type on the Spears Study Area Is Dominated by Green Ash and Swamp Privet. March 1972.

TABLE XVII

VEGETATION ANALYSIS FOR WET BOTTOMLAND FOREST STRATA, SPEARS STUDY AREA

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
			Tree				
Green Ash	17	139.0	88.2	80.0	14.2	5.2	3.0
Hackberry	14	96.3	65.0	80.0	6.4	5.5	2.8
American Elm	7	26.6	13.9	30.0	1.4	5.6	2.4
Privet	2	20.2	9.3	10.0	2.7	3.5	2.1
Pecan	1	9.3	4.6	10.0	.6	5.8	---
Red Haw	1	8.6	4.6	10.0	.4	7.5	---
Total	42	300.0	185.6	220.0	25.7	5.3	0.6 (1SE= .09)
			Shrub				
Privet	11	126.1	186.0	40.0	0.7	3.9	1.9
Green Ash	16	108.5	270.6	70.0	0.2	2.8	1.5
Hackberry	10	44.7	169.1	30.0	T[a]	1.7	1.0
Smilax sp.	2	12.0	33.8	10.0	T	3.4	0.9
American Elm	1	8.8	16.9	10.0	T	0.9	---
Total	40	300.0	676.5	160.0	0.9	2.8	0.9 (1SE= .13)

[a]T indicates value of less than 0.1.

of this community is composed almost exclusively of swamp privet and seedlings of green ash and southern hackberry. This type has a basal area of 2.2 m^2 per ha and an average basal area per plant of 0.001 m^2. Density of shrubs in this type is 676.4 stems per 0.4 ha with an average spacing of 2.43 m between plants.

Dry bottomland forest occupied about 22.7 ha on the study site (Figs. 26 and 27). It is the most complex of the habitats occurring on the area and has the greatest diversity of wildlife (Table XVIII). This forest type has a tree density of 142.1 stems per 0.4 ha and an average distance between trees of 5.3 m. It has an estimated basal area of 38.1 m^2 per ha and an average basal area of 0.1 m^2 per stem. Elms clearly dominate the tree strata, but oaks, such as northern red oak, swamp white oak (*Q. bicolor*) and burr oak (*Q. macrocarpa*), and pecan are also important components of the tree strata. However, many other species of trees occasionally occur on the site (Table XIX).

The shrub layer of the dry bottomland forest is equally diverse and dense. It has an estimated 1,833.3 stems per 0.4 ha with an average mean distance between plants of 1.49 m. Basal area of shrubs per acre is 4.7 m^2 per ha with an average basal area per stem of 0.001 m^2. Pecan and elm seedlings, poison ivy (*Rhus radicans*), and greenbrier (*Smilax* sp.) dominate this shrub layer.

Figure 26. The Deep Fork of the North Canadian River Is a Sluggish Stream, Twisting and Turning Through a Narrow Corridor of Bottomland Forest in Creek, Okfuskee, and Okmulgee Counties, Oklahoma. Walker Study Area, November 1969.

Figure 27. The Bottomland Forest Presents a Green Wall of Dense Vegetation in the Summer. This Habitat Is Preferred by Gray Squirrels in East-Central Oklahoma. Spears Study Area, July 1971.

TABLE XVIII

VEGETATION ANALYSIS FOR DRY BOTTOMLAND FOREST STRATA, SPEARS STUDY AREA

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
			Tree				
American Elm	41	65.7	35.1	58.5	3.2	5.0	3.4
Pecan	19	41.8	16.3	34.2	2.9	8.3	5.3
Northern Red Oak	16	32.8	13.7	26.8	2.1	6.6	3.6
Winged Elm	16	24.0	13.7	24.4	0.9	6.2	2.7
Green Ash	15	20.5	12.8	22.0	0.6	5.2	3.6
Hackberry	13	20.3	11.1	19.5	0.9	6.1	3.8
Sycamore	16	18.4	5.1	14.6	1.5	6.3	5.3
Burr Oak	7	17.1	6.0	17.1	1.1	6.3	3.5
Cottonwood	6	12.6	5.1	12.2	0.7	7.0	3.6
Red Elm	6	11.1	5.1	14.6	0.4	4.4	2.2
Black Willow	4	6.8	3.4	7.3	0.1	5.7	5.4
Swamp White Oak	2	6.1	1.7	4.9	0.5	4.0	1.0
Box Elder	3	5.4	2.6	7.3	0.2	8.7	5.7
Red Mulberry	3	3.8	2.6	4.9	T[a]	5.8	2.7
Black Walnut	2	3.4	1.7	4.9	0.1	3.6	1.5
Plum	2	3.1	1.7	4.9	T	2.9	1.9
White Ash	2	2.7	1.7	2.4	0.1	6.1	4.9
Persimmon	1	1.6	0.9	2.4	T	16.5	---
Hickory	1	1.6	0.9	2.4	T	15.4	---

[a]T indicates value of less than 0.1.

TABLE XVIII (continued)

Species	n	Importance Value	Absolute: Density	Absolute: Frequency	Basal Area (m² per 0.4 ha)	Mean Distance (m): Mean	Mean Distance (m): Standard Dev.
Redbud	1	1.5	0.9	2.4	T	5.6	---
Total	176	300.0	142.0	287.8	166.0	6.1	1.58 (1SE= .12)
			Shrub				
Pecan	15	66.8	1,401.8	26.8	0.8	2.7	2.8
American Elm	11	43.7	1,028.0	17.1	0.5	4.4	2.9
Poison Ivy	41	36.2	3,831.6	17.1	T	0.7	0.6
Smilax sp.	21	23.7	1,962.5	14.6	T	1.2	0.7
Green Ash	7	21.8	654.2	7.3	0.3	2.6	1.3
Privet	10	21.4	934.5	12.2	0.1	2.6	1.3
Rubus sp.	9	11.6	841.1	9.8	T	3.9	3.3
Pepperbush	7	10.4	654.2	9.8	T	0.9	0.7
Hackberry	8	8.2	747.6	4.9	T	1.3	0.6
Persimmon	6	7.4	560.7	4.9	T	2.8	1.2
Red Mulberry	1	6.6	93.5	2.4	0.1	0.8	---
Hickory	3	6.4	280.4	7.3	T	0.9	0.4
Northern Red Oak	6	6.1	560.7	2.4	T	1.5	1.6
Buckbrush	3	4.9	280.4	4.9	T	0.8	0.4
Burr Oak	2	4.9	186.9	4.9	T	1.4	0.7
Ilex sp.	2	4.3	186.9	4.9	T	4.6	4.6
Plum	3	3.5	280.4	2.4	T	0.9	0.4
Vitis sp.	3	3.4	280.4	2.4	T	1.5	1.0
Amelanchier sp.	1	2.3	93.5	2.4	T	0.9	---
Unknown	1	2.2	93.5	2.4	T	0.9	---

TABLE XVIII (continued)

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
Redbud	1	2.1	93.5	2.4	T	0.9	---
Moonseed	1	2.1	93.5	2.4	T	2.2	---
Total	162	300.0	15,139.6	165.9	1.9	1.7	1.15 (1SE= .09)

TABLE XIX

CHECKLIST OF FOREST TREES FOUND ON THE SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Species
cottonwood (*Populus deltoides*)
black willow (*Salix nigra*)
black walnut (*Juglans nigra*)
pecan (*Carya illinoensis*)
white hickory (*Carya tomentosa*)
northern red oak (*Quercus borealis*)
pin oak (*Q. palustris*)
black oak (*Q. velutina*)
blackjack oak (*Q. marilandica*)
burr oak (*Q. macrocarpa*)
post oak (*Q. stellata*)
overcup oak (*Q. lyrata*)
swamp white oak (*Q. bicolor*)
white elm (*Ulmus americana*)
winged elm (*U. alata*)
slippery elm (*U. fulva*)
southern hackberry (*Celtis laevigata*)
red mulberry (*Morus rubra*)
Osage orange (*Maclura pomifera*)[a]
sycamore (*Platanus occidentalis*)
service-berry (*Amelanchier arborea*)
hawthorn (*Crataegus* sp.)
Chickasaw plum (*Prunus angustifolia*)
black cherry (*P. serotina*)
red bud (*Cercis canadensis*)
coffee tree (*Gymnocladus dioicus*)
honey locust (*Gleditsia triacanthos*)[a]
black locust (*Robinia pseudocacia*)
deciduous holly (*Ilex decidua*)
box elder (*Acer negundo*)
dogwood (*Cornus florida*)
rough-leaf dogwood (*C. drummondii*)[b]
chittamwood (*Bumelia lanuginosa*)
persimmon (*Diospyros virginiana*)
white ash (*Fraxinus americana*)
green ash (*F. pennsylvanica*)
swamp privet (*Forestiera acuminata*)[b]

[a]Probably introduced by previous settlers; it is found only at sites of old buildings.

[b]Common on study area but usually classified as a woody shrub.

TABLE XIX (continued)

Species
catalpa (*Catalpa speciosa*)[a]
buttonbush (*Cephalanthus occidentalis*)[b]

Pecan Orchard. Pecan orchard occupied 92.7 ha of the study area and is a virtual monoculture consisting only of pecan trees, although occasionally another tree species occurs in the sampling (Figs. 28, 29, and 30). Density in this forest type is 26.4 stems per 0.4 ha with an average spacing between trees of 12.4 m. A basal area of 11.5 m^2 ha occurs, with an average basal area of 0.17 m^2 per stem (Table XX). No analysis of the shrub layer was made in the pecan grove because constant mowing and grazing activity have removed most of it. Greenbrier and poison ivy are probably the dominants, being associated closely with the trunks of the pecan trees.

The average annual production of pecans on the study site, based on kg sold, between 1958 to 1971, was 10,639 (1SE=3,132) kg per year. However, as shown by Fig. 31 and Table XXI, pecan production varies considerably between years on the site and statewide. Correlation between pecan production on the Spears Study Area and statewide (r=.71) indicates that the same general trends in pecan production were present on the study area as occurred statewide.

Vegetation of the Entire Study Area. The estimate of vegetation characteristics for the forested portion of the Spears Study Area is given in Table XXII. Using stratified random sampling techniques described by Cochran (1963) these values represent the entire area with proper weighting given to existing strata. Of the 27 species of trees

Figure 28. The Pecan Orchard of the Spears Study Area, Okmulgee County, Oklahoma. April 1970.

Figure 29. The Open Pecan Orchard of the Spears Study Area. July 1970. Ungrazed and Unmowed Due to Flooding of the Area, Luxuriant Ground Vegetation Develops Quickly on the Site.

Figure 30. Flooding of the Pecan Orchard on the Spears Study Area Was a Common Occurrence in 1970-1972. It Is the Periodic Flooding That Keeps Land Along the River from Being Converted to Agricultural Uses. June 1970.

TABLE XX

VEGETATION ANALYSIS FOR PECAN ORCHARD STRATA, SPEARS STUDY AREA

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
			Tree				
Pecan	724	282.2	25.4	100.0	4.6	14.0	7.7
Black Willow	10	6.0	0.4	4.8	T[a]	14.8	8.1
Sycamore	4	3.0	0.1	2.1	T	21.6	16.2
Pin Oak	5	2.8	0.2	2.1	T	14.0	7.0
Box Elder	2	1.5	0.1	1.1	T	23.2	26.3
American Elm	2	1.3	0.1	1.1	T	19.8	18.6
Burr Oak	1	1.2	0.1	1.1	T	19.4	---
Northern Red Oak	1	0.7	T	0.5	T	21.2	---
Cottonwood	1	0.7	T	0.5	T	9.9	---
Green Ash	1	0.7	T	0.5	T	24.9	---
Total	752	300.0	26.4	113.8	4.6	14.1	.95 (1SE= .03)

[a]T indicates value of less than 0.1.

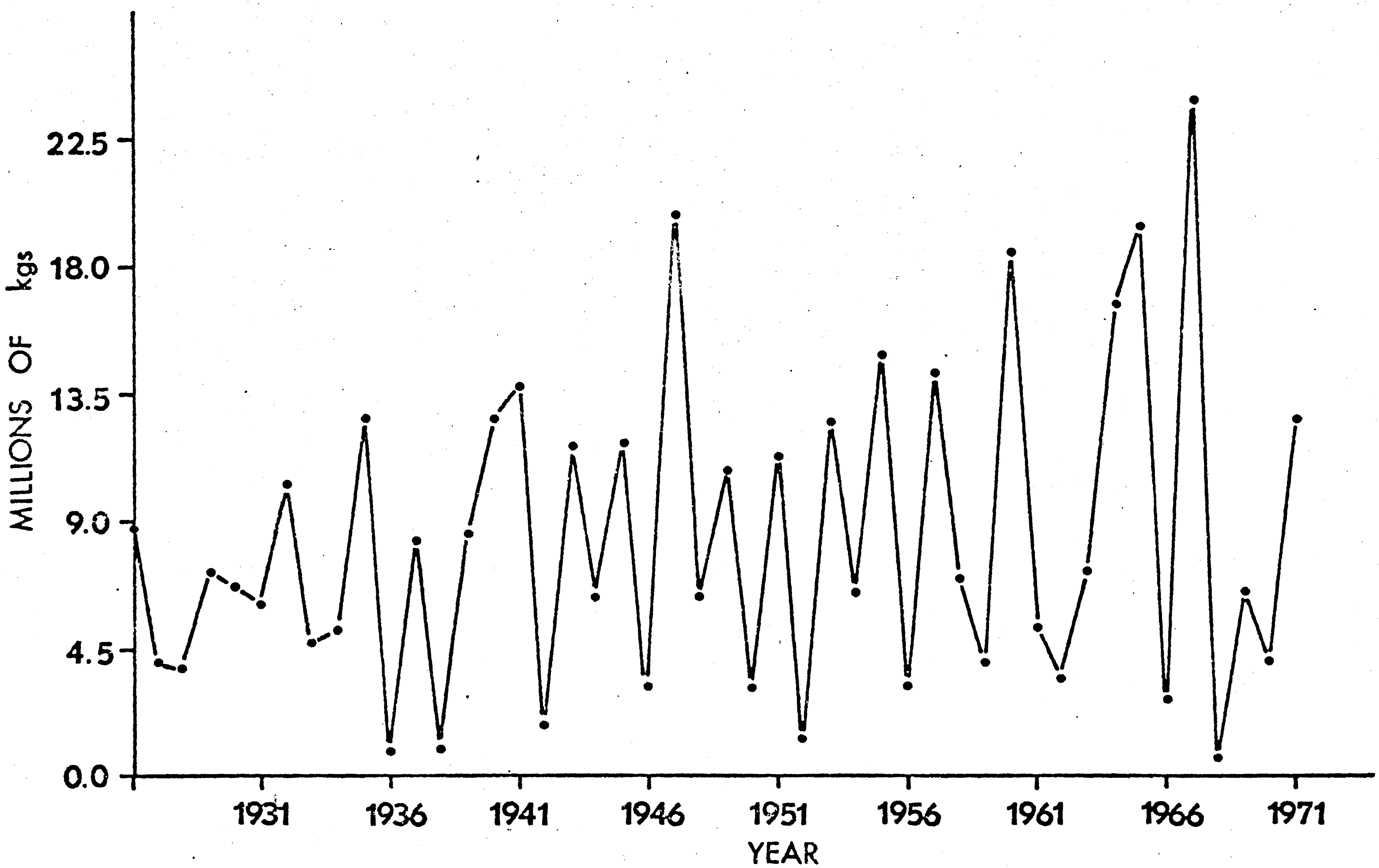

Figure 31. Production of Pecans in Oklahoma.

TABLE XXI

PECAN PRODUCTION ON THE SPEARS STUDY AREA. DATA PROVIDED BY PERSONAL RECORDS BASED ON SALES OF PECANS, 1958-1971

Year	Statewide Production (1,000's of kg)	Production on Spears Area (kg)
1958	6,975	900
1959	4,050	900
1960	18,450	3,600
1961	5,220	22,500
1962	3,420	450
1963	7,200	16,650
1964	16,650	18,000
1965	19,350	31,500
1966	2,700	no crop reported
1967	23,850	30,150
1968	675	no crop reported
1969	6,525	2,250
1970	4,050	4,050
1971	12,600	18,000[b]

[a]Values taken from Pittmen and Kastens (1973).

[b]Estimated production, only about 25 percent of the pecan crop harvested due to flooding in October 1971 which made harvest impossible after mid October.

TABLE XXII

VEGETATION ANALYSIS FOR THE ENTIRE SPEARS STUDY AREA

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
			Tree				
Pecan	744	204.4	27.5	77.5	4.9	12.1	22.0
American Elm	57	17.1	2.1	13.7	0.2	4.7	13.9
Post Oak	52	11.5	1.9	8.0	0.1	3.0	5.2
Green Ash	35	10.2	1.3	6.9	0.1	5.1	13.3
Hackberry	27	8.0	1.0	6.1	0.1	5.1	9.4
Winged Elm	22	6.8	0.8	5.7	0.1	5.3	8.1
Northern Red Oak	17	6.3	0.6	4.6	0.1	6.5	14.4
Sycamore	10	5.0	0.4	3.8	0.1	10.9	36.9
Black Willow	14	4.8	0.5	4.6	T[a]	10.6	24.0
Burr Oak	9	3.9	0.3	3.4	T	8.0	22.2
Cottonwood	7	2.7	0.3	2.3	T	6.5	10.0
Black Oak	9	2.7	0.3	2.3	T	4.4	7.5
Red Elm	6	2.3	0.2	2.3	T	3.9	6.3
Box Elder	5	2.1	0.2	1.9	T	12.7	45.6
Hickory	7	2.0	0.3	1.9	T	8.6	10.1
Blackjack Oak	5	1.8	0.2	1.9	T	5.1	11.2
Pin Oak	5	1.7	0.2	1.5	T	12.3	20.0
Red Mulberry	4	1.2	0.2	1.2	T	4.1	8.9
Swamp White Oak	2	1.0	0.1	0.8	T	3.5	2.8

[a]T indicates value of less than 0.1.

TABLE XXII (continued)

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
Black Walnut	2	0.8	0.1	0.8	T	3.2	4.2
Privet	2	0.8	0.1	0.4	T	3.0	6.1
Plum	2	0.7	0.1	0.8	T	2.5	5.5
Chittamwood	2	0.7	0.1	0.8	T	3.1	8.5
White Ash	2	0.5	0.1	0.4	T	5.3	14.0
Persimmon	1	0.4	T	0.4	T	14.4	---
Redbud	1	0.4	T	0.4	T	4.9	---
Total	1,050	300.0	38.8	154.6	5.9	10.2	2.5 (1SE= .07)
			Shrub				
American Elm	22	36.7	117.8	5.7	0.3	3.2	2.1
Pecan	15	35.6	80.3	4.6	0.4	2.4	2.4
Privet	22	32.6	117.8	4.2	0.3	3.0	2.3
Green Ash	23	27.7	123.2	5.3	0.2	2.4	1.2
Poison Ivy	45	25.1	241.0	6.5	T	0.7	0.8
Smilax sp.	24	17.7	128.5	5.7	T	1.3	1.0
Post Oak	16	16.0	85.7	3.1	0.1	1.1	0.7
Hackberry	18	12.0	96.4	3.8	T	1.3	0.8
Hickory	9	11.1	48.2	3.1	0.1	1.9	1.6
Dogwood	18	10.2	96.4	2.7	T	1.0	0.6
Buckbrush	12	8.2	64.3	2.7	T	0.9	0.4
Chittamwood	6	7.6	32.1	1.9	T	1.6	1.1
Rubus sp.	10	6.5	48.2	2.3	T	1.2	0.6
Pepperbush	7	5.8	37.5	2.3	T	0.8	0.6

TABLE XXII (continued)

Species	n	Importance Value	Absolute Density	Absolute Frequency	Basal Area (m^2 per 0.4 ha)	Mean Distance (m) Mean	Mean Distance (m) Standard Dev.
Blackjack Oak	3	5.7	16.1	1.2	T	1.4	0.4
Vitis sp.	6	5.7	32.1	2.3	T	1.3	0.6
Northern Red Oak	6	5.4	32.1	1.9	T	1.3	1.4
Red Mulberry	2	5.1	10.7	0.8	T	1.2	0.7
Persimmon	6	3.6	32.1	0.8	T	2.5	1.1
Amelanchier sp.	4	3.3	21.4	1.2	T	0.8	0.4
Plum	3	2.8	16.1	1.2	T	0.8	0.4
Ilex sp.	3	2.7	16.1	1.2	T	3.4	3.1
Winged Elm	3	2.3	16.1	0.8	T	0.7	0.2
Burr Oak	2	2.2	10.7	0.8	T	1.2	0.6
Smooth Sumac	3	2.0	16.1	0.4	T	0.8	0.3
Redbud	2	1.9	10.7	0.8	T	1.4	0.8
Moonseed	2	1.8	10.7	0.8	T	1.1	1.2
Unknown	1	0.9	5.4	0.4	T	0.8	---
Virginia Creeper	1	0.9	5.4	0.4	T	0.7	---
Total	294	300.0	1,574.4	68.7	16.8	1.6	0.9 (1SE= .05)

encountered during sampling, pecan dominates the overall area. No one species of shrub dominates, but poison ivy occurs in all strata and has the highest importance value for the shrub group. Elm, pecan, hackberry, green ash, and swamp privet are also important members of the shrub component.

The overall tree density on the study area was 38.8 stems per 0.4 ha with 10.2 m spacing between trees. Basal area for the trees averaged 14.6 m^2 per ha with an average spacing between plants of 1.6 m. Shrubs had a basal area of 3.85 m^2 per ha with an average basal area of 0.0009 m^2 per stem.

The bottomland forest on the Spears Study Area had fewer stems per acre but these stems were larger than trees in bottomland stands examined by Rice and Penfound (1959). The upland sites on the study area had both a greater density and basal area than that noted in other upland oak forest stands (Rice 1965).

Density of Den Trees on Spears Study Area. Considerable difference between the density of den trees in the different habitat types occurs on the study area (Table XXIII). Dens found in the pecan orchard were usually found in large pecan trees, such as at Station 83, usually occurring where stubs of limbs of the tree have broken off. These dens appeared to have been used traditionally by squirrels for a long time (Figs. 32, 33, and 34). The dead

TABLE XXIII

DENSITY OF DEN TREES PRESENT ON THE SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Habitat Type	Total Trees in Sample	Number of Den Trees in Sample	Percent of Den Trees in Sample (95%CI)	Den Trees Per 0.4 Ha on Area
Pecan orchard	752	172	23 (20-26)	6
Bottomland forest	204	67	33 (27-39)	48
wet bottomland	40	11	28 (16-46)	51
dry bottomland	164	56	34 (26-42)	48
Post oak-blackjack oak forest	92	0 (14[a])	--	1

[a]Actual count of den trees present in post oak-blackjack oak forest. Of the 92 trees sampled in this forest type, none were classified as suitable for squirrel denning.

Figure 32. Overmature Pecan Trees, such as at Station 83, Provide Excellent Den Sites for Fox Squirrels in the Open Pecan Orchard. Spears Study Area, March 1972.

Figure 33. Dens Usually Are Established in Pecan Trees at the Point Where a Limb Has Broken off or Died. Spears Study Area, March 1972.

Figure 34. Squirrels May Occupy the Same Den Site for a Number of Years with Constant Chewing Keeping the Tree from Closing the Opening. Spears Study Area, March 1972.

stubs of old pecan trees, poisoned in thinning operations in the orchard, provided potential den sites for squirrels and other wildlife (Fig. 35). Many escape dens were present in the pecan orchard as many of the older pecan trees either had butt cavities or similar openings higher on their trunks (Figs. 36 and 37). Periodically, these pecan den trees, weakened by age, are blown over during high winds (Fig. 38).

Elms dominate the choice as potential den trees in the bottomland, while virtually all den trees in the pecan orchard are pecan. Post oak is the major den tree in the post oak-blackjack oak forest. A significant difference exists between the dbh and classification as a potential den tree (Kolmogorov-Smirnov Test, D=.1576; P=.01) with 51 percent of the den trees having a dbh between 41 and 64 cm (Table XXIV).

<u>Density of Leaf Nests on Spears Study Area</u>. No leaf nests were found in any trees selected for analysis using the point-centered-quarter method in either the post oak-blackjack oak or bottomland forest. Only 10 trees among 752 tallied in the pecan orchard, 1.3 percent, had leaf nests present. Because of this low occurrence of leaf nests, no statistical analysis for these data was possible.

The density of leaf nests on 41.7 ha of the study area, obtained by a total count of nests in March 1971 and

Figure 35. Killed by Earlier Clearing Operations in the Pecan Orchard, Standing Dead Stubs Provide Potential Dens for Squirrels. Spears Study Area, March 1971.

Figure 36. Old Pecan Trees Often Have Hollow, Open Bases Which Provide at Least an Escape Den for Squirrels. Spears Study Area, March 1972.

Figure 37. Cavities Above the Ground May Also Serve as Escape Dens for Squirrels. Spears Study Area, March 1972.

Figure 38. Older Den Trees, Especially Pecans, Are Subject to Wind Damage. Several Dens Were Lost in 1972 on the Spears Study Area. March 1972.

TABLE XXIV

DIAMETER BREAST HEIGHT (DBH) FREQUENCIES OF DEN TREES ON SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Species of Tree	DBH in Cm							
	Less 25	26-38	39-51	52-64	65-76	77-89	90+	n (%)
Bottomland Forest								
American Elm	4	7	3	2	3	--	--	19 (28.4)
Pecan	1	--	1	2	--	4	--	8 (11.9)
Green Ash	1	2	3	--	2	--	--	8 (11.9)
Hackberry	--	4	2	1	--	--	--	7 (10.4)
Red Oak	1	1	1	3	--	1	--	7 (10.4)
Burr Oak	--	1	1	--	2	--	--	4 (6.0)
Winged Elm	--	2	2	--	--	--	--	4 (6.0)
Box Elder	2	--	1	--	--	--	--	3 (4.5)
Sycamore	--	--	--	--	--	2	--	2 (3.0)
Red Elm	--	--	2	--	--	--	--	2 (3.0)
Swamp White Oak	--	--	--	--	--	1	--	1 (1.5)
Black Willow	--	1	--	--	--	--	--	1 (1.5)
Cottonwood	--	--	--	--	1	--	--	1 (1.5)
Subtotal	9	18	16	8	8	8	--	67 (100.0)
Pecan Orchard								
Pecan	2	5	24	74	43	20	5	173 (99.4)
Red Oak	--	--	1	--	--	--	--	1 (0.6)
Subtotal	2	5	25	74	43	20	5	174 (100.0)

TABLE XXIV (continued)

Species of Tree	DBH in Cm							
	Less 25	26-38	39-51	52-64	65-76	77-89	90+	n (%)
			Post Oak-Blackjack Oak Forest					
Post Oak	--	6	4	--	--	--	--	10 (71.4)
Black Oak	--	--	1	2	--	--	--	3 (21.4)
Blackjack Oak	--	--	1	--	--	--	--	1 (7.1)
Subtotal	--	6	6	2	--	--	--	14 (99.9)
Total	11	29	47	84	51	28	5	255

March 1972, is given in Table XXV. Generally, the post oak-blackjack oak forest had more leaf nests than did the bottomland forest and pecan orchard. However, there was no significant negative correlation between the density of tree dens and leaf nests on the study area (r=-.65) although such a relationship seems reasonable. Fewer leaf nests would be needed by squirrels when there were adequate den trees available for squirrel use.

TABLE XXV

DENSITY OF LEAF NESTS ACCORDING TO TYPE OF HABITAT ON THE 41.7 Ha AREA OF SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, MARCH 1971 AND MARCH 1972

Type of Habitat	Amount of Area (ha)	Percent of Total Area	Leaf Nests		Percent of Nests Occurring in Habitat Types		Average Area Per Nest (ha)	
			1971	1972	1971	1972	1971	1972
Pecan Orchard	28.7	69	9	8	40.9	30.8	3.2	3.6
Bottomland Forest	6.5	16	3	1	13.6	3.8	2.1	6.4
Upland Forest	2.0	5	1	3	4.5	11.5	2.0	0.7
Brush Fringe	1.6	4	9	14	40.9	53.8	0.2	0.1
Standing Water	1.2	3	0	0	0.0	0.0	0.0	0.0
Pasture	1.6	4	0	0	0.0	0.0	0.0	0.0
Total	41.7	100	22	26			1.9	1.6

CHAPTER V

HOME RANGE, MOVEMENTS, AND POPULATION DENSITIES OF FOX AND GRAY SQUIRRELS

Introduction

Little published information exists describing the habitat preferences, densities, and movements of fox and gray squirrels within and between specific habitat types similar to those existing in eastern Oklahoma. Extensive changes in land use and the resulting ecological effects that accompany these changes necessitate having this knowledge if we are to manage these squirrel populations effectively. Information on squirrel densities and movements was collected from January 1970 through August 1973 on the Spears Study Area in western Okmulgee County along the Deep Fork of the North Canadian River (Fig. 1).

Methods and Materials

A grid was established in the study area and 172 livetraps were distributed throughout the area (Fig. 39). Trap density averaged one trap per 0.76 ha overall. Distribution varied from one trap per 0.52 ha in the bottomland forest to one trap per 1.13 ha in the post

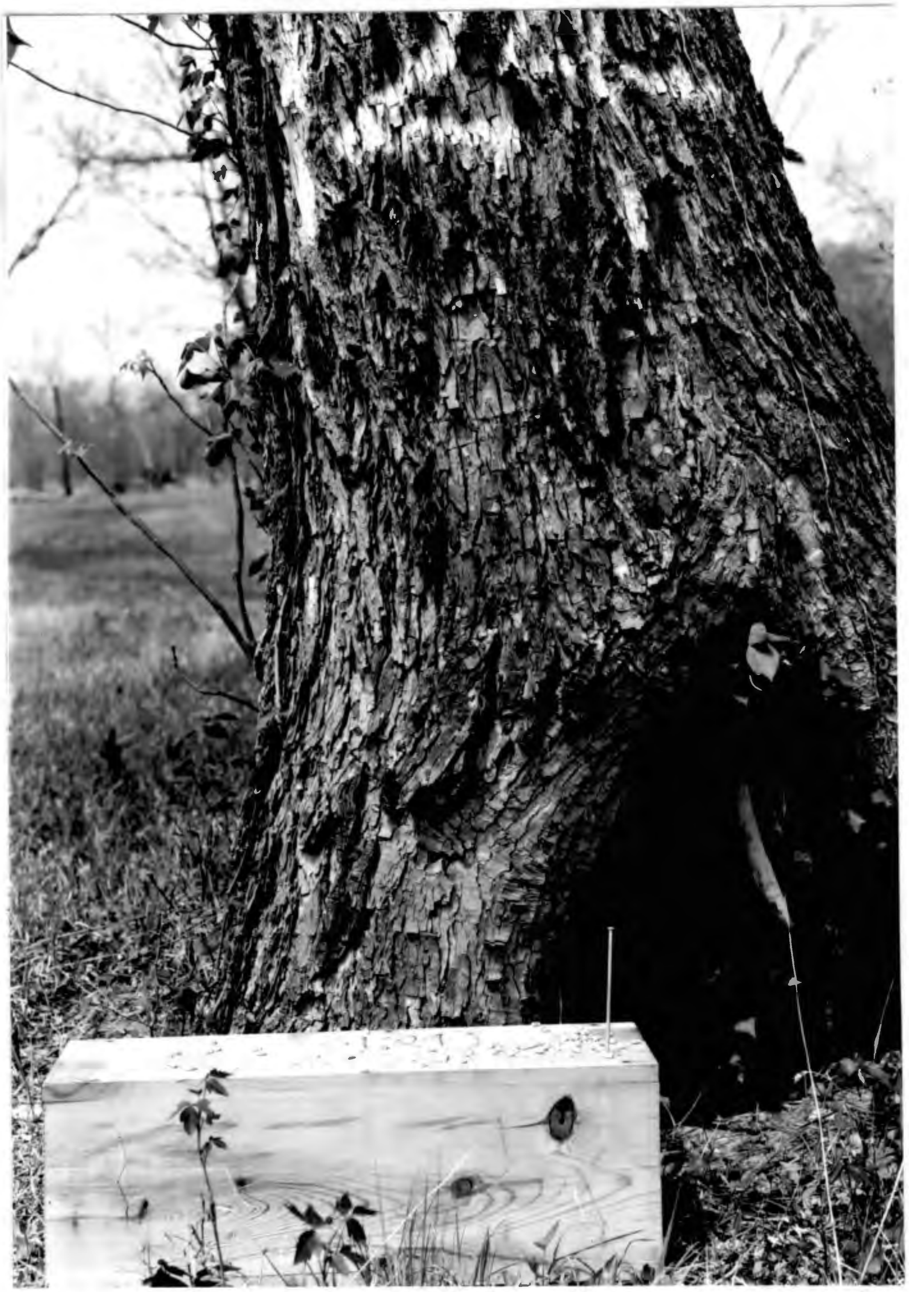

Figure 39. Squirrel Trap Utilized on Spears Study Area, 1970-1972. Number on the Pecan Tree Denotes Permanent Trapping Station Location.

oak-blackjack forest, and to one trap per 0.8 ha in pecan orchard. Traps were placed at the base of the largest trees within each habitat. Each tree then constituted a trap station and was serially numbered. The exact location of each trap station was determined with a surveyor's transit and stadia; and a base map, scale 2.54 cm=30.48 m was then constructed showing the relationship between trap stations throughout the study area.

After initial experimentation with various baits, such as pecans, peanuts, walnuts, and peanut butter, the best trap bait was found to be shelled corn. Captured squirrels were held in a wire handling cone while being weighed, and a serially numbered ear tag (Number 1, National Band and Tag Company) was placed in one ear for individual identification. Hair was clipped off the terminal portion of the tail for identifying free-ranging squirrels without capturing them (Figs. 40, 41, and 42). All animals were released at their sites of capture.

Escape radii were determined by observing the direction and destination of each squirrel after its release from the trap. If a squirrel entered a tree den, the azimuth to the den was taken by hand compass and the shortest distance from the trap station to the escape den measured with a metal tape.

Movements of squirrels were revealed by trapping squirrels marked previously at other trap stations and by recovering tagged animals harvested by hunters. A map of the

Figure 40. Each Squirrel Trapped Was Permanently Marked with a Serially Numbered Metal Ear Tag.

Figure 41. Weights of Each Captured Squirrel Were Taken with the Aid of a Wire Handling Cone.

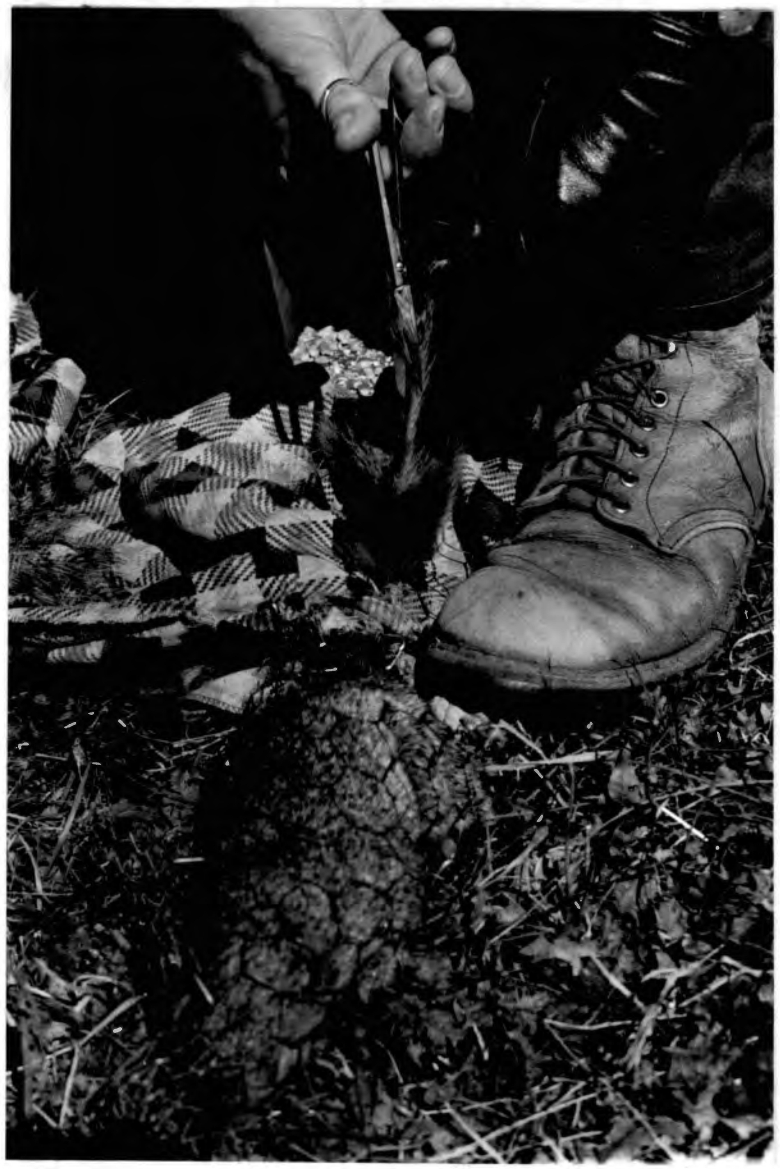

Figure 42. Identification of Marked Squirrels Was Aided by Clipping off a Portion of the Hair on Each Squirrel's Tail. This Mark Was Often Visible up to 85 m away.

movements of each individual was then drawn and the extent of these movements measured. Calculations of home ranges are based on escape radii, recaptures, and tag returns from hunters.

The minimum area method (MHR) was used to calculate home range (Dalke 1948). Points of recovery were connected by straight lines and the size of the enclosed area then measured with a compensating polar planimeter. Maximum length of range, the distance of a line between extreme points of capture, was also determined for each recaptured squirrel.

Squirrel population densities were determined by using equations developed for mark-recapture estimates of population density: the Petersen Index (1896), the Schnabel Index (Schnabel 1938), and regression and MLE techniques based on the frequency of captures of individuals (Eberhardt 1969). The Petersen Index, used in May to establish squirrel numbers based on hunter harvest, was modified by using all marked animals known to be alive in a given period rather than only the marked individuals from the previous capture period (Lidicker 1966). Confidence limits were set on the Petersen and Schmabel estimates using the Chapman (1948) tables. The MLE and regression methods of population estimation have been previously described by Nixon, et al. (1967) and Eberhardt (1969). A count of leaf nests constructed by squirrels on a portion of the study area and information on hunter success per unit of effort were also collected to provide additional information on the number of squirrels on the Spears Study Area.

The minimum number of individuals known to be alive in the squirrel population at any one time was obtained by plotting the first and last dates of capture or recovery for each squirrel and counting the number of interceptions for a particular date.

Results and Discussion

Responses of Fox and Gray Squirrels to Traps

Table XXVI presents a summary of livetrapping activities on the Spears Study Area from March 1970 through February 1972. In 15,113 trap nights, 583 squirrels were trapped with 2.98 fox squirrels taken for each gray squirrel handled.

Considerable variation in catch per 100 trap nights is evident, with most of the squirrels being captured in either the fall or winter months (Fig. 43). An overall capture rate of 3.97 squirrels per 100 trap nights was maintained during the 12 different trapping periods.

Of 266 fox squirrels tagged, 52.3 (159) percent were not recovered after initial tagging; 69.2 percent (72) of the gray squirrels were caught only once. The recapture frequencies of fox and gray squirrels by sex and age class are presented in Table XXVII and in Figs. 44, 45, and 46.

TABLE XXVI

SUMMARY OF LIVETRAPPING RESULTS ON SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

		Number of Squirrels Captured				Totals		
		Fox		Gray				
Period	Number of Trapnights	New	Recapture	New	Recapture	New	Recapture	All
March 1970	1,744	15	0	2	0	17	0	17
April 1970	1,713	23	0	10	1	33	1	34
May 1970	366	1	0	0	0	1	0	1
June 1970	491	0	0	0	0	0	0	0
August 1970	1,585	10	0	3	0	13	0	13
November 1970	458	14	0	3	1	17	1	18
December 1970	1,327	100	2	32	0	132	2	134
January 1971	1,313	37	0	21	0	58	0	58
February 1971	687	38	0	14	0	52	0	52
March 1971	1,578	54	5	20	3	74	8	82
April 1971	1,972	49	2	9	0	58	2	60
January 1972	1,879	88	3	21	0	109	3	112
Total	15,113	429	12	135	5	564	17	581

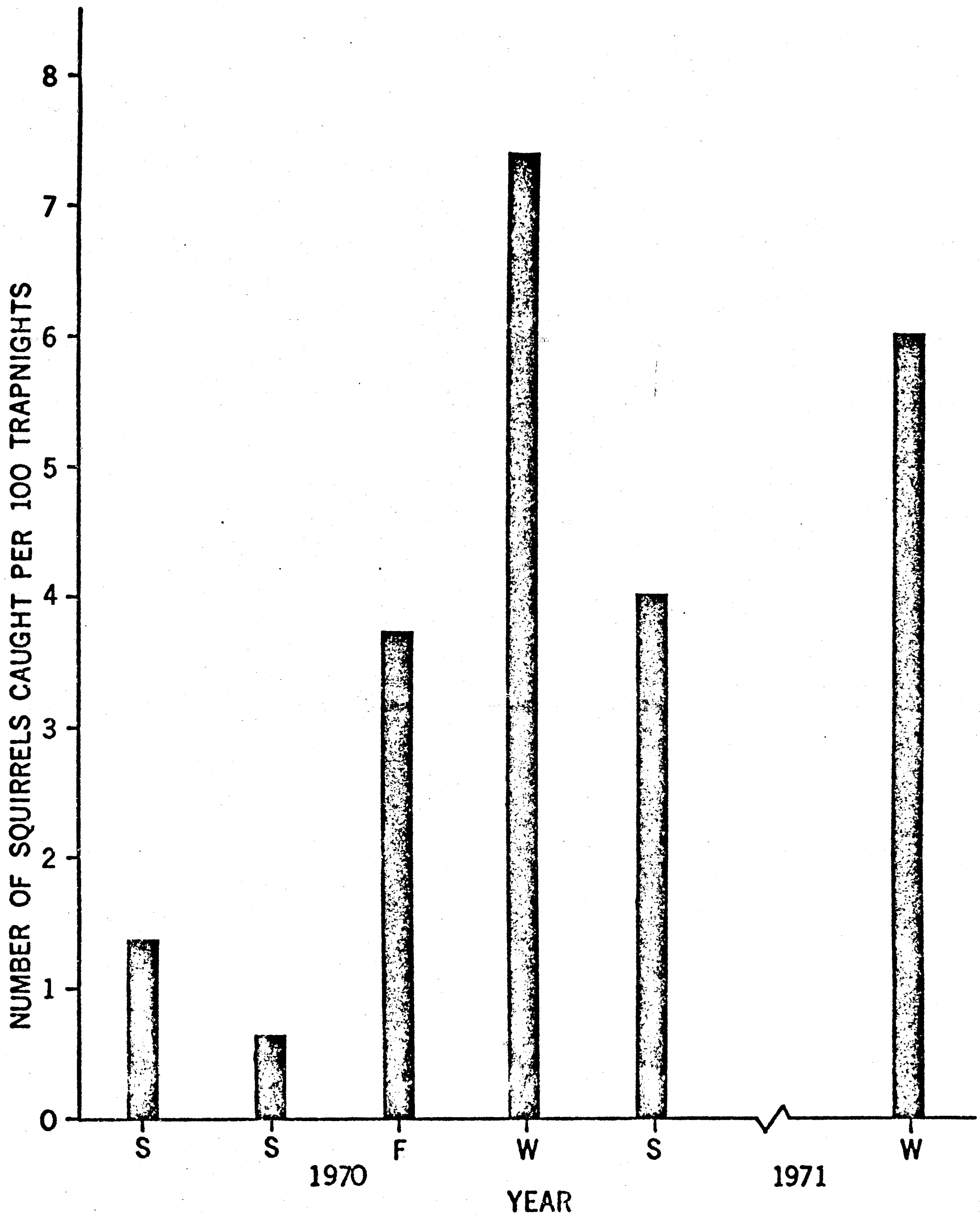

Figure 43. Number of Squirrels Livetrapped Per 100 Trap Nights, Spears Study Area, 1970-1972.

TABLE XXVII

FREQUENCY OF RECOVERY OF PREVIOUSLY MARKED FOX AND GRAY SQUIRRELS, SPEARS STUDY AREA, 1970-1972, BASED ON LIVETRAPPING AND RETURN OF TAGGED SQUIRRELS BY HUNTERS

Times Captured	Number	Percent
	Fox Squirrels	
1	159	52.3
2	102	33.9
3	31	9.9
4	10	3.3
5	2	0.7
Total	304	
	Gray Squirrels	
1	72	69.2
2	31	29.8
3	1	1.0
Total	104	

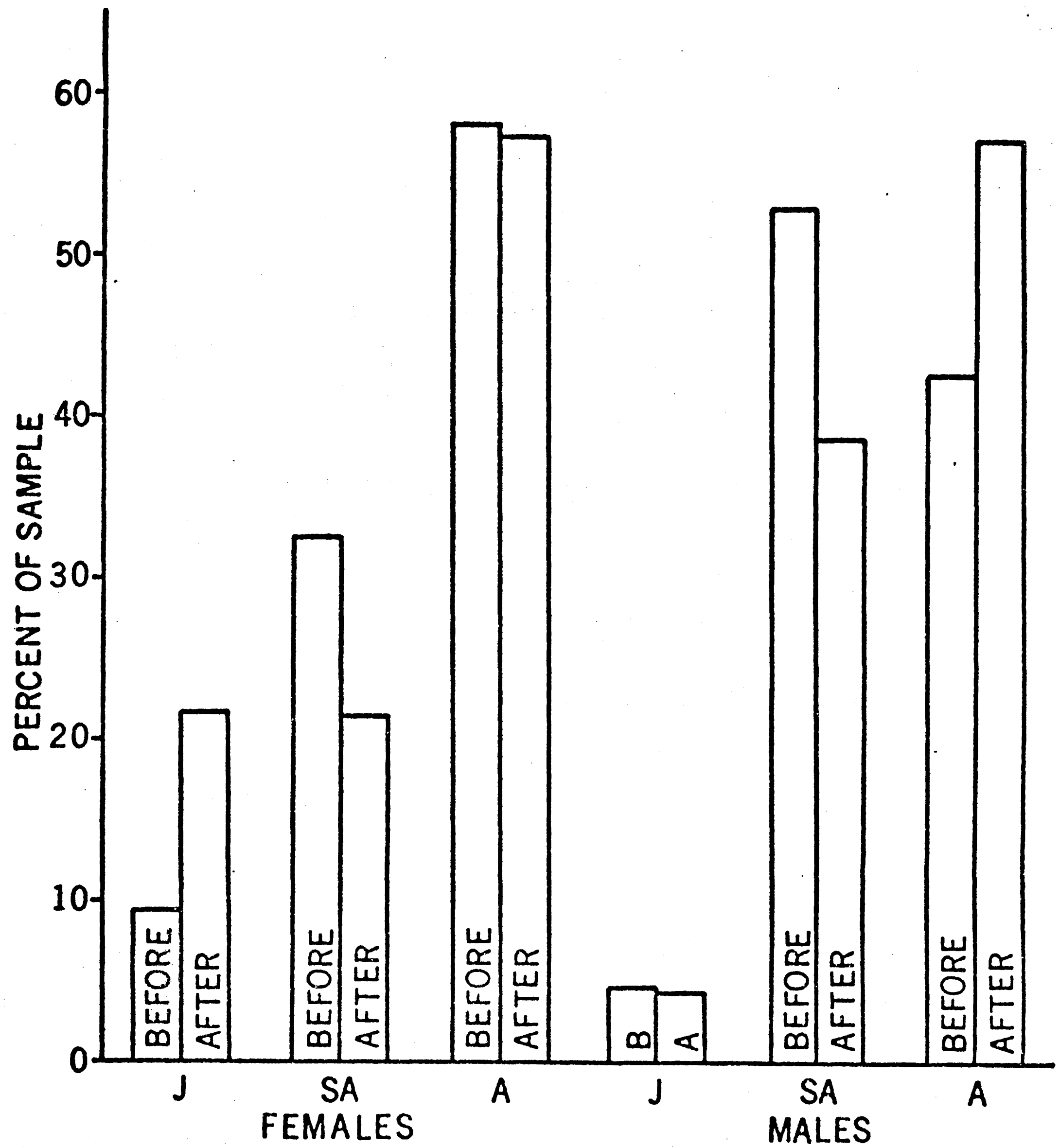

Figure 44. Response of Fox Squirrels to Recapture During Mark-Recapture, Spears Study Area, 1970-1972. The Letter J Indicates Juvenile, SA Subadult, and A Adult Age Classes. Before Represents the Sample Composition at the First Capture Time and After Indicates the Sample Composition of Squirrels Captured More Than Once.

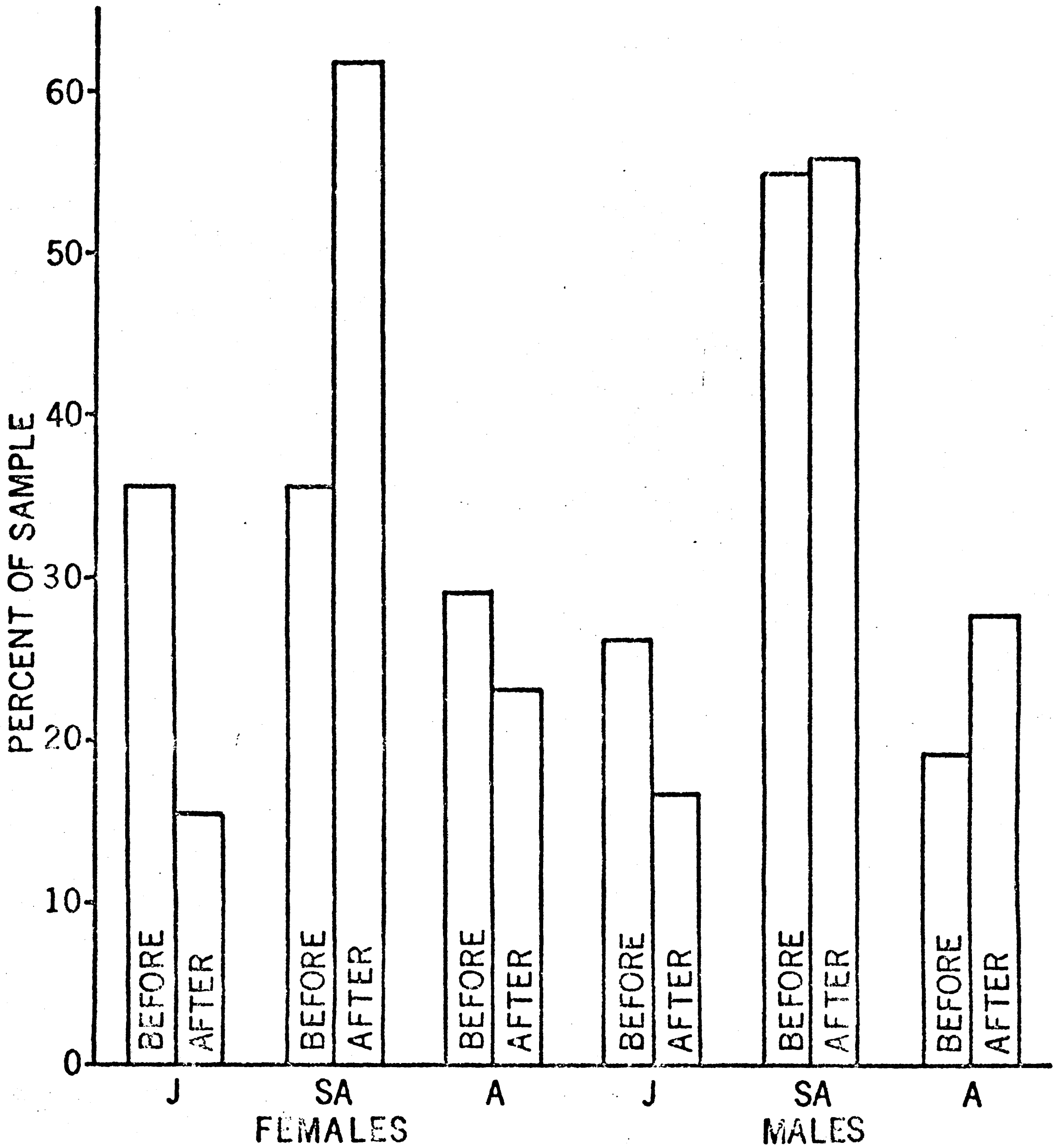

Figure 45. Response of Gray Squirrels to Recapture During Mark-Recapture, Spears Study Area, 1970-1972. The Letter J Indicates Juvenile, SA Subadult, and A Adult Age Classes. Before Represents the Sample Composition at the First Capture Time and After Indicates the Sample Composition of Squirrels Captured More Than Once.

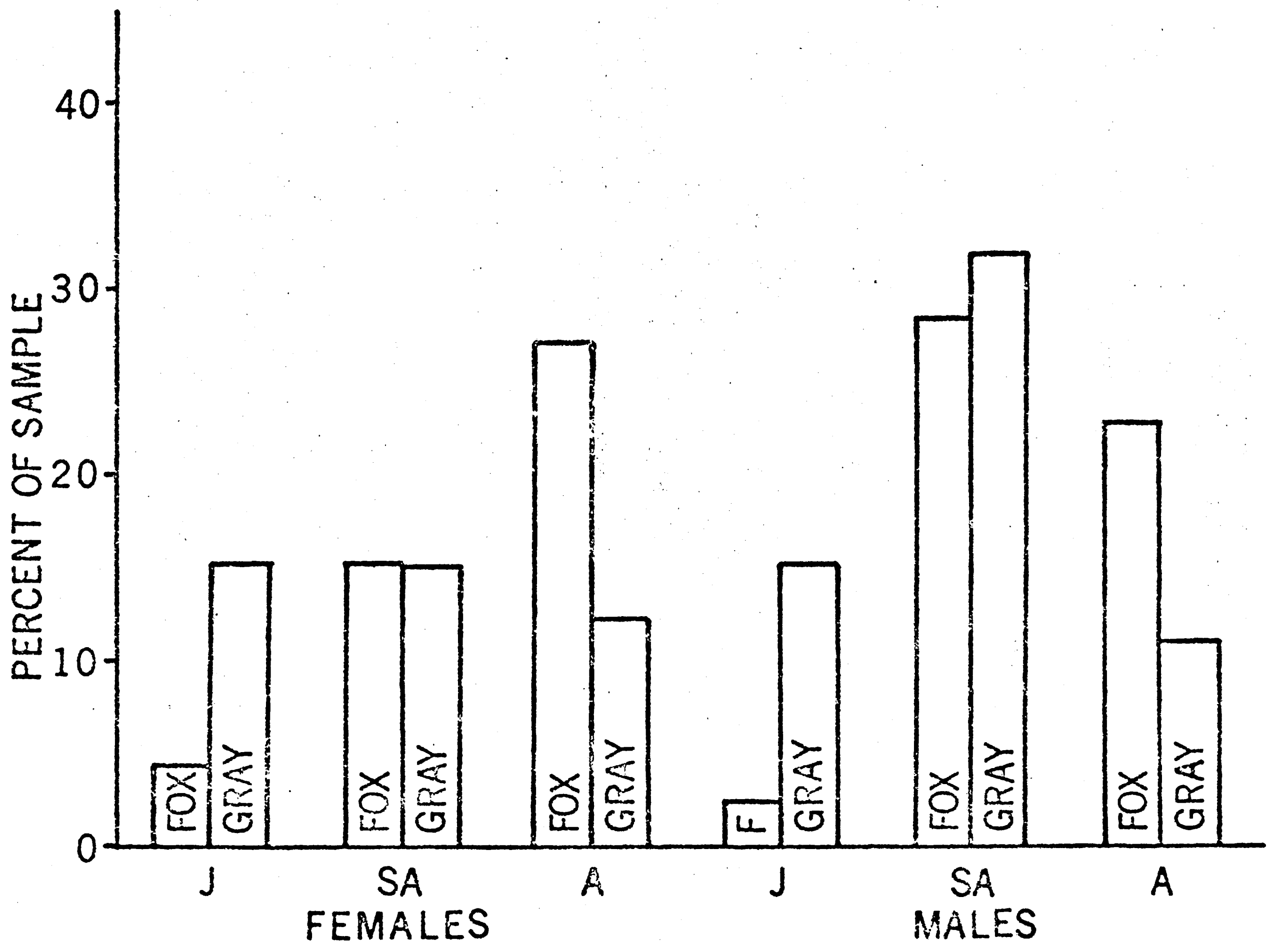

Figure 46. Distribution of Sexes and Age Classes in Livetrapped Squirrels, Spears Study Area, 1970-1972.

Trapping and handling of fox squirrels affected their future catchability. A significant difference (Chi-square value=8.81, P=.01) existed between the sex and age structure of the fox squirrels trapped once and those squirrels trapped two or more times. The same type of analysis of gray squirrel captures also indicated a significant difference (Chi-square value=5.40, P=.025) between the sex and age ratios obtained in a sample of gray squirrels captured once and those obtained in a sample of squirrels trapped two or more times.

The trapability of juvenile female fox squirrels and adult male fox squirrels increased whereas trapability of the other sex and age classes decreased in their portions of the sample. Subadult male fox squirrels showed, at least temporarily, the greatest trap avoidance of the fox squirrel group, decreasing 14.5 percent from their initial sample's composition after repeated trap experience.

Statistically significant changes in trapability of gray squirrels were also indicated. The proportion of subadult females and adult females increased in the sample after repeated captures, whereas both juvenile females and males became less trappable after their initial captures.

The sex ratio of livetrapped fox squirrels on the Spears Study Area was 100 females:115 males (n=159), whereas a ratio of 100 females:119 males was obtained from fox squirrels shot on or near the study area. Neither estimate differed significantly from the expected 50:50 sex ratio (P=.05).

The sex ratio of livetrapped gray squirrels on the Spears Study Area was 100 females:136 males (n=73), whereas a sex ratio of 100 females:116 males (n=397) was obtained from gray squirrels shot on or near the study area. Neither estimate differed significantly from the expected 50:50 sex ratio (P=.05). A comparison of sex and age ratios obtained from livetrapped and animals shot by hunters revealed no statistical difference between these estimates (Table XXVIII).

Effect of Environmental Factors on Responses to Traps

Trap responses of fox and gray squirrels on the Spears Study Area in relation to maximum and minimum temperatures and days since measurable precipitation were analyzed. Data on these trap responses were collected on 127 days from the beginning of March 1970 through February 1972. Weather data were obtained from the weather station west of Okmulgee, Oklahoma, 10 miles (16 km) southeast of the Spears Study Area. Linear analysis was used to obtain correlation coefficients between environmental factors and trapping success (Simpson, et al. 1960).

As shown by the negative correlation coefficients, fewer squirrels were captured during the colder and wetter portions of trap periods (Table XXIX). Trapping success

TABLE XXVIII

COMPARISON OF SEX RATIOS OF LIVETRAPPED SQUIRRELS AND SQUIRRELS SHOT BY HUNTERS, SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Sampled By	n	Females:Males= Females:Male Ratio	Chi-square Value	P
		Fox Squirrels		
trap	159	74:85 = 100:115	3.76	0.1
shot	397	182:217 = 100:119	3.09	0.1
		Gray Squirrels		
trap	104	44:60 = 100:136	2.46	0.5
shot	397	184:213 = 100:116	2.12	0.5

TABLE XXIX

LINEAR CORRELATIONS BETWEEN SQUIRREL TRAPPING SUCCESS AND ENVIRONMENTAL CONDITIONS ON THE SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Weather Factor	Correlation Coefficient	Degrees of Freedom	Significance Level
Minimum Temperature	-.362	46	.02
Maximum Temperature	-.256	45	.10
Days Since Last Measureable Precipitation	-.415	22	.05

also decreased when higher temperatures occurred, although no statistically significant correlation coefficient was found for this relationship. Figures 47 and 48 indicate the relationships between temperatures and trapping success on the study area. If possible, livetrapping under these conditions should not be used for population estimates or determination of squirrel activity periods.

Home Ranges of Fox and Gray Squirrels

Seton (1909) first discussed the concept of home range, but Burt (1943) first clarified the concept of home range as being distinct from that of territory. Dice (1952) stressed the habitual use of an area in daily activities as being home range and specifically defined home range as the area an animal covers in its day-to-day travels. Brown (1962) reviewed the concept of home range in small mammals and Sanderson (1966) reviewed movements of the mammal group.

For the purposes of this work, lifetime range is considered synonymous with home range. Lifetime range may be useful to denote the total area with which an animal has become familiar, including seasonal home ranges, excursions for mating, and routes of movement (Jewell 1966). McNab (1963) has considered the ecological implications of energy requirements, biomass, and home range by converting biomass figures into metabolic energy

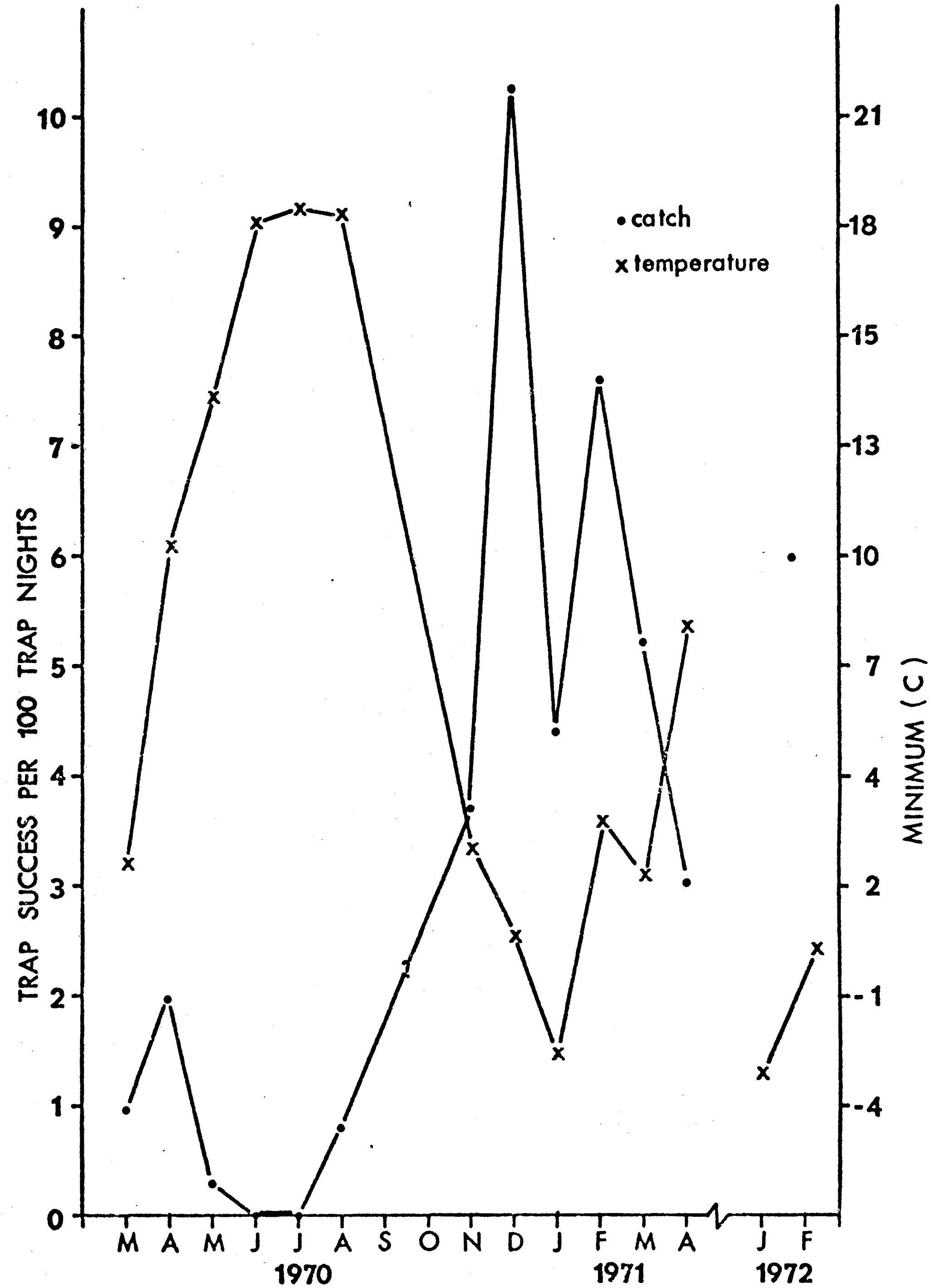

Figure 47. Relationship Between Squirrel Trap Response and Maximum Temperature (C) on the Spears Study Area, 1970-1972.

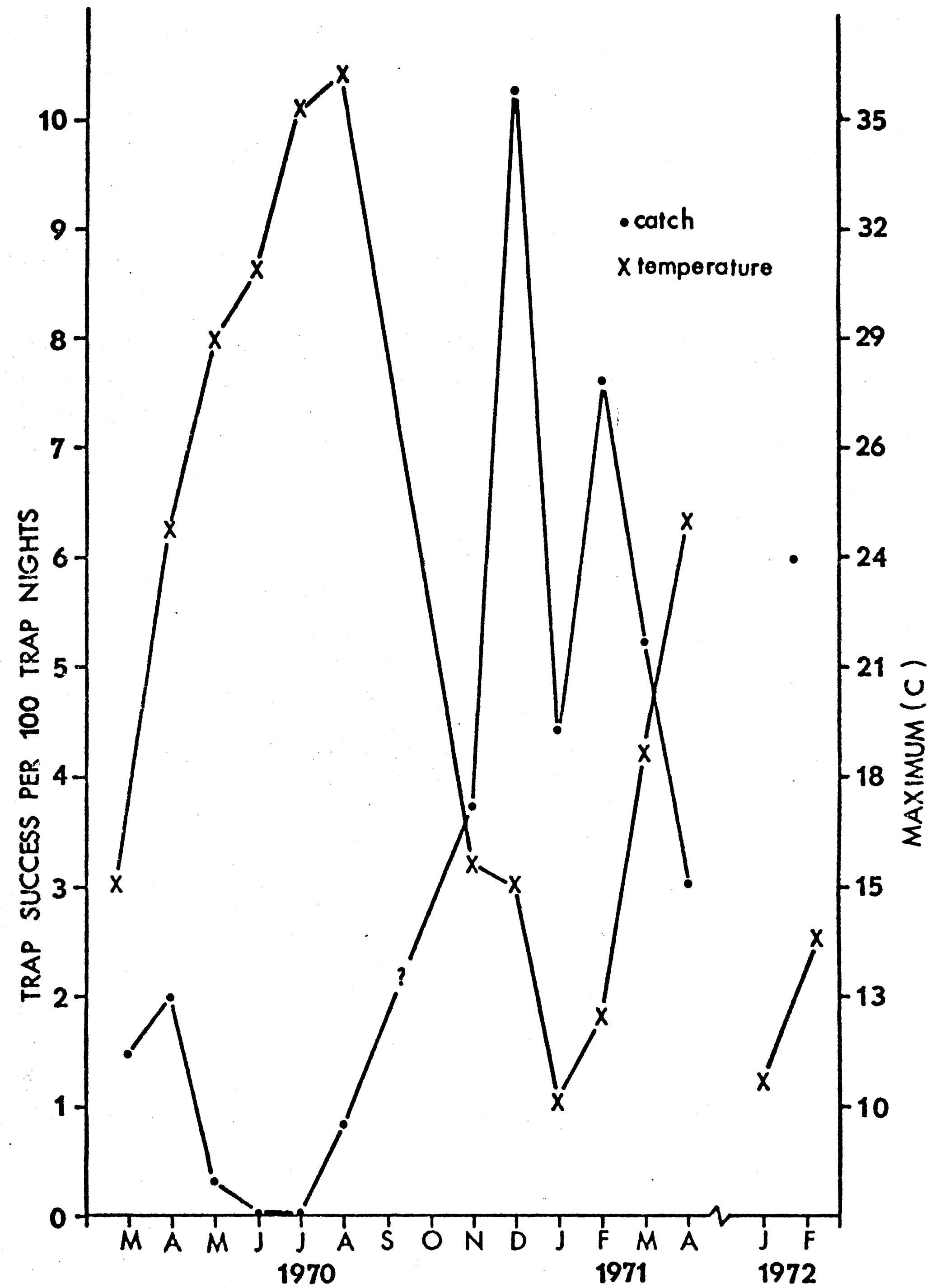

Figure 48. Relationship Between Squirrel Trap Response and Minimum Temperature (C) on the Spears Study Area, 1970-1972.

expenditures. He found that home range size could be expressed as a function of body weight which was directly comparable with the function relating basal metabolic rate to body weight. Calhoun and Casby (1958) have emphasized that the understanding of the biology of home range has considerable relevance to the problem of population density.

There are many techniques for characterizing home range (Sanderson 1966). Probabilistic home-range models have been proposed by Hayne (1949), Dice and Clark (1953), Calhoun and Casby (1958), Harrison (1958), and White (1964). Jennrich and Turner's (1969) choice of a bivariate normal distribution is the most general of the probabilistic models and it seems adequate for characterizing the home range of many animals occupying homogeneous habitats, including those species exhibiting a noncircular home range (Stumpf and Mohr 1962). None of these models, however, is appropriate for animals occupying a nonhomogeneous habitat such as an ecotone (Van Winkle, et al. 1973).

Numerous methods for actually calculating the size of home range for an individual have been presented. Most of these methods establish the home range as an area inside discrete boundaries beyond which an animal is assumed not to roam (Strickel 1946, Mohr 1947). Hayne (1949) presented the concept that some parts of the home range are more intensively used than others. He gave a method for calculating the geometric center of activity and suggested that the probability of capture of an animal decreases as the distance from the center of activity increases. Harrison (1958) presented a method for calculating the diameter of the concentric probability zone that contains 68.26 percent of the captures and, in theory, 68.26 percent of the animal's activity. The important aspect of Harrison's (1958) standard diameter concept is that the standard diameter of activity of an individual, a sex, a species, or a population can be calculated.

Reported sizes of home ranges for fox and gray squirrels vary from approximately 0.4 ha in size to more than 8.1 ha (Allen 1943, Robinson and Cowan 1954, Flyger 1960, Taylor 1966, Jones 1970, Doebel and McGinnes 1974). Using radiotelemetry, Geeslin (1970) found that fox squirrels in oak woodlands similar to the post oak-blackjack oak forests of east-central Oklahoma had an average home range of 1.2 ha (n=43). Female fox squirrels had an average home range of 1.3 ha whereas the males had an average home range of 1.1 ha.

In this study, home ranges were calculated for 43 fox squirrels and 3 gray squirrels, based on three or more recoveries for each squirrel (Table XXX). Adult male fox squirrels had larger minimum home ranges than did the adult females and juvenile-subadult male age classes.

TABLE XXX

HOME RANGES OF FOX AND GRAY SQUIRRELS, SPEARS STUDY AREA, OKMULGEE COUNTY, OKLAHOMA, 1970-1972

Category	n	Minimum Home Range (ha)	(1SE)	Maximum Length of Home Range Meters	(1SE)	Maximum Width of Home Range Meters	(1SE)	Length X Width Ratio	(1SE)	n	Haynes Radii Average	(1SE)
						Fox Squirrel						
Adult Females	8	.44	(.15)	140.4	(19.5)	61.8	(18.9)	1:.42	(.103)	28	61.1	(5.8)
Adult Males	19	2.87	(1.16)	281.0	(32.3)	77.9	(19.1)	1:.249	(.044)	72	111.6	(8.7)
Juvenile-Subadult Females	2	1.09	(.84)	302.4	(4.9)	82.9	(62.8)	1:.270	(.210)	9	97.2	(20.1)
Juvenile-Subadult Males	14	.76	(.48)	245.0	(49.7)	36.6	(8.8)	1:.184	(.040)	47	105.5	(14.6)
						Gray Squirrel						
Juvenile-Subadult[a]	3	.25	(.13)	141.4	(96.0)	12.8	(4.6)	1:.11	(.04)	10	58.2	(14.0)

[a]Combined due to small sample size.

Adult male minimum home ranges were longer and wider than those of the other two groups.

The general shape of the minimum home range was distinctly noncircular. The home range of adult males was almost four times as long as wide, and maximum length and maximum width ratio of the adult females range was 1:42. The ranges of adult males were narrower than those of the adult females although the age class of juvenile-subadult males had the most linear home ranges of the entire fox squirrel group.

<u>Movements of Fox and Gray Squirrels</u>

The movement radii from the center of activity (Haynes 1949) were greater in adult males than in adult females (P=.05) but no significant difference in the length of these radii existed between the two age classes of fox squirrel males. Of the eight squirrels recovered outside the study area, only two traveled farther than 1.6 km from the area. One male fox squirrel, classed as a subadult when tagged on 9 August 1970, was recovered 279 days later on 15 May 1971, at a straight-line distance of 11.1 km westward on the Deep Fork at the Walker Study Area. The other fox squirrel, classed as a subadult female when tagged on 24 January 1971, was recovered 254 days later, 7.5 km west of the Spears Study Area along the Deep Fork in the bottomland forest.

Only 1.8 percent (8) of the squirrels tagged on the study area were recovered outside the Spears Study Area. During the study there was no conclusive evidence that many squirrels emigrated after being tagged.

There was considerable movement of squirrels between habitat types on the study area. Of the male fox squirrels, 26.8 percent changed habitat types between recaptures as did 21.4 percent of the female fox squirrels. Males were more likely to change habitat types than were the female squirrels (P=.05). No gray squirrels were recovered in habitat other than bottomland forest or its ecotone, the brush fringe along the river (Fig. 49).

Escape radii for fox and gray squirrels are presented in Table XXXI. A significant difference between adult female and adult male fox squirrel escape distances exists (P=.05) with males traveling almost twice as far as the females after their release at the trap site to seek shelter. No significant difference existed between the juvenile female and juvenile male escape radii of the fox squirrels.

A difference between gray squirrel male and female escape distances may also exist (P=.10), with female grays traveling farther than the males, but too few observations were collected for verification.

No significant difference (P=.05) between the average escape radii of all fox squirrels and all gray squirrels followed to shelter was indicated.

Figure 49. A Few Gray Squirrels Remained in This Brush Fringe Bordering the Deep Fork and the Open Pecan Orchard. None Occurred in the Pecan Orchard Area Where This Brush Fringe Was Lacking. Spears Study Area, March 1972.

TABLE XXXI

ESCAPE RADII OF FOX AND GRAY SQUIRRELS, SPEARS STUDY AREA

Sex and Age Class	n	Average Escape Radii in Meters (1SE)
	Fox Squirrels	
Juvenile-Subadult Female	25	19.3 (5.0)
Juvenile-Subadult Male	58	18.0 (3.3)
Adult Female[a]	43	13.9 (3.1)
Adult Male	63	27.5 (4.5)
All	189	20.6 (2.0)
	Gray Squirrels	
All Females	14	19.8 (6.7)
All Males	9	17.6 (5.1)
All	23	18.9 (4.5)

[a]Adult males x adult female fox squirrel escape radii significantly different (t-9.95). No significant differences between juvenile male and female fox squirrels or gray squirrel males and females P=.05).

Once released from the traps, fox squirrels did not escape to shelter in an equal fashion (Chi-square value= 18.8, P=.05) but 25 percent of the time (27 out of 108) traveled northward between 337 degrees and 23 degrees true bearing. Forty-three percent of the squirrels (83 of 191) sought refuges in the tree at the trap station; the remainder fled elsewhere.

Population Densities of Fox and Gray Squirrels on the Spears Study Area

Efforts to estimate the population densities of fox and gray squirrels on the Spears Study Area from the beginning of March 1970 through May 1972 were only partially successful. Repeated flooding of the study area hampered trapping efforts and failure to recapture adequate numbers of previously marked squirrels resulted in low precision for the estimates that were obtained (Table XXXII). Figure 50 shows the general population trends on the study area during 1970 to 1972.

Both contagion and heterogeneity may affect the population estimates on the study area (Marten 1970). This results in bias in the estimates and makes the interpretation of the results questionable.

The assumptions usually stated for mark-recapture techniques: no emigration, no recruitment or deaths or loss or gain of marks during the estimation period, were probably only partially met during this trapping. The

TABLE XXXII

POPULATION ESTIMATES BASED ON RECAPTURES OF PREVIOUSLY MARKED SQUIRRELS

			Population Estimates			
					Geometric	
Trapping Period	Number of Individuals Captured (n)	Total Number of Captures	Petersen	Schnabel	MLE	Regression
March 1970	17	17	--	90[a]	--	--
April 1970	33	34	--	465(33-9,062)	1,122	1,034
May 1970	48	48	432	--	--	--
June 1970	0	0	--	--	--	--
August 1970	13	13	--	162	--	--
November 1970	17	18	--	221(16-4,323)	306	--
December 1970	134	136	--	471(274-746)	9,116	--
January 1971	58	58	--	282(155-470)	--	--
February 1971	52	52	--	360(99-1,063)	--	--
March 1971	74	82	--	190(133,260)	758	676
April 1971	58	60	--	94(62-135)	1,742	1,740
May 1971	75	75	323(196-505)	--	--	--
January 1972	109	112	--	244(153-367)	4,192	4,072
May 1972	47	47	353(148-722)	--	--	--

[a]Adults only, no young available yet to be trapped.

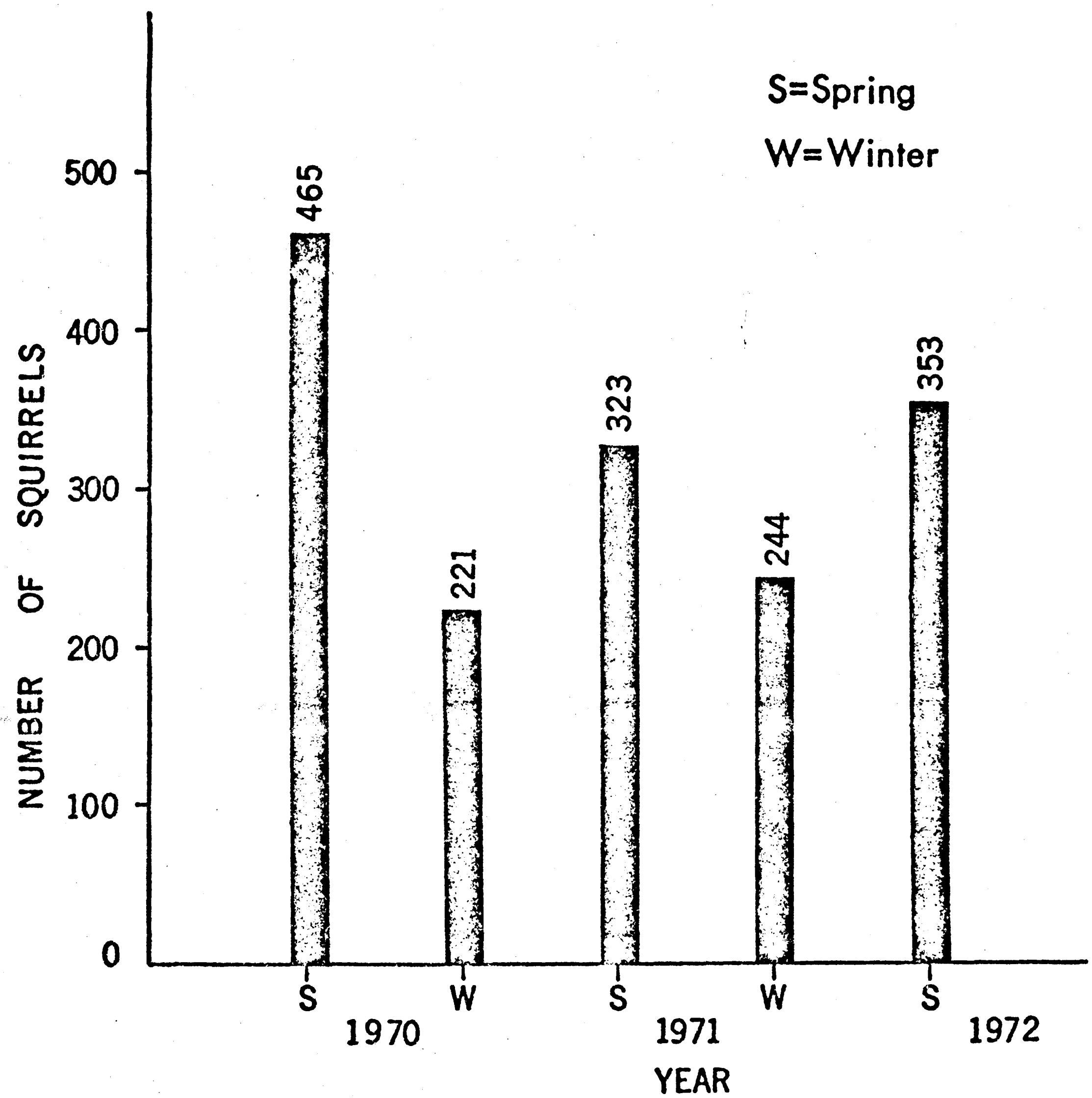

Figure 50. Population Estimates of Fox and Gray Squirrels on the Spears Study Area, 1970-1972.

assumption of equal probability of capture among individuals in the population and random mixing has been shown to be false. Failure of hunters to return tagged squirrels taken from the area also probably contributed to errors in the estimation process.

The basic conditions required for meaningful estimates based on the maximum likelihood estimation (MLE) for the geometric distribution and regression techniques for a geometric distribution, with the total capture in any sampling period being 1.5 to 2.0 times the number of individuals handled, was not met. It resulted in unrealistic population estimates obtained with both of these formulas.

Although usually producing an underestimate of the actual population present (Edwards and Eberhardt 1967), the Schnable method was used to estimate population densities when sequential trapping was used (Schnabel 1938). Where applicable, an estimate of population numbers was provided by the unmodified Petersen Index (Petersen 1896).

Eberhardt, et al. (1963), Edwards and Eberhardt (1967), Nixon, et al. (1967) and Eberhardt (1969) discussed the problems associated with estimation of population densities based on mark-recapture methods. Marten (1970) provided information on the use of regression in estimating the number of individuals never captured in the trapping period. Use of Gaskell and George's (1972) Bayesian modification of the estimate based on the

Petersen Index produced virtually identical estimates to those from the unmodified formula, so this modification was not used.

Jones (1970) found that the Petersen Index appeared to be the best technique for obtaining population estimates. He found that the Eberhardt formula for the maximum likelihood estimate (MLE) proved to be consistently higher than either of the other two estimates he used and often produced irrational estimates (Jones 1970). However, Strandgaard (1967) found that in roe deer (*Capreolus capreolus*) more than two-thirds of the population must be captured and marked to obtain a reliable measure of population size. This percentage of marking probably was not reached on the Spears Study Area.

Multiple-capture analyses clearly violate most, if not all, of their basic assumptions, under the field conditions encountered in this study. Consequently, their results are questionable and safely serve only as a gross index of population trends. Other methods of trend estimation, such as hunter kill per hour or trip or total harvest can supply essentially the same information under the existing conditions on the Spears Study Area.

A concentrated live-trapping operation immediately prior to the hunting season and perhaps at other selected seasons throughout the year and the use of the modified Petersen Index appear, at this current state of the art, to be the best approach to estimating density. Other techniques may work well on relatively small, controlled study areas but not on large tracts under conditions similar to those found on the Spears Study Area.

By examining trapping records and plotting the span of time an individual squirrel was known to be alive on the study area, a minimum number of individuals present was determined. In 1970, between March and December, 224 different squirrels, 1 per 0.61 ha were known to be present. From January through December 1971, 256 squirrels were known definitely to be on the area; 1 per 0.53 ha of woodland.

During the 29 months of records on the area, 391 squirrels were removed from the 133 ha. There were 318 known to have been harvested by hunters, and another 73 died in traps, primarily during unexpected flooding and low temperatures (Table XXXIII).

If a 10 percent crippling loss is assumed, the minimal harvest by hunters on the area was about 150 squirrels per year or one squirrel per 0.89 ha of woodland.

Although there was no evidence that many squirrels left the study area, there may have been a mass immigration of squirrels onto the area in December 1970. Flooding prevented the harvest of approximately 75 percent of the fairly good pecan crop of 1970, and after the waters went down in early December abundant food was available for the squirrels. This could explain the sudden jump in the

TABLE XXXIII

SQUIRRELS KNOWN REMOVED FROM SPEARS STUDY AREA

Period	Shot: Total Number	Shot: Number Marked	Died in Trapping: Total Number	Died in Trapping: Number Marked
March 1970	0	0	3	0
May 1970	48	0	0	0
August 1970	31	3	1	1
September 1970	4	0	0	0
December 1970	0	0	15	1
Total	83	3	19	2
January 1971	0	0	2	0
February 1971	0	0	14	2
April 1971	14	3	0	0
May 1971	63	18	0	0
June 1971	25	3	0	0
July 1971	9	3	0	0
August 1971	8	3	1	0
October 1971	17	3	0	0
November 1971	2	1	0	0
December 1971	1	0	0	0
Total	139	34	17	2
January 1972	0	0	4	0
February 1972	0	0	21	8
March 1972	2	2	0	0
May 1972	46	3	0	0
July 1972	6	0	0	0
Total	54	5	25	8
Grand Total	276	42	61	12

capture rate experienced on the study area during this time (Table XXXII).

CHAPTER VI

MORPHOMETRICS AND ESTIMATION OF AGE IN FOX AND GRAY SQUIRRELS

Introduction

Although fox and gray squirrels are common in eastern Oklahoma, no thorough description of their morphometrics exists for this area. Beginning in August 1970 and extending until June 1972, monthly collections of squirrels were made along the Deep Fork of the North Canadian River in Okmulgee and Okfuskee Counties (Fig. 1). One important use of these physical measurements of squirrels collected was to establish age classes with which to describe the general population dynamics of these two species.

A variety of techniques have been used to establish the age of tree squirrels. Body weights (Uhlig 1955b, 1955c), pelage (Sharp 1958, Barrier and Barkalow 1967), condition of genitalia (Kirkpatrick 1955, Kirkpatrick and Barnett 1957, Kirkpatrick and Hoffman 1960, Mossman, et al. 1955), and the degree of epiphyseal closure of the radius and ulna bones (Petrides 1951, Carson 1961) all provide varying degrees of success in establishing several age classes of squirrels.

It now appears that one of the best techniques for determining age structure within a group of squirrels is the use of the dry weight of the crystalline eye lens as the age indicator (Beale 1962, Fisher and Perry 1970). Originally used by Lord (1959,1961) and others (Martinson, et al. 1961, Sanderson 1961), it is now an accepted technique for determining age in certain groups of mammals. Friend (1968) has reviewed the use of this technique and made suggestions regarding standardization of the procedure. Initially, eye lens weight was used to establish age classes of squirrels collected during this study.

Methods and Materials

During the study, 442 fox and 355 gray squirrels were obtained from hunters at check stations along the Deep Fork River primarily at the Okmulgee Public Hunting Area, from my own hunting activities, from road kills, and from squirrels that died during livetrapping operations on the Spears Study Area. Specimens were often temporarily frozen until necropsied. Weights of each animal were taken to the nearest gram on an Ohaus triple-beam balance and standard measurements were taken. These included: total length (taken from the tip of the nose to the tip of the last tail vertebra), tail length (length from the base of the tail to the posterior tip of the tail vertebrae), body length (the difference between the total length and tail measurement), length of the hind foot (length from the heel to the tip of the claw on the longest toe), and height of ear (distance from the notch below the ear opening to the tip of the ear, excluding hair). All body measurements were taken with a metal tape measure and recorded to the nearest millimeter on a necropsy form.

The eyes were removed from all squirrels collected, wrapped in cheesecloth, and stored in 4-liter glass jars containing 10 percent formalin until analyzed during June 1973.

Lenses were removed from the eyes, placed in a water-filled petri dish, and, if necessary, cleansed carefully of extraneous material with a camel-hair brush. They then were placed in a 95 percent alcohol solution for 3 to 5 min for partial dehydration to reduce the problem of the lens sticking to the drying vial and damaging its surface. All lenses were placed in 9 x 30 mm glass vials and dried in a hot-air oven at a temperature of 80 C as suggested by Lord (1959). A drying period of 48 h was adopted because weight loss of drying eye lenses after that time was not significant. Beale (1962) also found little weight loss occurring in lenses after 48 h of drying time. After drying was completed, the lenses were weighed on an analytical balance and their weight recorded to the nearest 0.1 mg. Any lens that evidenced sloughing off of tissue or appeared grossly atypical in color or shape was discarded. Because the eye lenses are hygroscopic, they were placed immediately after removal from the drying oven into a vacuum dry-seal desiccator, containing dessicant, remaining there to prevent moisture pickup by the lenses until weighed.

Tissue was removed from the skull of the squirrel in the following manner. After removing the brain from the skull by flushing with water injected through the foramen magnum with a 20-cc syringe, the skull was placed in a dilute ammonia solution and sealed in a glass jar. The jar was then placed in a hot-water bath of approximately 90 C for 45 min until the tissue was a brilliant reddish-pink color. The skull was then removed from the jar and washed under running tap water until all remaining adhering tissue had been removed. After drying, all measurements were taken with the same pair of Mitutoyo dial calipers and were recorded to the nearest 0.1 mm on the necropsy form.

Cranial measurements generally follow those of Moore (1959). The following cranial measurements were taken: occipitonasal length (the greatest length of the skull from the anteriormost tip of the nasals to the posteriormost point on the supraoccipital), orbitonasal length (the distance from the anterior edge of the right orbit, taken in the notch of the lacrimal bone, to the anterior tip of the right nasal bone), zygomatic breadth (the greatest distance across the zygomatic arch perpendicular to the long axis of the skull), orbital length (the greatest inside distance from the anterior edge of the orbit, in the notch of the lacrimal bone, to the posterior extremity of the orbit on the edge of the zygomatic process of the squamosal), orbital width (the greatest inside measurement, approximately at right angles to the line of the orbital length, from the frontal to the jugal), interorbital breadth (the least distance across the frontals between the rims of the orbits, excluding the reducing effect of the supraorbital notches), postorbital constriction (the least breadth of the skull immediately posterior to the postorbital processes of the frontals), length of the maxillary tooth row (the greatest length of the row of the right upper cheek teeth, including the third premolar, if present; this is a measurement of the teeth, not of the alveoli), and the length of the infraorbital canal (the least distance from the anterior margin of the suborbit to the lateral lip of the infra-orbital foramen).

All measurement data were subsequently transcribed and analyzed with a CDC 3150 computer at The Computer Center, California State University, Fresno. Statistical differences between paired measurements between sex and age classes were performed using the t test for a difference between two independent means with unequal sample sizes (Sokal and Rohlf 1969).

Results and Discussion

General Morphometrics

Descriptive statistics for the physical characteristics of fox and gray squirrels collected during the study are presented in Tables XXXIV and XXXV. The statistical results of values obtained and compared between males and females of the same age class are given in Tables XXXVI and XXXVII. Adult female fox squirrels were significantly heavier than adult male fox squirrels collected during the study, but the subadult male fox squirrels were heavier than the subadult female fox squirrels. Allen (1943) found female fox squirrels in Michigan to be larger than the males. Reproductive activities of the females may account for this weight difference.

No significant difference was found in the body weight of males and females in the three age classes of gray squirrels, although the adult females were slightly heavier than were the adult males. Brown and Yeager (1945) found no difference in weight between male and female gray squirrels in Illinois.

Both the subadult and adult female fox squirrel age classes were significantly longer than the subadult and adult age classes of the males. Only the subadult male fox squirrels had significantly longer body length than the subadult female group.

TABLE XXXIV

PHYSICAL CHARACTERS OF FOX SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

	Juvenile		Subadult		Adult	
Character	n	Average (1SE)	n	Average (1SE)	n	Average (1SE)
Body Weight						
Female	45	415.2 (8.3)	35	565.8 (11.4)	73	692.0 (8.0)
Male	52	415.7 (9.7)	56	593.9 (7.2)	149	680.2 (5.1)
Stomach Contents						
Female	44	11.1 (1.2)	29	10.2 (1.7)	68	17.1 (1.9)
Male	49	7.5 (0.7)	54	10.1 (1.3)	138	13.7 (1.1)
Total Length						
Female	46	452.0 (3.5)	37	488.4 (3.9)	68	504.2 (1.9)
Male	52	454.5 (3.4)	66	493.9 (2.6)	139	503.3 (1.4)
Tail Length						
Female	41	219.1 (2.2)	37	228.1 (1.9)	60	228.8 (1.3)
Male	46	218.6 (1.5)	64	228.5 (1.7)	123	228.7 (1.0)
Body Length						
Female	42	234.7 (2.0)	41	261.1 (2.5)	71	276.3 (1.2)
Male	46	237.0 (2.2)	69	265.7 (1.7)	145	275.4 (0.8)
Hind Foot						
Female	43	63.4 (0.3)	41	64.8 (0.3)	71	64.8 (0.3)
Male	47	63.7 (0.3)	71	64.5 (0.3)	148	65.2 (1.8)
Ear Length						
Female	43	21.8 (0.2)	41	29.1 (0.2)	71	28.6 (0.2)
Male	47	28.0 (0.2)	71	29.0 (0.2)	148	28.9 (0.1)
Eye Lens Weight						
Female	48	21.8 (0.2)	27	32.6 (0.7)	60	44.8 (0.7)
Male	59	22.6 (0.7)	62	33.8 (0.5)	125	44.0 (0.5)

TABLE XXXIV (continued)

Character	Juvenile		Subadult		Adult	
	n	Average (1SE)	n	Average (1SE)	n	Average (1SE)
Occipitonasal Length						
Female	20	59.9 (0.5)	22	62.5 (0.2)	59	63.7 (0.2)
Male	23	59.8 (0.6)	48	62.3 (0.3)	118	63.7 (0.1)
Zygomatic Breadth						
Female	29	33.8 (0.2)	26	35.2 (0.1)	64	36.1 (0.1)
Male	32	33.7 (0.3)	57	35.3 (0.1)	128	35.8 (0.1)
Orbitonasal Length						
Female	25	23.9 (0.5)	27	26.1 (0.2)	69	26.2 (0.4)
Male	31	24.3 (0.3)	54	26.3 (0.1)	131	26.4 (0.2)
Orbital Length						
Female	35	19.6 (0.1)	30	20.2 (0.1)	68	20.2 (0.1)
Male	44	19.5 (0.1)	61	20.1 (0.1)	136	20.3 (0.1)
Orbital Width						
Female	30	13.4 (0.1)	30	13.8 (0.1)	69	13.9 (0.1)
Male	34	13.5 (0.1)	63	13.9 (a)	137	13.9 (a)
Interorbital Breadth						
Female	44	18.3 (0.1)	32	19.5 (0.1)	70	20.3 (0.1)
Male	57	18.1 (0.1)	63	19.8 (0.1)	135	20.3 (0.1)
Postorbital Constriction						
Female	45	19.8 (0.1)	32	19.9 (0.1)	70	20.0 (0.1)
Male	58	19.7 (0.1)	58	20.3 (0.1)	133	20.1 (0.1)

[a]Standard error (1SE) less than 0.1.

TABLE XXXIV (continued)

Character	Juvenile n	Juvenile Average (1SE)	Subadult n	Subadult Average (1SE)	Adult n	Adult Average (1SE)
Maxillary Tooth Row Length						
Female	48	10.9 (0.1)	34	11.1 (0.1)	74	10.9 (0.1)
Male	58	10.8 (0.1)	65	11.0 (a)	144	10.9 (a)
Infraorbital Canal Length						
Female	48	6.2 (0.1)	30	6.7 (0.1)	73	6.9 (0.1)
Male	59	6.1 (0.1)	69	6.8 (0.1)	142	6.0 (a)

TABLE XXXV

PHYSICAL CHARACTERS OF GRAY SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Character	Juvenile		Subadult		Adult	
	n	Average (1SE)	n	Average (1SE)	n	Average (1SE)
Body Weight						
Female	61	310.8 (8.8)	63	461.1 (8.5)	41	526.1 (5.0)
Male	83	329.3 (4.9)	59	468.7 (5.9)	39	506.1 (8.9)
Stomach Contents						
Female	42	7.4 (0.8)	57	9.1 (0.8)	38	11.2 (1.5)
Male	76	8.2 (0.9)	54	6.4 (0.7)	33	9.6 (1.7)
Total Length						
Female	60	418.9 (3.2)	61	446.1 (3.1)	33	460.3 (3.1)
Male	84	417.5 (1.9)	64	452.5 (2.2)	34	455.4 (2.7)
Tail Length						
Female	46	202.0 (2.6)	55	204.7 (1.7)	30	207.3 (1.9)
Male	77	200.5 (1.1)	61	207.0 (1.4)	34	206.8 (2.0)
Body Length						
Female	48	219.2 (2.6)	60	244.4 (2.1)	37	251.6 (1.5)
Male	78	219.4 (1.5)	64	245.6 (1.7)	40	248.7 (1.2)
Hind Foot						
Female	48	60.8 (0.4)	61	60.7 (0.3)	38	61.1 (0.3)
Male	79	60.6 (0.3)	63	61.6 (0.3)	40	62.0 (0.4)
Ear Length						
Female	47	30.1 (0.2)	60	29.7 (0.2)	37	30.3 (0.3)
Male	78	30.4 (0.2)	65	30.9 (0.2)	40	31.0 (0.3)
Eye Lens Weight						
Female	47	21.9 (0.6)	58	33.8 (0.7)	37	44.6 (0.7)
Male	61	22.9 (0.4)	57	34.0 (0.5)	41	44.5 (0.6)

TABLE XXXV (continued)

Character	Juvenile		Subadult		Adult	
	n	Average (1SE)	n	Average (1SE)	n	Average (1SE)
Occipitonasal Length						
Female	12	57.4 (0.7)	40	591. (0.5)	33	59.8 (0.2)
Male	22	56.5 (0.3)	42	59.1 (0.2)	25	60.0 (0.3)
Zygomatic Breadth						
Female	19	31.5 (0.3)	50	32.5 (0.2)	33	33.7 (0.1)
Male	33	31.9 (0.5)	57	32.7 (0.1)	30	33.5 (0.2)
Orbitonasal Length						
Female	29	22.8 (0.6)	44	24.8 (0.3)	36	25.3 (0.2)
Male	38	22.9 (0.1)	44	24.9 (0.4)	28	25.8 (0.4)
Orbital Length						
Female	35	18.7 (0.1)	55	19.1 (0.1)	36	19.0 (0.1)
Male	49	18.5 (0.1)	60	19.2 (0.1)	32	19.0 (0.1)
Orbital Width						
Female	23	13.0 (0.2)	54	13.2 (0.1)	36	13.2 (a)
Male	41	13.1 (0.1)	55	13.1 (a)	33	13.2 (0.1)
Interorbital Breadth						
Female	54	17.0 (0.1)	57	18.5 (0.1)	36	19.0 (0.1)
Male	70	17.2 (0.1)	60	18.5 (0.1)	35	19.0 (0.1)
Postorbital Constriction						
Female	49	18.7 (0.1)	56	19.0 (0.1)	38	19.4 (0.1)
Male	69	18.8 (0.1)	61	19.1 (0.1)	33	19.3 (0.1)

[a] Standard error (1SE) less than 0.1.

TABLE XXXV (continued)

Character	Juvenile		Subadult		Adult	
	n	Average (1SE)	n	Average (1SE)	n	Average (1SE)
Maxillary Tooth Row Length						
Female	56	10.2 (0.1)	54	10.8 (0.2)	37	10.7 (0.1)
Male	70	10.2 (a)	60	11.0 (0.2)	29	10.7 (0.1)
Infraorbital Canal Length						
Female	58	5.7 (0.1)	50	6.7 (0.1)	39	6.8 (0.1)
Male	74	6.0 (0.1)	64	6.6 (0.1)	33	6.9 (0.1)

TABLE XXXVI

ANALYSIS OF BODY MEASUREMENTS OF FEMALE AND MALE FOX SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Character	Age Class					
	Juveniles t value	(df)	Subadults t value	(df)	Adults t value	(df)
Body Weight	NS	(95)	2.04[b]	(89)	2.07[b]	(220)
Weight of Stomach Contents	NS	(91)	10.87[c]	(81)	1.32[a]	(206)
Total Length	NS	(96)	2.14[b]	(101)	2.50[b]	(205)
Tail Length	NS	(85)	NS	(99)	NS	(181)
Body Length	NS	(86)	1.98[b]	(108)	NS	(214)
Hind Foot	NS	(88)	NS	(110)	NS	(217)
Ear Length	NS	(88)	NS	(110)	NS	(217)

[a]Indicates significance at the .1 level.

[b]Indicates significance at the .05 level.

[c]Indicates significance at the .01 level.

NS indicates not significant at or above the .1 level.

TABLE XXXVI (continued)

Character	Age Class					
	Juveniles t value	(df)	Subadults t value	(df)	Adults t value	(df)
Eye Lens Weight	NS	(105)	3.33[c]	(87)	1.70[b]	(183)
Occipitonasal Length	NS	(41)	NS	(68)	NS	(177)
Zygomatic Breadth	NS	(59)	NS	(81)	NS	(192)
Orbitonasal Length	NS	(54)	4.32[c]	(79)	NS	(198)
Orbital Length	NS	(77)	NS	(89)	NS	(202)
Orbital Width	NS	(62)	NS	(91)	NS	(204)
Interorbital Breadth	2.82[c]	(99)	12.00[c]	(93)	NS	(203)
Postorbital Constriction	NS	(101)	2.35[b]	(97)	1.96[b]	(201)
Maxillary Tooth Row Length	NS	(104)	NS	(97)	NS	(218)
Infraorbital Canal Length	6.58[c]	(105)	NS	(97)	NS	(213)

TABLE XXXVII

ANALYSIS OF BODY MEASUREMENTS OF FEMALE AND MALE GRAY SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Character	Age Class					
	Juveniles t value	(df)	Subadults t value	(df)	Adults t value	(df)
Body Weight	NS	(142)	NS	(120)	NS	(120)
Weight of Stomach Contents	NS	(116)	2.62[b]	(109)	3.49[c]	(69)
Total Length	NS	(142)	5.01[c]	(114)	2.44[c]	(62)
Tail Length	NS	(105)	NS	(114)	NS	(62)
Body Length	NS	(124)	NS	(122)	4.44[c]	(75)
Hind Foot	2.86[c]	(125)	7.50[c]	(122)	3.13[c]	(75)
Ear Length	NS	(123)	15.00[c]	(123)	8.30[c]	(75)

[a]Indicates significance at the .1 level.

[b]Indicates significance at the .05 level.

[c]Indicates significance at the .01 level.

NS indicates not significant at or above the .1 level.

TABLE XXXVII (continued)

Character	Age Class					
	Juveniles t value	(df)	Subadults t value	(df)	Adults t value	(df)
Eye Lens Cut	NS	(106)	NS	(113)	NS	(76)
Occipitonasal Length	NS	(30)	NS	(80)	NS	(73)
Zygomatic Breadth	NS	(40)	NS	(105)	40.00[c]	(61)
Orbitonasal Length	NS	(65)	NS	(86)	NS	(62)
Orbital Length	NS	(82)	NS	(113)	8.62[c]	(66)
Orbital Width	NS	(62)	NS	(107)	NS	(67)
Interorbital Breadth	NS	(122)	NS	(115)	NS	(69)
Postorbital Constriction	NS	(116)	NS	(115)	NS	(69)
Maxillary Tooth Row Length	NS	(124)	6.67[c]	(112)	3.13[c]	(64)
Infraorbital Canal Length	2.03[a]	(130)	NS	(122)	NS	(70)

Eye lens weights were statistically different in size between the subadult and adult groups, but this difference measured only 0.1 mg.

Other differences between the sexes are shown in Tables XXXVI and XXXVII. Few were consistent and may represent varying growth rates with time and/or the vagaries of a relatively small sample size.

<u>Eye Lens Weights</u>

Eye lens weights were plotted in the form of a histogram to determine the natural breaks or low frequency points in the distribution. These break points are considered the separation points between cohorts or age classes of squirrels. The generalized distribution of lens weights for 334 fox squirrels and 309 gray squirrels are shown in Figures 51 and 52.

By inspection of Figure 51, juvenile fox squirrels had an eye lens weight of 30 mg or less; subadults 31-41 mg, and adults a lens weight of more than 41 mg. Figure 52 shows that gray squirrels with eye lens weights less than 27 mg were juveniles, while subadults had eye lens weighing from 28 to 39-41 mg, and adults had a lens weight of more than 41 mg. These weights for each age class match approximately those given by Fisher and Perry (1970) and Beale (1962). Unfortunately, known-age squirrels were not available from this study, so the accuracy of this lens distribution could not be determined.

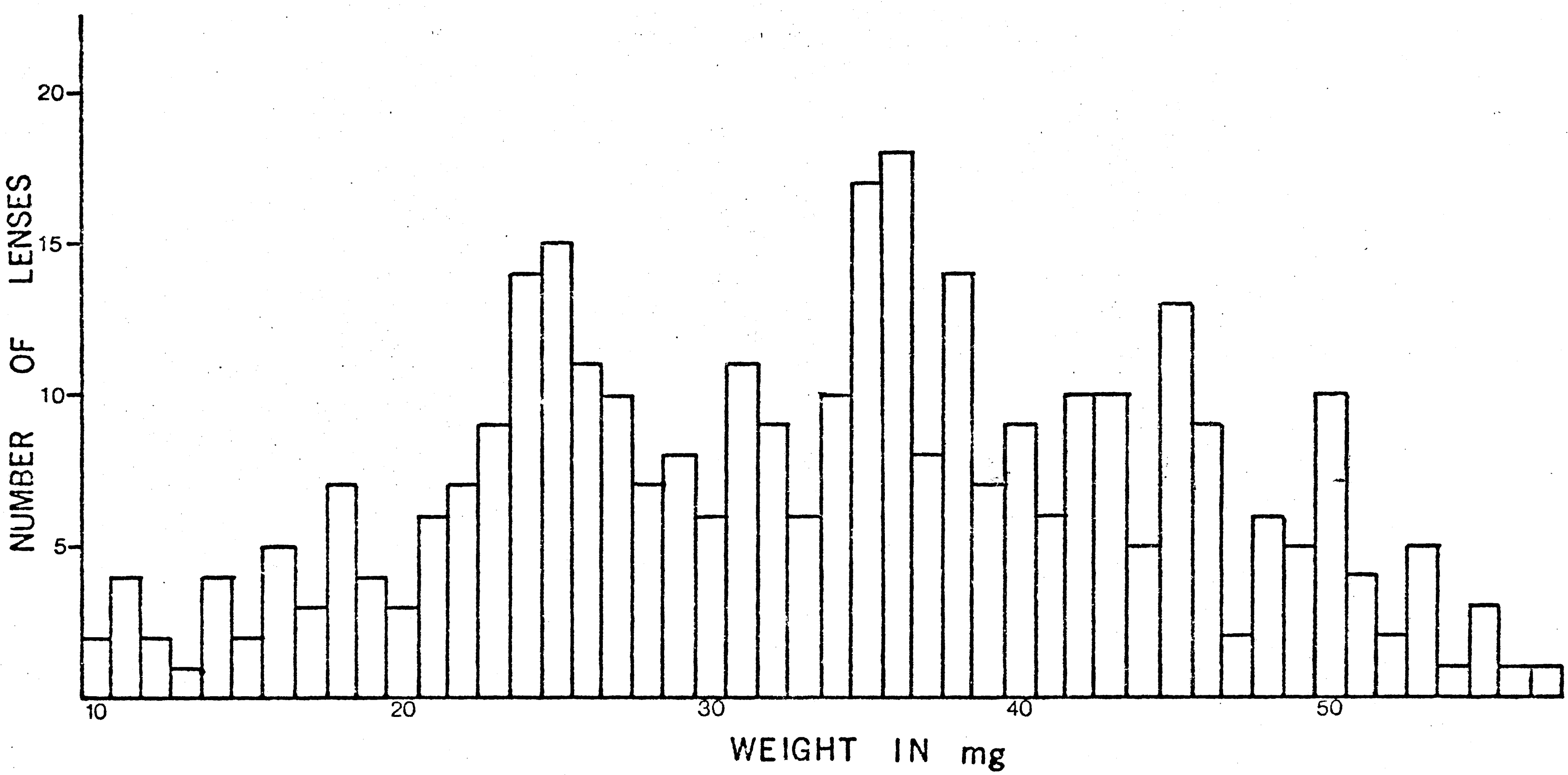

Figure 51. Distribution of Eye Lens Weights of Fox Squirrels During 1970-1972 in East-Central Oklahoma.

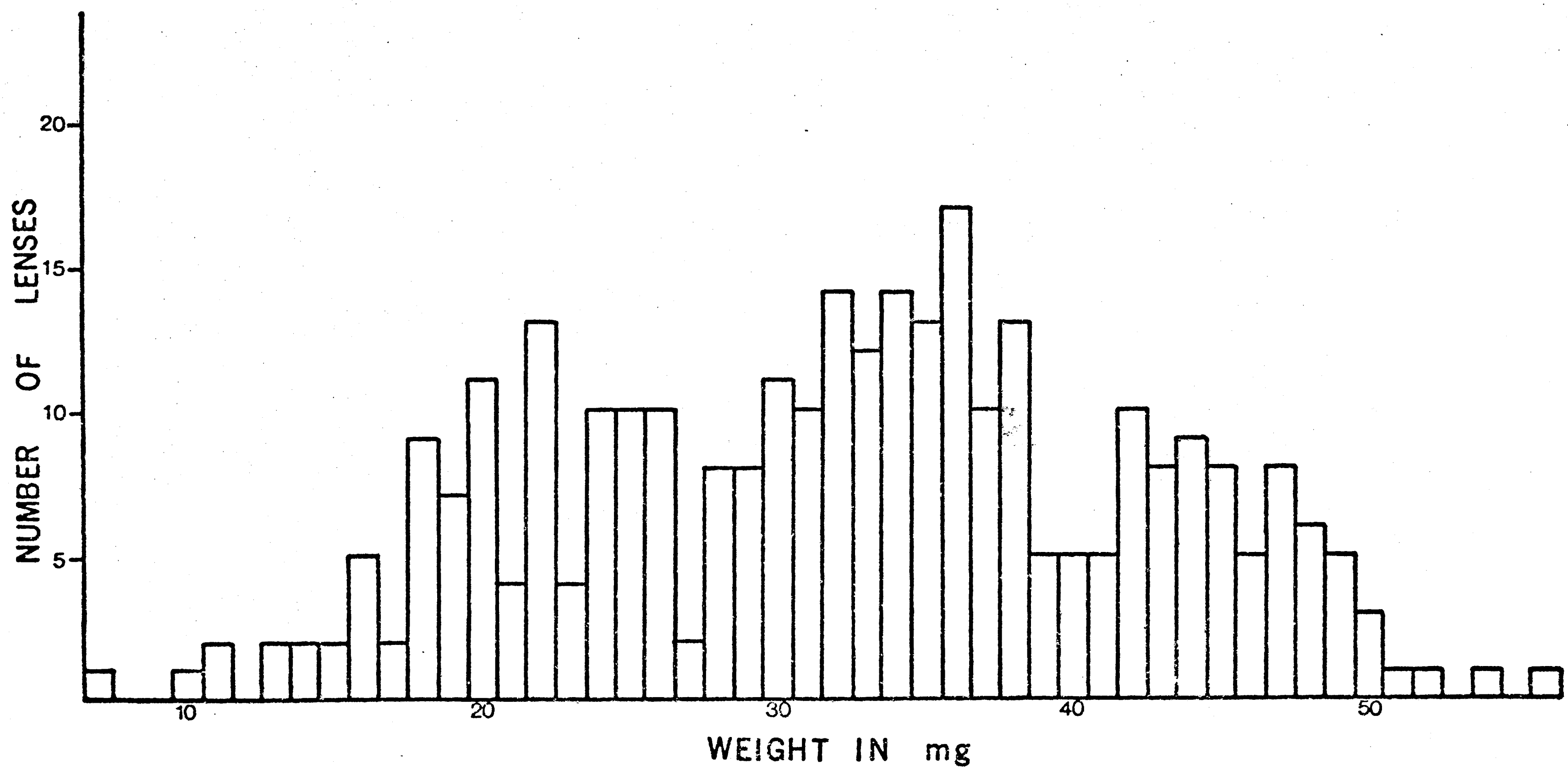

Figure 52. Distribution of Eye Lens-Weights of Gray Squirrels During 1970-1972 in East-Central Oklahoma.

Body Weights of Squirrels

Seasonal variability in the average weights of fox and gray squirrels has been reported by several researchers (Allen 1943, Thoma and Marshall 1960, Short and Duke 1971, Goodrum 1972). Generally, squirrel weights in the southern areas of the United States decline from early winter to a low point in summer and then increase rapidly in the fall, in response to an increase in food availability. Weight loss is greatest in fox squirrels during the spring in Michigan (Allen 1943). Goodrum (1972) correlated the weight losses with temperature data and found an inverse correlation indicated, although he felt parasites also contributed to weight loss.

Data collected during this study generally conform with that previously reported (Fig. 53), although there are some obvious differences in response between sexes. Adult female fox squirrels lost weight in the summer and early fall months and then began regaining weight in the winter months. Adult male fox squirrels had marked summer weight loss and then a steady gain in weight during the fall and winter months.

Weight changes in the gray squirrels was less pronounced but followed the same general pattern of weight loss in the summer and then an increase in weight in the later months. The spring increase in weight may be due to inclusion of pregnant animals or reflect an increase in

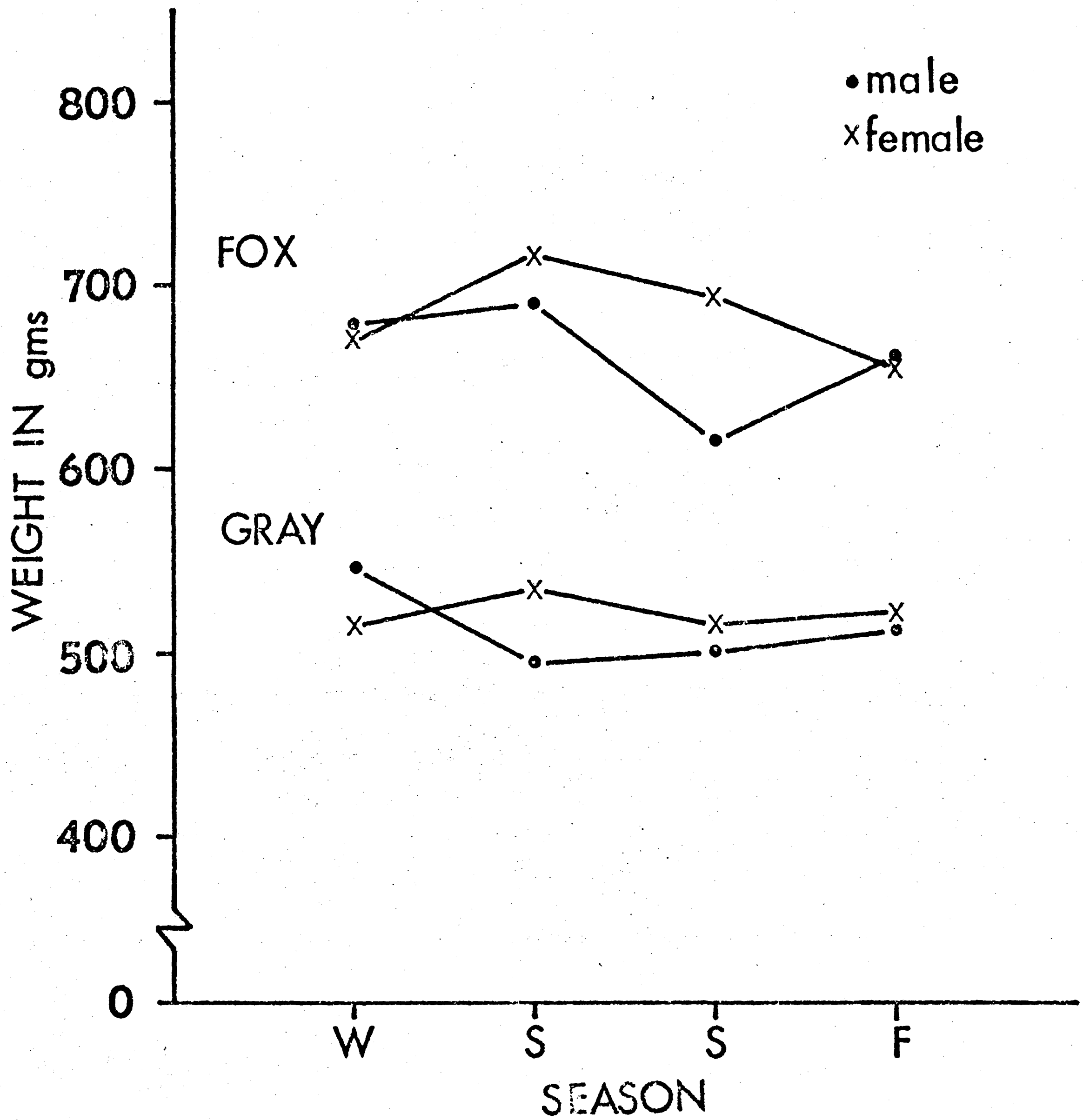

Figure 53. Seasonal Fluctuations in the Weights of Adult Fox and Gray Squirrels, Collected in Okmulgee and Okfuskee Counties, Oklahoma, 1970-1972.

food supplies that become available in April on the study area.

Examination of changes in the weight of live-trapped fox squirrels indicates that the magnitude of individual weight changes may be large (Tables XXXVIII and XXXIX). Total weight gain for adult male fox squirrels were slight: +.0444 gms per day, based on 2,365 days in the record of 29 individuals. The adult females had a negative gain: losing on the average -0.029 gms per day, based on 2,064 days of record for 17 animals. Too few squirrels were recaptured to permit the calculation of the gray squirrel rate of gain on the study area.

Livetrapped fox squirrels followed the same pattern of weight change as did the sample of squirrels collected by hunting (Table XL). Gray squirrels also followed the same general pattern of weight change (Table XLI).

Technical Problems in Examining Eye Lens

The microwave oven has been used by researchers in drying biological materials to reduce the drying time from days to often an hour or less (Burks, et al. 1974). In initial trials to determine the appropriate drying time for squirrel lenses, I used an Amana Radar Range Model RR3 on a sample of 10 squirrel lenses. Each lens was examined and weighed at the start of the trial and at 30-, 60-, 90-, and 120-min intervals to determine if this

TABLE XXXVIII

WEIGHT CHANGES OF LIVETRAPPED FOX SQUIRRELS ON THE SPEARS STUDY AREA

	Sample Size		Total Weight		
	n	Days	Change (gm)	Average (gm)[a]	Range
Adult Male	29	2,365	+105	+0.04	236 (-103 to + 87)
Adult Female	17	2,064	- 60	-0.03	
Juvenile-Subadult Male	15	2,847	+718	+0.25	286 (-159 to +127)
Juvenile-Subadult Female	8	691	+560	+0.81	453 (- 58 to +395)
Total	69	7,967	1,443	+0.18	123 (+ 7 to +130)

[a]Negative gains subtracted from positive gains in calculation of net daily gain.

TABLE XXXIX

SEASONAL WEIGHTS OF LIVETRAPPED FOX SQUIRRELS ON THE SPEARS STUDY AREA

Season	n	Juvenile Average	(1SE)	n	Subadult Average	(1SE)	n	Adult Average	(1SE)
Winter									
Female	5	423.2	(8.5)	21	559.8	(9.3)	24	723.7	(10.1)
Male	6	392.5	(27.4)	52	575.0	(6.4)	63	674.9	(5.4)
Spring									
Female	9	369.4	(17.9)	8	534.0	(20.4)	31	667.5	(8.8)
Male	3	340.3	(35.3)	21	583.8	(8.5)	21	655.8	(8.7)
Summer									
Female	2	415.0	(20.0)	--	--	(--)	1	675.0	(--)
Male	1	435.0	(--)	3	495.0	(11.5)	3	645.0	(10.0)
Fall									
Female	--	--	(--)	1	473.0	(--)	--	--	(--)
Male	1	473.0	(--)	--	--	(--)	3	622.3	(16.3)

TABLE XL

SEASONAL WEIGHTS OF FOX SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Season	n	Juvenile Average	(1SE)	n	Subadult Average	(1SE)	n	Adult Average	(1SE)
Winter									
Female	--	--	(--)	3	626.7	(13.8)	6	670.7	(14.4)
Male	3	502.7	(12.4)	9	604.4	(18.2)	6	674.8	(11.4)
Spring									
Female	32	407.6	(10.6)	10	538.5	(26.2)	34	715.4	(12.0)
Male	35	401.8	(9.6)	22	598.8	(12.1)	42	689.9	(6.2)
Summer									
Female	6	422.0	(7.9)	12	552.7	(16.9)	15	693.0	(18.8)
Male	7	470.6	(30.4)	11	582.5	(16.2)	9	614.9	(21.4)
Fall									
Female	7	444.1	(18.6)	10	590.6	(17.7)	18	654.1	(12.2)
Male	7	392.6	(31.8)	14	588.4	(13.8)	16	657.2	(13.7)

TABLE XLI

SEASONAL WEIGHTS OF GRAY SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Season	n	Juvenile Average	(1SE)	n	Subadult Average	(1SE)	n	Adult Average	(1SE)
Winter									
Female	--	--	(--)	2	506.0	(17.0)	1	517.0	(--)
Male	3	296.0	(74.3)	5	477.0	(15.7)	4	546.0	(63.2)
Spring									
Female	41	295.6	(9.3)	21	474.4	(9.6)	21	534.7	(7.6)
Male	53	324.3	(8.7)	23	474.4	(8.2)	12	495.9	(13.1)
Summer									
Female	12	335.5	(14.0)	14	451.9	(14.0)	10	514.1	(10.1)
Male	13	352.5	(14.1)	13	454.5	(9.5)	15	500.9	(12.4)
Fall									
Female	8	351.5	(38.3)	26	451.8	(7.8)	9	520.7	(7.8)
Male	14	333.7	(21.9)	18	469.6	(14.4)	8	511.8	(9.9)

rapid drying technique could be utilized for squirrels' lenses.

I judged this technique to be unsuccessful with squirrel lenses because after 30 min in the microwave oven, extensive charring was evident on 30 percent (3 of 10) of the lenses; and after 1 h, 80 percent (8 of 10) were charred. Charring represents potential loss of materials other than unbound water in the tissue, causing an unmeasurable bias in the data collected. The lack of constancy in the amount of charring occurring in the lenses, perhaps a function of size with the smaller lenses appearing to be more charred than the larger lenses, precludes predicting charring loss between lenses.

Based on measured weight changes, Figure 54 shows that 100 min is needed to completely dry the lens. More experimentation in this area may provide necessary modifications to make the use of microwave ovens possible in studying squirrel eye lenses. It has proven useful in drying other lenses, such as coyote (Canis latrans) lenses (Burks, et al. 1974).

Considerable variation in weight occurred between the right and left lenses of both the fox and gray squirrels. As suggested by Edwards (1967), only the weight of the heavier lens of each pair was used in estimating age.

This variation in weight could have been caused by freezing and thawing of the lenses. Freezing frequently results in lens tissue being sloughed off (Edwards 1967).

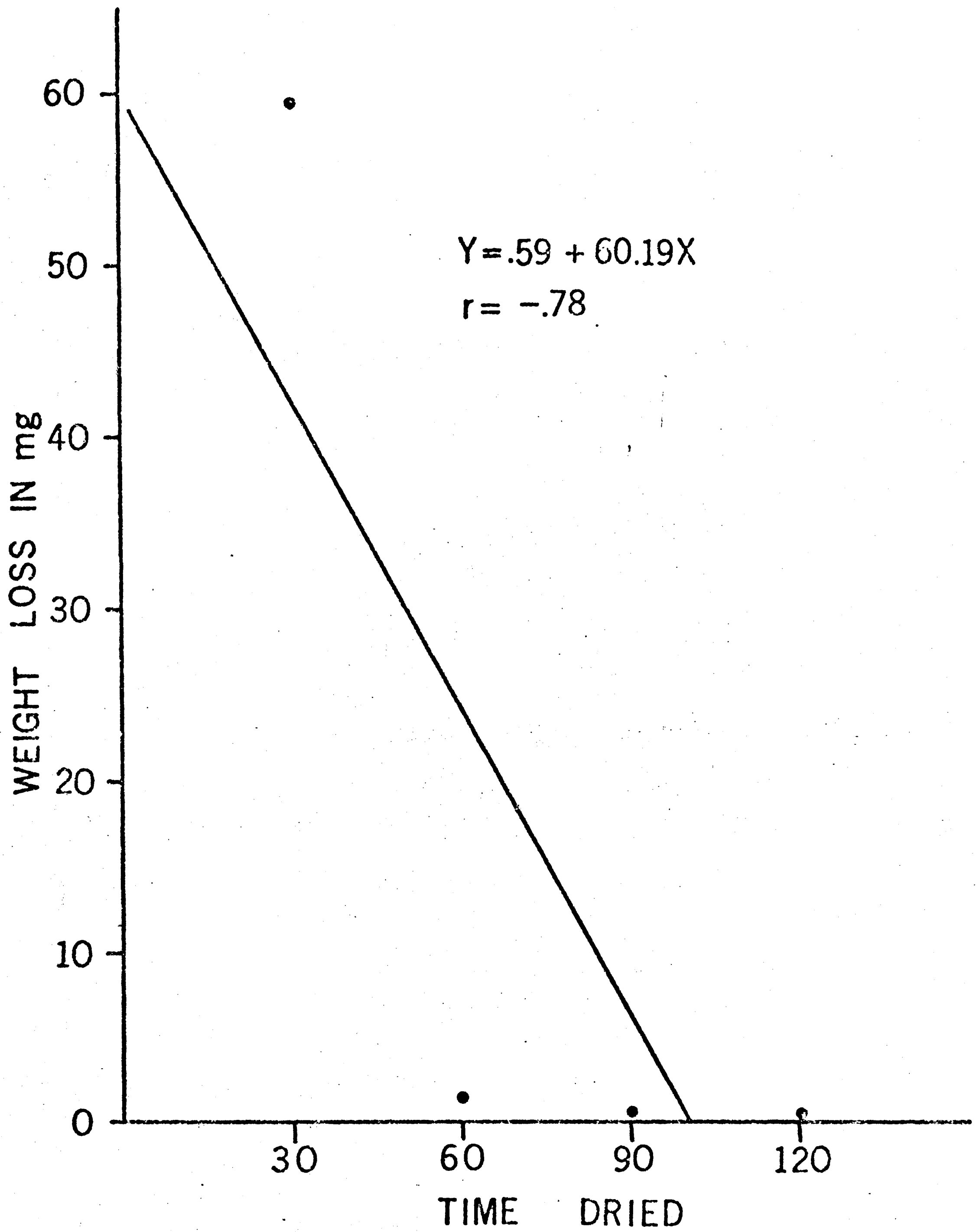

Figure 54. Drying Curve for Squirrel Eye Lenses, Utilizing Microwave Oven.

Development of an Age Index (AI) for Tree Squirrels

Reliance on any one physical feature to establish age classes or cohorts accurately of unknown-age animals is often unsuccessful. Variability of growth rates of the individual character being measured, changing environmental conditions, and genetic diversity contribute to the difficulties of establishing age classes. Eye lens weights in this study show general groupings for apparently different age classes or cohorts, but they were not as definitive as desired. Because of the availability of large samples and numerous physical measurements, an attempt was made to combine various morphometric values in such a way as to separate cohorts within the squirrel population.

Because two distinct breeding periods exist for squirrels, animals should fall into one of k classes or cohorts if the selection of physical attributes is made properly. This idea that polymodality of frequency distributions will denote actual cohorts within the population being sampled was the basis for the development of this age index. Theoretically, there could be 17 cohorts alive at any one time in the population; based on a cohort's average life span of 8 years (Barkalow, et al. 1970). However, because so few individuals are still alive in these oldest cohorts, 9 or 10 distinct groupings probably indicate success with this approach.

The shorter the parturition period, the sharper or more distinct these groupings should become. The faster the growth, the more distinct the classes should become; whereas the more uniform the growth rates between classes, the more overlap is to be expected between k classes. The more variation of any one or more physical characters being measured, the more overlap will occur between groups (Simpson, et al. 1960).

An attempt was made to combine several morphometric values into a usable index from which a more precise determination of age could be determined. Most physical features do not grow in a strictly linear relationship with age (time) but follow more closely a nonlinear progressionary curve, usually Sigmoid in shape (Sussman 1960, Brown 1973). Parks (1970a, 1970b, 1970c) discussed this relationship of physiological growth to time.

The theoretical relationship between linear and nonlinear growth rates and percent of development is shown in Figure 55. The equations expressing this relationship are:

$$\text{GROWTH} = X/MX + (X/MX * MX - X/MX) \qquad (1)$$

where:

growth = proportion of growth completed at a given time;

MX = maximum growth expected to be attained in animal's lifetime; and

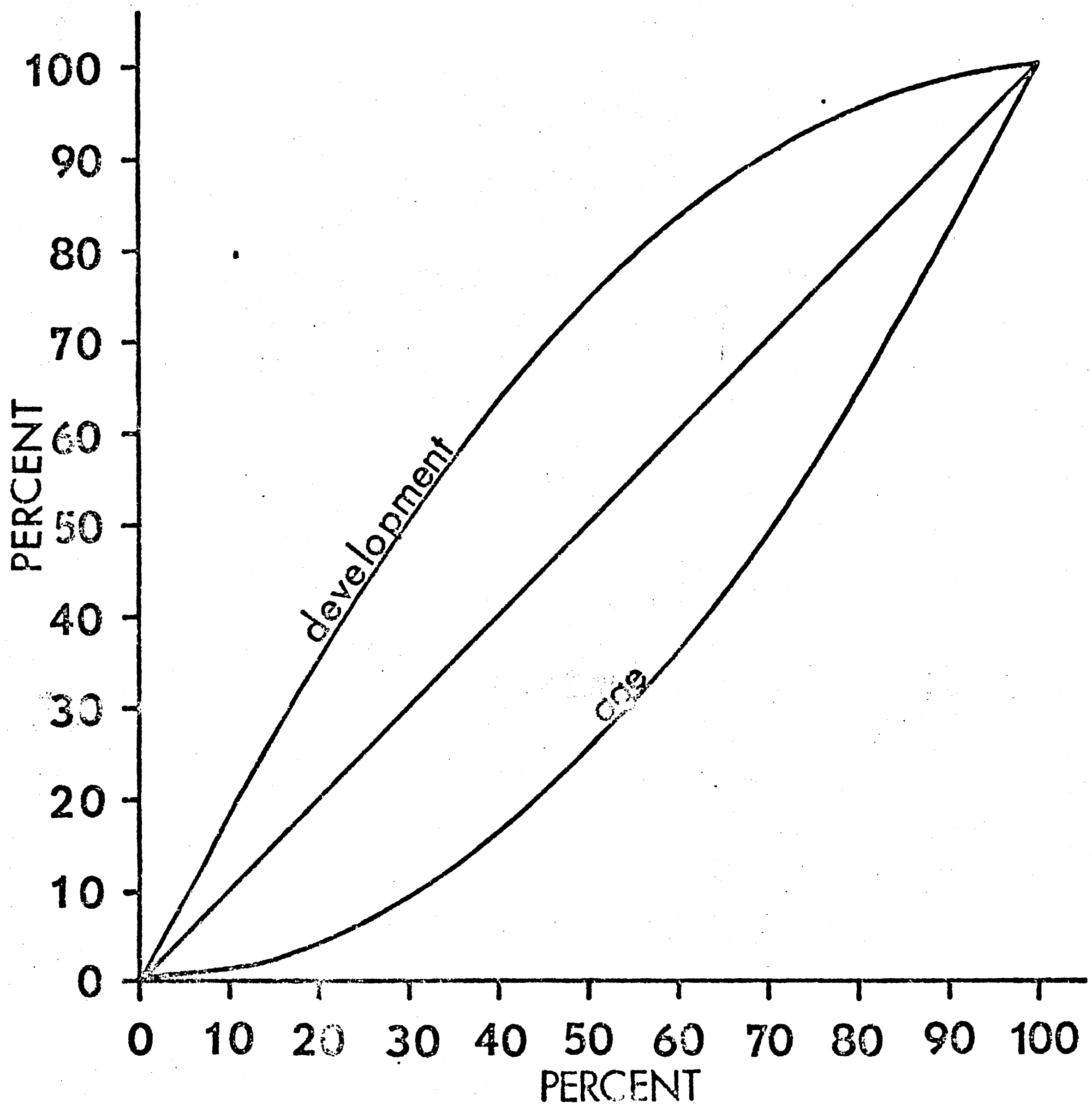

Figure 55. Theoretical Relationships Between Linear and Nonlinear Growth and Percentage of Chronological Development.

X = growth attained at time the measurement or observation was made.

But under most circumstances, more than one variable (characteristic) is observed or measured, so that the equation used is changed to:

$$GROWTH = X_i/MX_i + \frac{(X_i/MX_i - (MX_i - X_i)/X_i}{N} \quad (2)$$

where:

N = the number of characteristics observed.

For easier understanding of Equation 2, it could be multiplied by 100 which would put the data in terms of percentage points or percent of total development achieved at time t.

But rate of growth is not what is needed for the predictive equation. To get the aging factor, growth must be linearized as a regular line, so by changing Equation 2 to:

$$AGE = \frac{X_i/MX_i - (X_i/MX_i - X_i)/MX_i}{N} \quad (3)$$

The curve produced by Equation 3 is almost the inverse of Equation 2. Thus in two steps the physiological growth curve has been solved for a general aging curve (Fig. 55).

Some basic assumptions must be met before the general equation can be used:

(1) the growth curve form must be true for the majority of characteristics observed;

(2) the maximum value must be considered an upper limit or the largest achieved by the animal in question;

(3) seasonal environmental fluctuations are not incorporated in the overall development of growth rates whereas, in fact, such as with weights of squirrels, they may be the source of real amounts of variation; and

(4) masking by linear characteristics, as indicated by the Law of Diminishing Returns, should probably be less than 40 percent (Parks 1970a).

If a small difference exists between different age classes using one physical character, some mathematical manipulations should be possible to sum these differences and in the process create discrete groupings of similarly aged animals. The equation developed to express this relationship is:

$$\text{AGE INDEX (AI)} = (100) * N \frac{\frac{X_i}{MX_i} - \frac{X_i}{MX_i} * \frac{XM_i - X_i}{MX_i}}{N} \qquad (4)$$

where:

X = value observed for specific morphometric character in original units of measurement;

MX = maximum value observed for a specific morphometric character in original units of measurement;

N = number of morphometric categories used in calculation of Age Index (AI); and

i = specific morphometric character used in the calculation.

All calculations were done on California State University's CDC 3150 computer. The computer programs employed to calculate the age index values and print out the frequency distribution of these values, and to develop the theoretical relationship between linear and nonlinear growth rates are on file at The Computer Center, California State University, Fresno.

Using Equation 4, age index values and frequency distributions for these age index values were constructed using total length, eye lens weight, occipitonasal length, and total weight. A total of 90 frequency diagrams were generated by the computer program. These frequency diagrams indicated age index groupings for species, sex and the combined sample for all possible combinations of the four morphometric values.

Application of Age Index to Aging Squirrels

The frequency distributions for morphometric factors do not all result in emphasizing differences between cohorts in the population. The combinations utilizing total length, total weight, and eye lens weight appear by inspection to have the greatest promise for the development of an age index. Use of these values results in a spread along most of the graph's axis and seem to be producing discrete units. Larger samples are needed to confirm this interpretation. Utilization of known-age animals, unavailable for this study, would also either confirm or deny the usefulness of this proposed technique.

Based on this approach, no apparent gain over the use of eye lens weights only for aging tree squirrels was apparent so the eye lens aging technique was retained.

CHAPTER VII

REPRODUCTIVE BIOLOGY OF FOX AND GRAY SQUIRRELS

Introduction

Information on the breeding biology of fox and gray squirrels was collected from May 1970 through May 1972 in the Deep Fork area (Fig. 1). These data were essential in constructing the decision-making model dealing with the biological implications of the opening dates of the squirrel hunting season. Although no published information on squirrel reproductive biology was available from Oklahoma, the general reproductive biology of fox and gray squirrels is relatively well known.

The term "breeding season," as generally and correctly used by most investigators, includes the combination of the oestrous, pregnancy, parturition and lactation periods (Uhlig 1955a). Both fox and gray squirrels are dioestrous, having two distinct breeding seasons annually (Hibbard 1935, Baumgartner 1940, Goodrum 1940, Allen 1942, 1943, Brown and Yeager 1945).

Males become sexually mature at an age of approximately 10-11 months and remain sexually active until the following summer period of July, August, and September (Kirkpatrick 1955, Kirkpatrick and Hoffman 1960, Martan, et al. 1970). Development and function of squirrel testes has been documented in detail by Kirkpatrick (1955). The morphology and function of accessory genital glands of male fox and gray squirrels also has been determined by a number of researchers (Mossman, et al. 1932, Mossman, et al. 1933, Allanson 1933, Hoffman 1952, Mossman, et al. 1955).

Fox and gray squirrels have a gestation period of 43 to 45 days (Asdell 1964). Squirrels typically produce their first litter when approximately 1 year old (Allen 1952). The production of litters by squirrels less than 10 months of age is uncommon but does occur if environmental conditions are favorable (Smith and Barkalow 1967). Conversely, social stress, triggered by food shortages, may prevent successful reproduction of the population (Nixon and McClain 1969).

Both fox and gray squirrels produce about three young per litter, although considerable variation in numbers is reported in the literature (Baumgartner 1940, Goodrum 1940, 1967, Allen 1943, Uhlig 1955a, Packard 1956, Kidd 1962, Longley 1963). The time of breeding becomes later in the year as one travels northward in the squirrel's range. Fox squirrels often breed earlier than do the gray squirrels in northern areas (Brown and Yeager 1945, Longley 1963).

Fox squirrels seem to show less variation in their breeding seasons than do the gray squirrels (Allen 1952).

The only detailed description of female reproductive biology for gray squirrels is the work done by Deanesly and Parkes (1933). They describe the function and morphology of the female's reproductive tract and include the sequential histological changes of corpora lutea during and after pregnancy.

Methods and Materials

From 15 May 1970 through May 1972 reproductive materials from fox and gray squirrels killed by hunters were collected for analysis from the Deep Fork study areas. Condition of testes was determined by their position, ascended (abdominal) or descended (scrotal); length of scrotal sac, if present; and overall appearance of external male genitalia. Testis and epididymides were removed from the scrotal sac and fixed in 10 percent formalin for examination later. Testes length and maximum diameter were measured to the nearest 0.1 mm with dial calipers; their volume determined to the nearest 0.1 cc by water displacement; and the weight of the testes taken after fixation in formalin on a Mettler electronic balance (Model H10T). The diameter of the bulbo-urethral Cowper's glands, which lie at the base of the squirrel's tail just lateral to the anus, was also measured with dial calipers to the nearest 0.1 mm. Both the maximum diameter of the

Cowper's gland, including the ductus glandulae bulbo-urethralis and the maximum diameter of the glandula bulbo-urethralis only were determined.

Female reproductive tracts were excised during necropsy and preserved in 10 percent formalin until examined. After fixing, the decapsulated ovaries were weighed to the nearest 0.1 mg on a Mettler electronic balance (Model H10T). Ovaries from both adult, subadult, and juvenile squirrels were sectioned at 8 to 15 micra and the complete set of serial sections mounted and stained with haemotoxylin-eosin. Every fifth to tenth section was then examined microscopically at 100-125 X to describe corpora lutea and general reproductive condition. The rest of the reproductive tract was examined for visible signs of pregnancy and placental scars. On the basis of morphological and histological structure of the ovaries, uterine tract, and mammae, females were grouped as anoestrous, proestrous, oestrous, postpartum anoestrous, and pregnant animals.

Examination of the mammae of livetrapped squirrels and those collected by hunting provided information on the lactation of female squirrels. Presence or absence of visible mammae provided a general guide to the female's past and current reproductive status.

Observations of breeding behavior in free-ranging animals, such as mating chases, supplemented the laboratory work dealing with reproductive biology.

Results and Discussion

External Appearance of Male Genitalia

The external appearance of the scrotal sac of the fox and gray squirrel males was adequate to distinguish between juveniles and subadult-adult age classes (Figs. 56, 57, and 58). Juvenile testes usually were abdominal and the scrotal sacs were either absent or small and completely haircovered. By contrast, in the older age classes of males scrotal sacs were readily visible and were sufficiently distinct to provide an aid to age determination. Generally, the subadult scrotal sacs were lighter colored and had more hair than did the scrota of adult males. Position of testes, either abdominal or scrotal, is an unreliable aid in determining sexual activity because these animals are able to retract the testes into the abdominal cavity at will and do so particularly under stress such as when being handled in livetrapping activities. Hoffman and Kirkpatrick (1960) caution that size alone is not a reliable indication of sexual status in male squirrels.

There was a significant difference between the length of the scrotal sacs of subadult X adult gray or fox squirrels (P=.01). Juvenile fox squirrels had an average scrotal length of 21 mm (1SE=1.6 mm), the subadult fox squirrels an average scrotal length of 34 mm (1SE=1.4 mm),

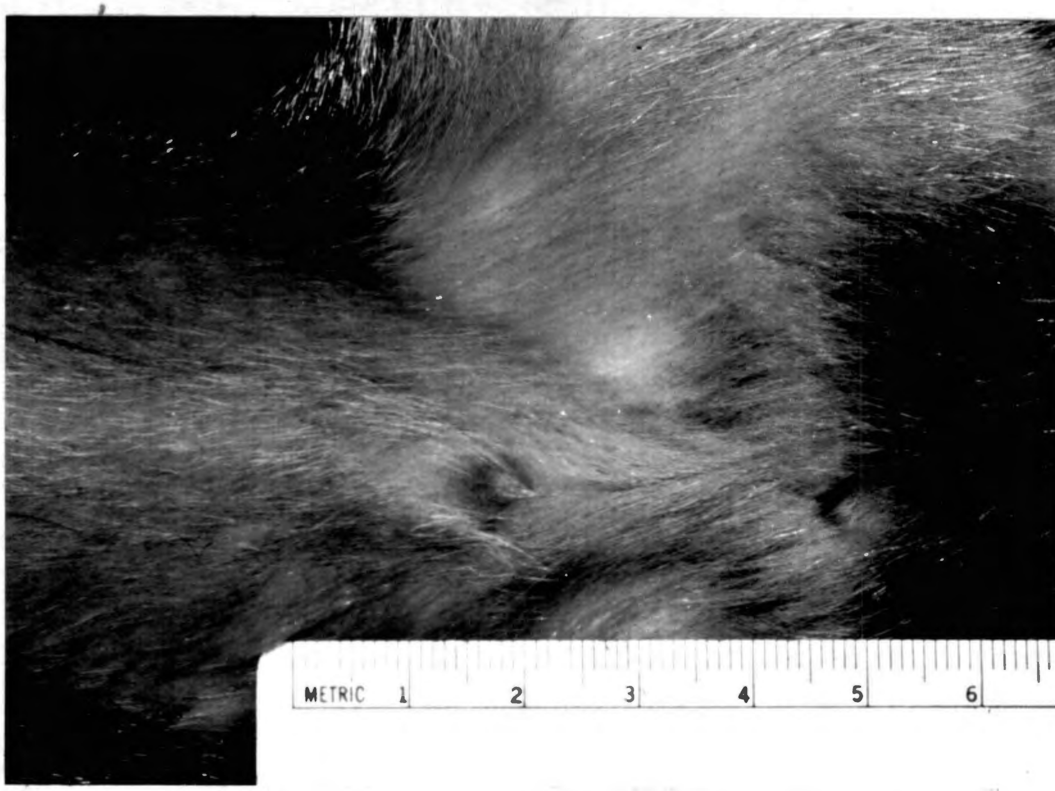

Figure 56. General Appearance of the Scrotal Sac of a Juvenile Male Fox Squirrel Collected on the Spears Study Area, May 1971.

Figure 57. General Appearance of the Scrotal Sac of a Subadult Male Fox Squirrel Collected on the Spears Study Area, May 1971.

Figure 58. General Appearance of the Scrotal Sac of an Adult Male Fox Squirrel Collected on the Spears Study Area, April 1971.

and the adults had an average length of 48 mm (1SE= 1.0 mm).

Juvenile gray squirrels had an average length of 21 mm (1SE=1.6 mm), the subadult gray males an average scrotal length of 33 mm (1SE=1.4 mm), and the adults had an average length of 43 mm (1SE=1.1 mm).

Morphometrics of Testes and Cowper's Glands

A summary of the physical measurements taken on materials collected from fox and gray squirrel males is presented in Tables XLII and XLIII. Based on physical measurements, adult male fox squirrels are least active sexually during the summer and fall months. They are most active during the winter and spring time periods (Fig. 59). In contrast, reproductive organs of adult male gray squirrels reach the greatest stages of development in the summer and winter months and are smallest in size in the fall (Fig. 60). Two peaks of reproductive activity are indicated in both species: in fox squirrels in the spring and winter and in gray squirrels in the summer and winter.

The subadult males follow the same general seasonal changes as do the adult males (Figs. 61 and 62). Juveniles do not show this pattern of development.

The Cowper's gland shows the greatest seasonal change in size of any of the male reproductive organs (Fig. 63). It is smallest in the fall and becomes largest in following

TABLE XLII

SEASONAL CHANGES OF MALE REPRODUCTIVE ORGANS OF FOX SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Character	(n) Winter	(n) Spring	(n) Summer	(n) Fall	(n) Average (SE)
			Juvenile		
Testes Length	(5)10.6(0.3)	(5) 8.1(1.9)	(5)10.4(1.0)	(8)10.6(1.0)	(22)10.0(0.6)
Testes Width	(4) 4.8(0.2)	(5) 3.9(0.9)	(5) 5.5(0.4)	(8) 5.7(0.6)	(22) 5.1(0.3)
Testes Volume	(4) .2(a)	(4) .2(a)	(5) 0.2(a)	(8) 0.3(0.1)	(21) 0.2(a)
Testes Weight	(4) .1(a)	(4) .1(a)	(5) 0.2(a)	(8) 0.2(0.1)	(21) 9.2(a)
Cowper's Max. Diam.	-- -- --	(1) 8.8 --	(1) 3.3 --	(1) 4.0 --	(3) 5.4(1.7)
Cowper's Gland	(3) 3.1(.4)	(3) 4.0(1.6)	(22) 2.9(a)	(6) 3.4(0.2)	(14) 3.4(0.3)
			Subadult		
Testes Length	(20)22.3(1.3)	(11)23.4(1.3)	(10)15.9(1.2)	(15)21.8(1.2)	(56)21.2(0.7)
Testes Width	(20)11.8(0.7)	(11)11.7(1.0)	(10) 7.4(0.4)	(15)11.2(0.6)	(56)10.8(0.4)
Testes Volume	(20) 2.0(0.3)	(11) 1.9(0.3)	(10) 0.5(0.1)	(15) 1.7(0.2)	(56) 1.6(0.1)
Testes Weight	(20) 2.0(0.3)	(11) 2.0(0.3)	(10) 0.5(0.1)	(15) 1.7(0.2)	(56) 1.7(0.1)
Cowper's Max. Diam.	(13)16.0(1.4)	(10)15.0(1.4)	(4)11.1(3.0)	(9) 7.8(0.6)	(36)13.1(0.9)
Cowper's Gland	(17) 9.8(1.2)	(10)19.7(1.4)	(5) 7.2(2.0)	(11) 5.8(0.5)	(43) 8.7(0.7)
			Adult		
Testes Length	(13)27.0(0.7)	(33)27.5(0.4)	(9)23.1(1.3)	(16)25.1(1.0)	(72)26.3(0.4)
Testes Width	(13)14.4(0.4)	(33)15.0(0.2)	(9)11.2(0.8)	(16)12.5(0.7)	(72)13.9(0.3)
Testes Volume	(13) 3.0(0.2)	(32) 3.4(0.1)	(9) 1.6(0.4)	(16) 2.3(0.3)	(71) 2.8(0.1)

[a]Value less than 0.1.

TABLE XLII (continued)

Character	(n) Winter	(n) Spring	(n) Summer	(n) Fall	(n) Average (SE)
Testes Weight	(13) 3.0(0.2)	(32) 3.4(0.1)	(9) 1.8(0.4)	(16) 2.3(0.3)	(71) 2.9(0.1)
Cowper's Max. Diam.	(14)20.5(1.3)	(31)20.1(0.8)	(10)12.5(1.7)	(8) 9.8(1.0)	(66)17.5(0.8)
Cowper's Gland	(14)15.6(1.0)	(31)15.1(0.6)	(10) 8.9(1.3)	(11) 6.6(0.6)	

TABLE XLIII

SEASONAL CHANGES OF MALE REPRODUCTIVE ORGANS OF GRAY SQUIRRELS COLLECTED IN OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

Character	(n) Winter	(n) Spring	(n) Summer	(n) Fall	(n) Average (SE)
			Juvenile		
Testes Length	(4) 8.3(.4)	(13) 8.5(.6)	(13) 8.2(.3)	(14)10.0(.8)	(44) 8.9(.3)
Testes Width	(4) 5.1(.3)	(13) 6.8(1.9)	(12) 4.5(.2)	(14) 5.3(.5)	(43) 5.5(.8)
Testes Volume	(4) .1(a)	(13) .1(a)	(13) .1(a)	(14) .2(a)	(44) .2(a)
Testes Weight	(4) .1(a)	(13) .1(a)	(13) .1(a)	(14) .2(a)	(44) .1(a)
Cowper's Max. Diam.	-- -- --	(1) 2.6 --	(1) 4.2 --	(3) 4.3(.9)	(5) 3.9(.6)
Cowper's Gland	-- -- --	(4) 2.8(.2)	(4) 3.6(.4)	(7) 3.4(.3)	(15) 3.3(.2)
			Subadult		
Testes Length	(11)20.4(1.7)	(12)21.8(.8)	(9)15.9(2.1)	(19)18.0(1.1)	(51)19.0(.7)
Testes Width	(11)11.3(1.1)	(11)12.2(.7)	(9) 8.3(1.1)	(19) 9.8(.7)	(50)10.4(.5)
Testes Volume	(10) 1.5(.3)	(12) 1.8(.2)	(9) .9(.3)	(19) 1.1(.2)	(50) 1.3(.1)
Testes Weight	(11) 1.7(.3)	(12) 1.8(.2)	(9) .8(.3)	(19) 1.2(.2)	(51) 1.4(.1)
Cowper's Max. Diam.	(9)15.8(1.5)	(8)15.3(.8)	(5)11.6(2.6)	(11) 8.5(.8)	(33)12.9(.9)
Cowper's Gland	(9)12.0(1.1)	(9)10.1(.8)	(5) 8.4(1.9)	(13) 5.7(.5)	(36) 8.7(.6)
			Adult		
Testes Length	(6)24.3(.9)	(9)23.1(.7)	(16)23.8(1.0)	(9)21.6(1.1)	(40)23.2(.5)
Testes Width	(6)13.4(.3)	(9)13.8(.3)	(16)12.6(.8)	(9)11.1(.5)	(40)12.7(.4)
Testes Volume	(6) 2.3(.2)	(9) 2.2(.1)	(16) 2.3(.2)	(9) 1.6(.2)	(40) 2.1(.1)

[a]Value less than 0.1.

TABLE XLIII (continued)

Character	(n) Winter	(n) Spring	(n) Summer	(n) Fall	(n) Average (SE)
Testes Weight	(6) 2.4(.2)	(9) 2.2(.1)	(16) 2.3(.3)	(9) 1.6(.2)	(40) 2.1(.1)
Cowper's Max. Diam.	(6)21.0(.9)	(9)19.0(1.1)	(8)19.4(.7)	(8) 9.4(1.1)	(31)17.0(1.0)
Cowper's Gland	(6)14.9(1.3)	(9)12.6(.7)	(8)13.9(.7)	(8) 7.1(.6)	(31)11.9(.7)

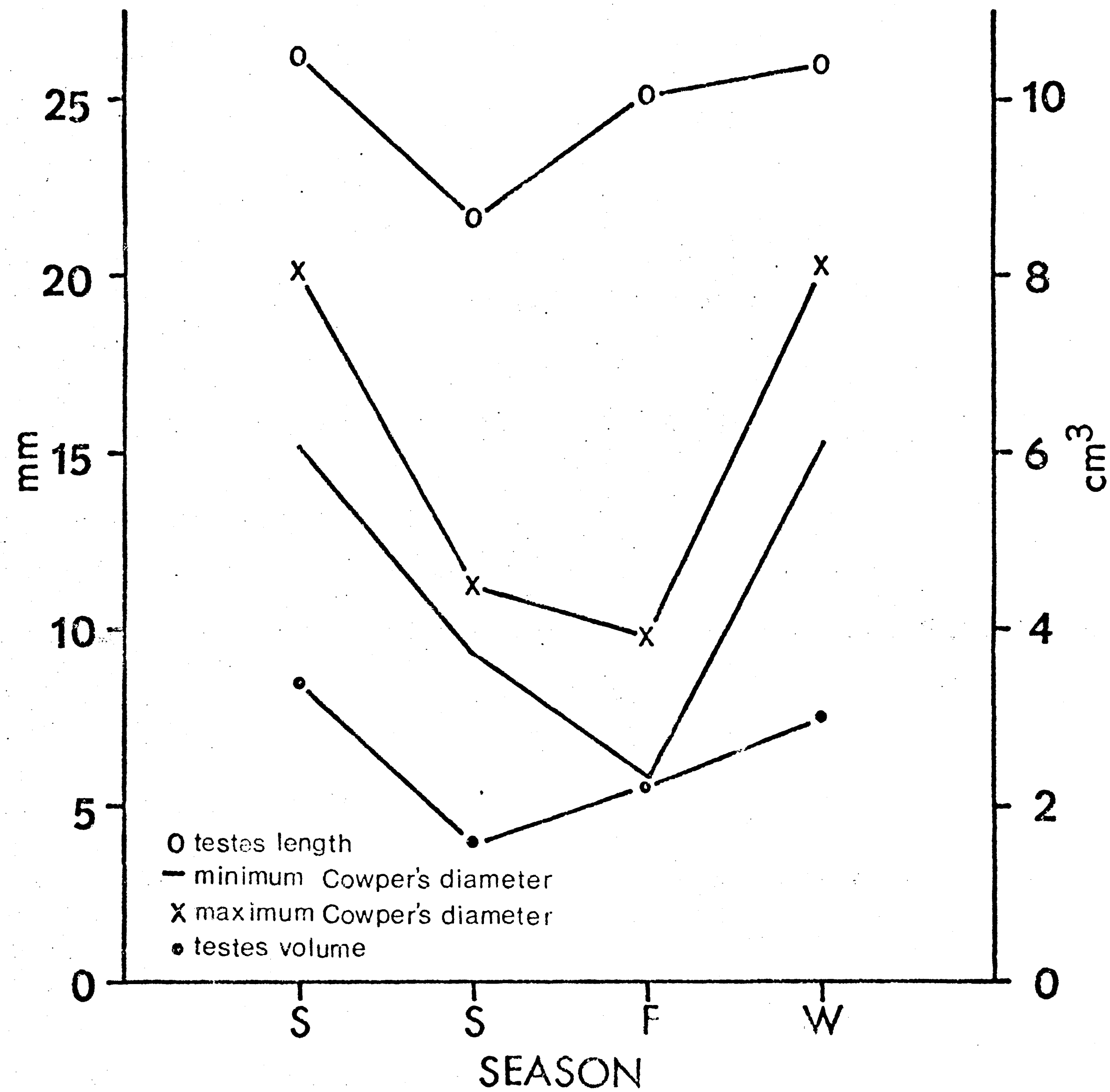

Figure 59. Seasonal Changes of Adult Fox Squirrel Reproductive Organs, 1970-1972.

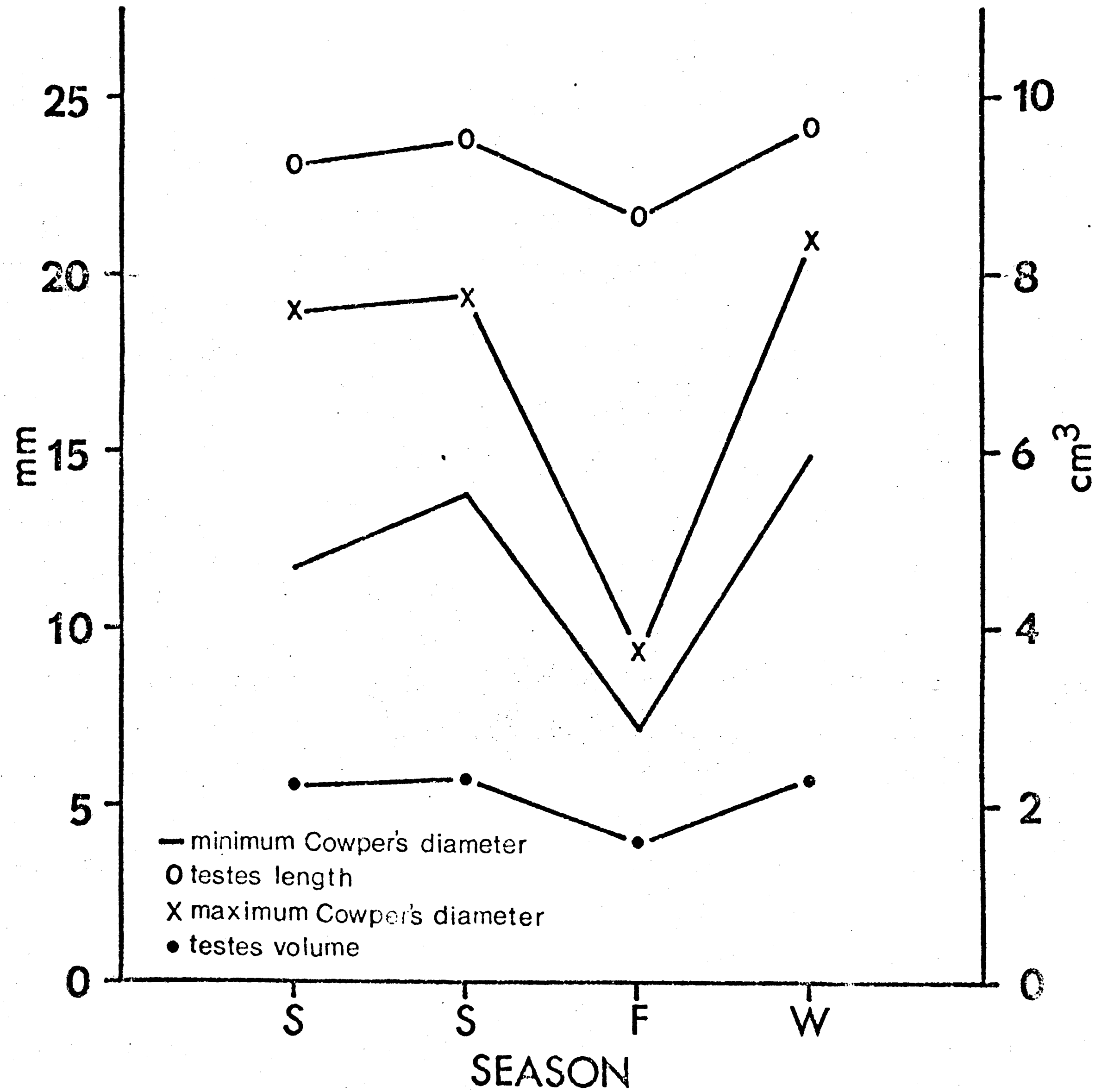

Figure 60. Seasonal Changes of Adult Gray Squirrel Reproductive Organs, 1970-1972.

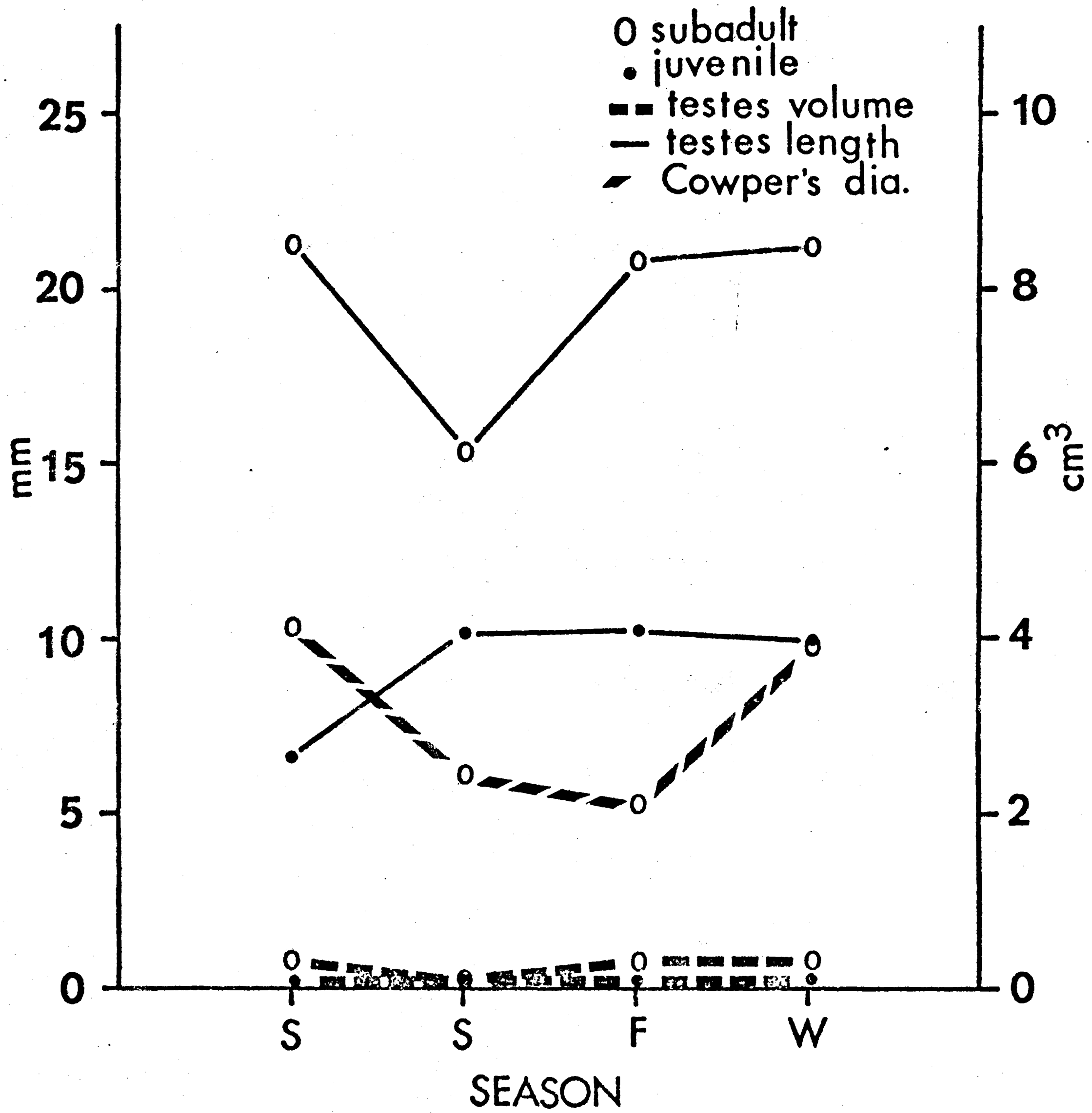

Figure 61. Seasonal Changes of Juvenile and Subadult Fox Squirrel Male Reproductive Organs, 1970-1972.

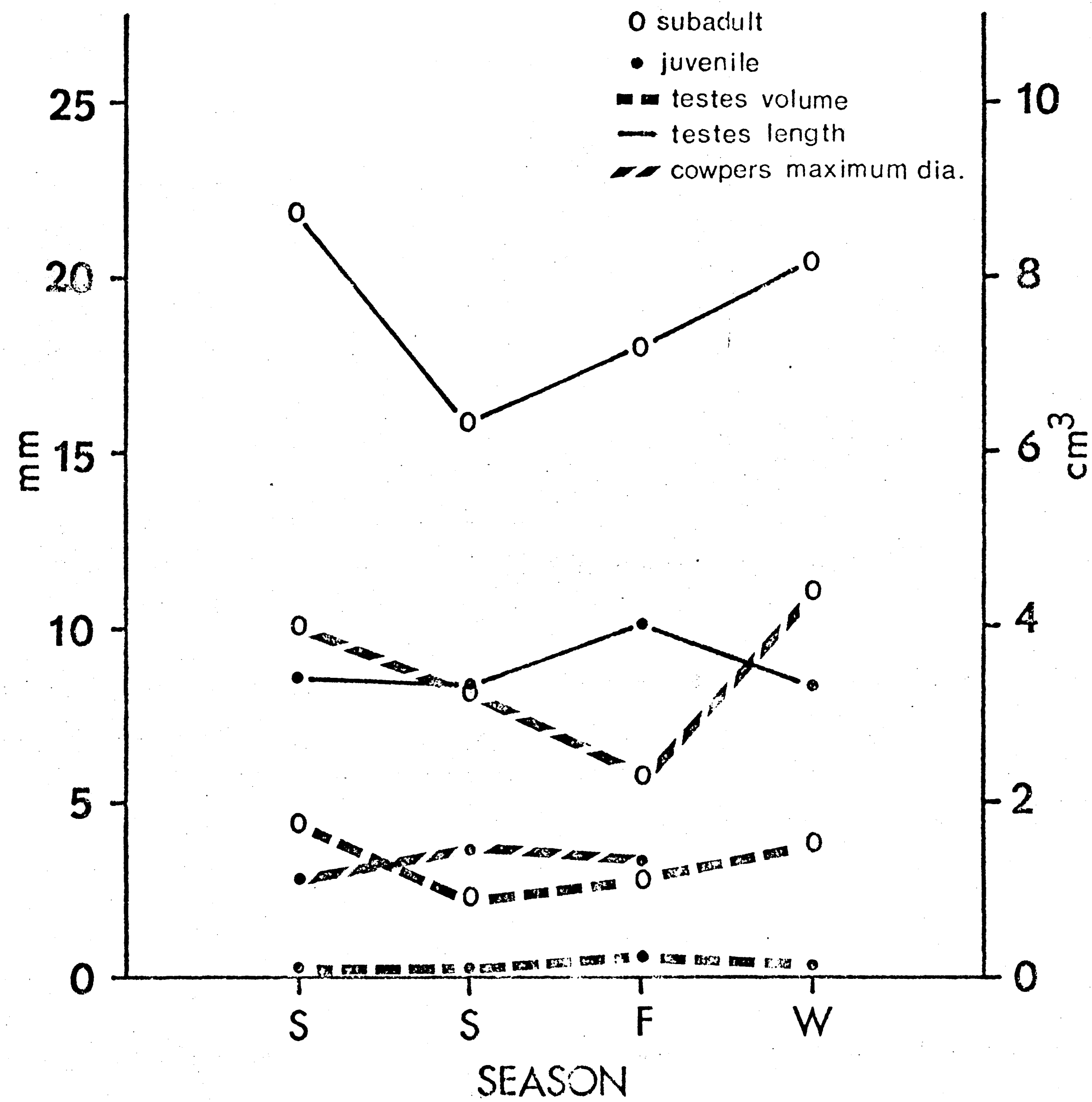

Figure 62. Seasonal Changes of Juvenile and Subadult Gray Squirrel Male Reproductive Organs, 1970-1972.

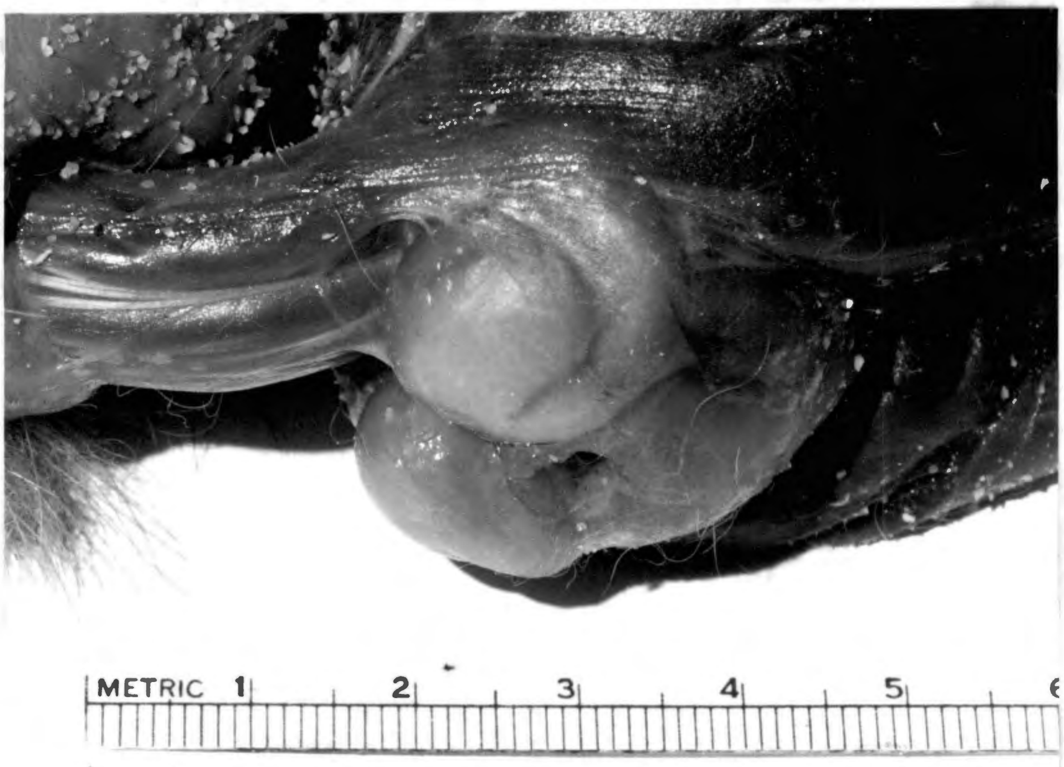

Figure 63. Cowper's Gland of an Adult Male Fox Squirrel, Side View, Collected on the Spears Study Area, December 1971.

months. Brown and Yeager (1945) found that the Cowper's glands in Illinois gray squirrels began to increase in size in October and reached maximum size in December; after December the glands decreased in size and reached a minimum diameter in September. Colin (1957) found that a similar size fluctuation in Cowper's glands existed in gray squirrels he studied in Alabama.

Male fox squirrels are believed to be sexually active when the Cowper's gland exceeds 20 mm in diameter (Brown and Yeager 1945). Cowper's glands of Kansas fox squirrels averaged more than 20 mm in diameter from November through early June and then decreased in size until September (Packard 1956). By late October the glands again were increasing in size and by November again averaged more than 20 mm in diameter.

Coefficients of correlation were calculated for the different measurements made on the male reproductive organs (Table XLIV). Significant correlations were indicated for all combinations of measurements at or below the .01 level. Weight and volume showed the highest degree of correlation in the fox squirrel group (r=.98) and in the gray squirrel group as well (r=.96). Scrotal length had the lowest overall coefficient of correlation for both groups.

TABLE XLIV

COEFFICIENTS OF CORRELATION FOR SELECTED MEASUREMENTS
OF MALE REPRODUCTIVE ORGANS

Relationship Tested	n	Coefficient of Correlation	Significance Level
Fox Squirrel			
Scrotum Length x Testes Length	52	.59	.001
Testes Length x Testes Volume	51	.80	.001
Testes Length x Testes Weight	52	.80	.001
Testes Volume x Testes Weight	51	.98	.001
Scrotum Length x Maximum Cowper's Diameter	41	.76	.001
Testes Length x Maximum Cowper's Diameter	38	.42	.010
Testes Volume x Maximum Cowper's Diameter	36	.56	.001
Testes Weight x Maximum Cowper's Diameter	37	.61	.001
Gray Squirrel			
Scrotum Length x Testes Length	48	.64	.001
Testes Length x Testes Volume	47	.90	.001
Testes Length x Testes Weight	47	.93	.001
Testes Volume x Testes Weight	47	.96	.001
Testes Length x Maximum Cowper's Diameter	37	.45	.010
Scrotum Length x Maximum Cowper's Diameter	38	.58	.001
Testes Volume x Maximum Cowper's Diameter	37	.51	.010
Testes Weight x Maximum Cowper's Diameter	37	.54	.001

Fertility of Female Fox and Gray Squirrels

Estimates of the fertility of female fox and gray squirrels were obtained from counts of corpora lutea present in the ovaries, pigment scars visible on the uterine wall, number of embryos, and counts of the number of young in litters of squirrels at their natural den sites (Table XLV).

No corpora lutea were present in the sectioned ovaries from 21 juvenile fox squirrels but they occurred in 13.8 percent (4 of 29) of the sets of ovaries of subadult fox squirrels and in 30.4 percent (21 of 69) of the sets of ovaries examined from adult fox squirrels (Table XLVI). The mean ovulation rate for adult fox squirrels was 3.0 (1SE=0.29).

Of the 102 sets of ovaries sectioned and examined of the female gray squirrel group, none of the 25 juveniles had corpora lutea present while 16.7 percent (5 of 30) of the subadults and 34.0 percent (16 of 47) of the adult female gray squirrels had visible corpora lutea. The mean ovulation rate for adult female gray squirrels was estimated to be 3.0 (1SE=0.25).

Because of the small samples involved, the graphical representation of the distribution of corpora lutea of the fox squirrel against time indicates only in a general way the time periods in which these structures were present (Fig. 64). Too few adult female gray squirrels

TABLE XLV

FERTILITY OF FEMALE FOX AND GRAY SQUIRRELS

Species	Number of Corpora Lutea			Number of Pigment Scars			Number of Embryos			Number of Young in Litter[a]		
	n	Average	(1SE)	n	Average	(1SE)	n	Average	(1SE)	n	Average	(1SE)
Fox	13	3.0	(0.29)	1	6.0	(--)	7	3.14	(0.33)	12	2.41	(0.14)
Gray	15	3.0	(0.25)	1	3.0	(--)	5	3.40	(0.24)	11	2.54	(0.20)

[a]Observed at den site, estimated age of squirrels between 6 and 10 weeks old.

TABLE XLVI

MONTHLY DISTRIBUTION OF CORPORA LUTEA IN FOX AND GRAY SQUIRRELS

Month	n	Juvenile Corpora Lutea	%	n	Subadult Corpora Lutea	%	n	Adult Corpora Lutea	%
Fox Squirrel									
December	--	--	--	1	0	0	6	2	33
January	--	--	--	1	1	100	2	2	100
February	--	--	--	4	1	25	10	4	40
March	--	--	--	--	--	--	4	2	50
April	4	0	0	--	--	--	3	0	0
May	6	0	0	3	0	0	15	5	33
June	1	0	0	2	0	0	--	--	--
July	--	--	--	1	0	0	3	0	0
August	4	0	0	7	0	0	8	2	25
September	4	0	0	5	0	0	12	3	25
October	2	0	0	3	2	67	5	1	20
November	--	--	--	2	0	0	1	0	0
Total	21	0	0	29	4	13.8	69	21	30.4

TABLE XLVI (continued)

Month	n	Juvenile Corpora Lutea	%	n	Subadult Corpora Lutea	%	n	Adult Corpora Lutea	%
Gray Squirrel									
December	1	0	0	2	0	0	4	1	25
January	--	--	--	--	--	--	--	--	--
February	--	--	--	2	0	0	--	--	--
March	--	--	--	1	0	0	--	--	--
April	5	0	0	--	--	--	3	0	0
May	4	0	0	1	0	0	12	3	25
June	2	0	0	--	--	--	1	0	0
July	1	0	0	--	--	--	--	--	--
August	6	0	0	7	2	29	13	7	54
September	2	0	0	4	2	50	5	1	20
October	2	0	0	7	1	14	5	2	40
November	2	0	0	2	0	0	4	1	25
Total	25	0	0	26	5	19	47	16	34

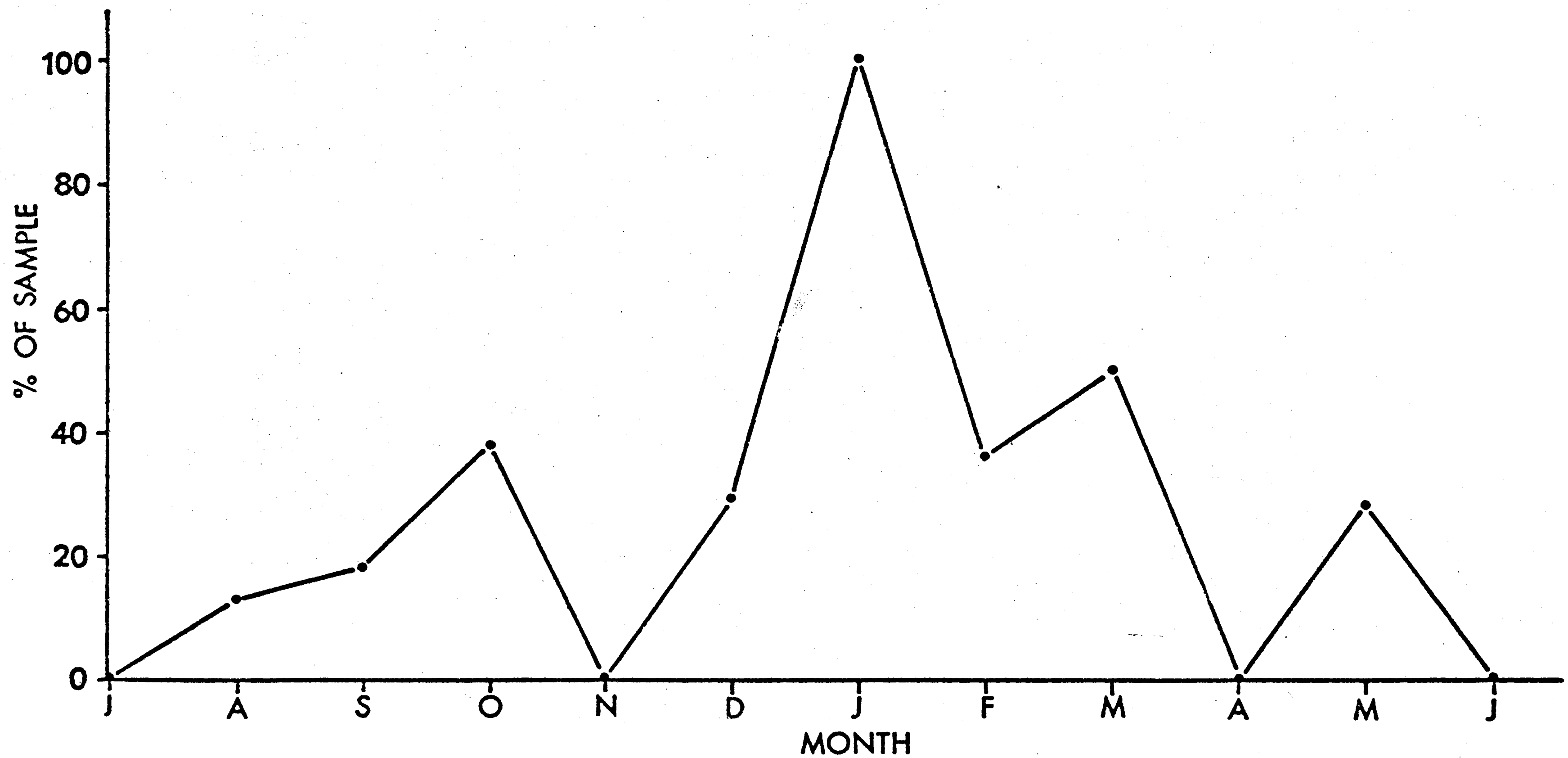

Figure 64. Distribution by Month of Corpora Lutea in Adult Female Fox Squirrel Ovaries, 1970-1972.

were collected during the winter portion of the study to indicate adequately the reproductive period of the gray squirrel group.

Only seven female fox squirrels were recovered that had visible embryos. An average foetal rate of 3.14 (1SE=0.33) was determined from this fox squirrel material. Of the five visibly pregnant gray squirrels obtained from hunters, an average foetal rate of 3.4 (1SE=0.24) was maintained. No statistical difference between the mean ovulation rate and foetal rate of either fox or gray squirrels was indicated.

Visibly pregnant fox squirrels were recovered in December (1), January (1), February (3), May (1), and July (1). Pregnant gray squirrels were found only in August (3) and October (2). No significant difference in the distribution of embryos between the left and right cornua of the uterus was indicated by either corpora lutea distribution or the distribution of embryos in the uterine tract.

The relationship between the crown-rump length and weight of 16 gray squirrel embryos is best expressed by the equation: $Y = A^{BX}$, an exponential function (Fig. 65). Using this equation, observed values were within an average of 14 percent of the predicted values of Y. Equations based on a linear function: $Y = A + BX$ deviated an average of 52.3 percent from predicted Y values; the power function: $Y = AB^{X}$ predicted Y values deviated an average

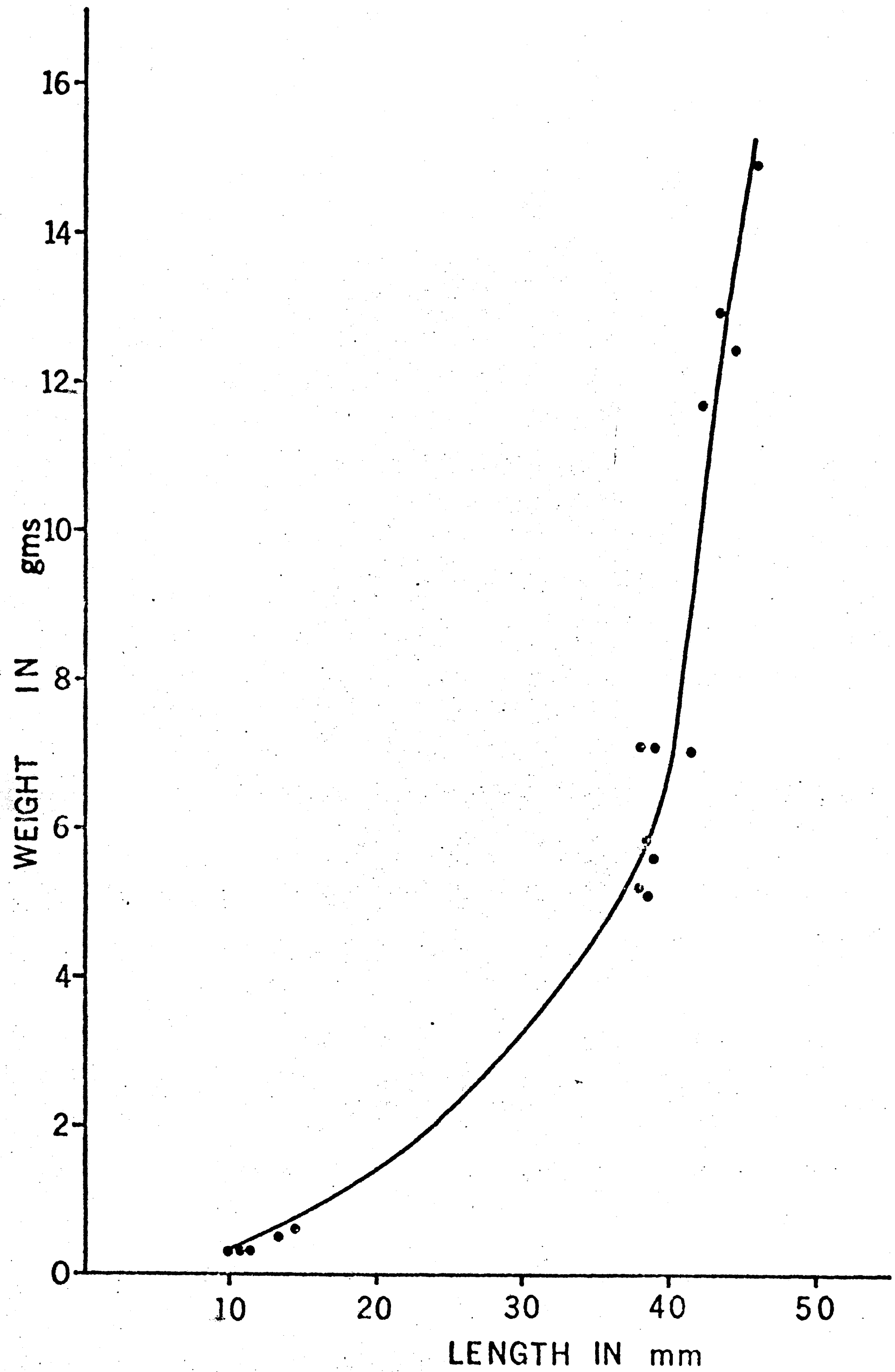

Figure 65. Length-Weight Relationships of Gray Squirrel Embryos.

of 17.3 percent from the observed value of Y. The hyperbolic functions: $Y = 1/(A + BX)$, $Y = A + (B/X)$, and $Y = X/(A + B^X)$ all predicted poorly the observed value of Y, varying 90 percent or more for it. Insufficient fox squirrel embryos were old enough for this type of analysis. Most of them consisted only of swellings in the uteral tract.

Visible pigment scars were found in only two uterine tracts. Special preparations of the uterine tract, such as discussed by Orsini (1962) apparently are necessary to allow fertility estimates based on this type of data.

Ovary weights of squirrels collected during the study indicate that juvenile fox squirrels had an average ovary weight of 9.9 mg (1SE=0.45); subadult females an average ovary weight of 17.2 mg (1SE=0.95); and adult female fox squirrels an average ovary weight of 23.3 mg (1SE=0.83) (Table XLVII).

Juvenile gray squirrels had an average ovary weight of 12.9 mg (1SE=0.74), subadult females an average ovary weight of 14.8 mg (1SE=.51); and adult females an average ovary weight of 21.8 mg (1SE=1.0).

The seasonal changes in ovary weight of adult female fox squirrels indicates that the heaviest ovaries occur from May to July and then decrease in average weight markedly until October when a second peak in weight increase continues until February (Fig. 66). Too few ovary

TABLE XLVII

SEASONAL CHANGES IN OVARY WEIGHTS OF FEMALE FOX AND GRAY SQUIRRELS

Month	n	Juvenile Average	(1SE)	n	Subadult Average	(1SE)	n	Adult Average	(1SE)
Fox Squirrel									
December	--	--		2	18.6	(3.14)	5	25.7	
January	--	--		--	--		3	25.1	(2.06)
February	--	--		3	19.8	(2.65)	10	27.7	(2.15)
March	--	--		--	--		3	26.0	(0.55)
April	4	3.7	(1.86)	--	--		3	16.4	(2.10)
May	6	8.4	(1.72)	5	18.4	(4.20)	14	27.3	(1.66)
June	1	8.2	(--)	2	13.2	(2.62)	--	--	
July	--	--		--	--		3	26.8	(3.60)
August	5	9.7	(0.85)	4	12.2	(2.11)	10	18.0	(1.70)
September	5	11.9	(1.14)	5	14.1	(1.70)	12	17.9	(1.24)
October	2	9.9	(1.41)	3	13.8	(6.10)	5	23.9	(3.69)
November	--	--		3	14.4	(5.77)	--	--	
Summary	23	9.9	(0.45)	27	17.2	(0.96)	68	23.3	(0.83)

TABLE XLVII (continued)

Month	n	Juvenile Average	(1SE)	n	Subadult Average	(1SE)	n	Adult Average	(1SE)
Gray Squirrel									
December	--	--		2	18.2	(1.64)	3	16.4	(0.23)
January	--	--		--	--		--	--	
February	--	--		2	18.6	(1.15)	--	--	
March	--	--		1	12.8	(--)	--	--	
April	5	10.3	(1.69)	--	--		3	17.2	(1.07)
May	3	11.2	(0.75)	2	13.9	(0.04)	11	24.1	(1.30)
June	1	14.4	(--)	--	--		2	21.6	(1.25)
July	1	8.8	(--)	--	--		--	--	
August	6	15.3	(1.46)	9	14.9	(0.77)	11	21.8	(2.04)
September	3	12.2	(1.52)	4	12.0	(0.78)	4	21.0	(3.15)
October	4	14.0	(2.81)	6	15.2	(1.38)	4	20.9	(4.94)
November	3	14.2	(1.53)	6	15.1	(1.47)	3	22.1	(6.64)
Summary	26	12.9	(0.74)	32	14.8	(0.51)	39	21.8	(1.00)

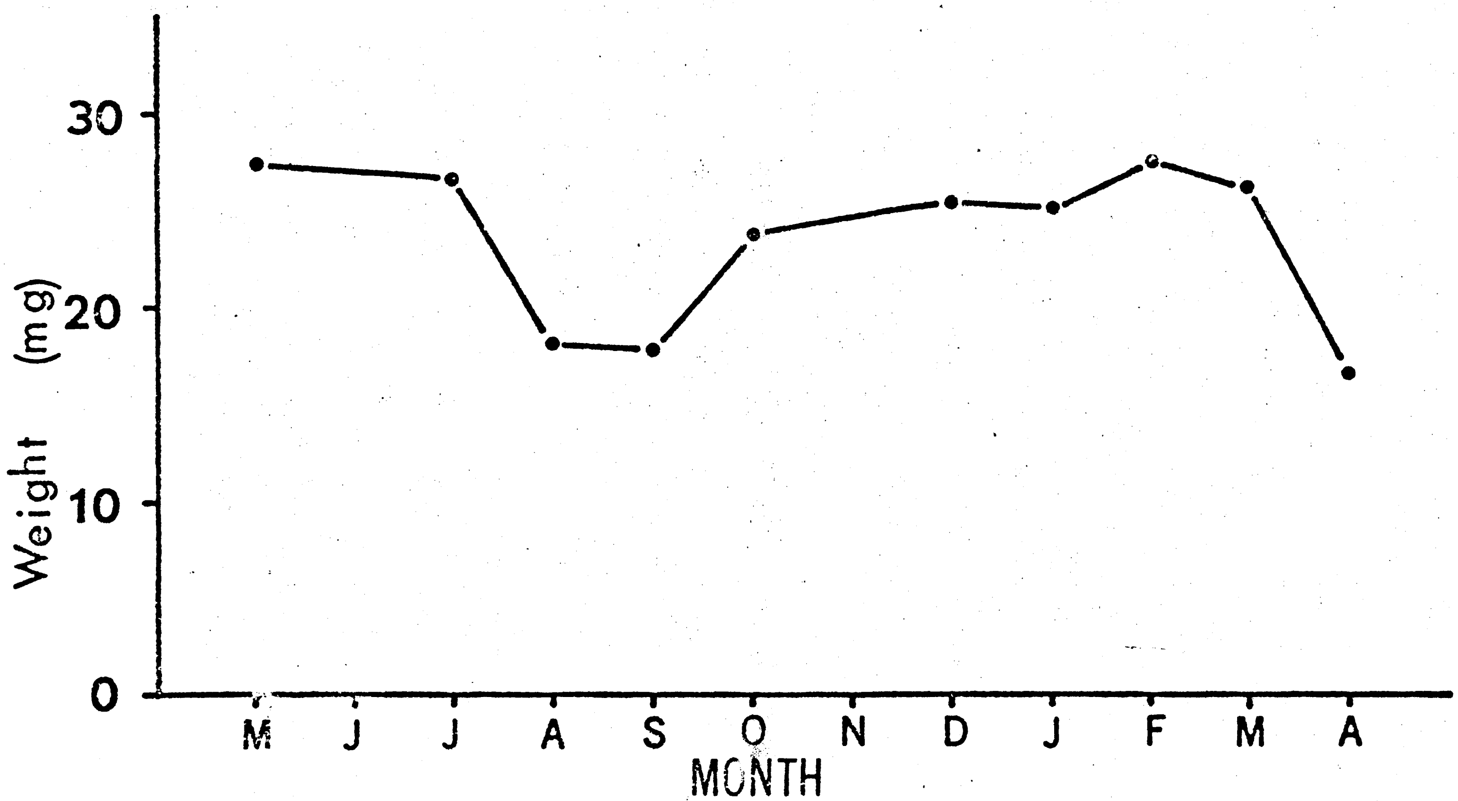

Figure 66. Seasonal Changes in Ovary Weights of Adult Female Fox Squirrels, 1970-1972.

weights of adult gray squirrels were obtained to plot their seasonal changes in weight.

Lactation Rates of Female Squirrels

Examination of the mammary glands of squirrels, either those killed by hunters or those livetrapped, resulted in 601 squirrels being examined during the study (Table XLVIII). No females classified as juveniles of either the fox or gray squirrels were found to be lactating.

Of the adult female fox squirrels, 55.6 percent (n=178) were found to be lactating; 3.8 percent of the subadult age class was lactating while none of these classified as juveniles were found to be lactating.

Of the gray squirrels, 50.5 percent of the adults were lactating when examined, 7.8 percent of the sub-adults, and none of the juveniles.

Two distinct peaks of lactation occurred for both the fox and gray squirrels with most of the squirrels examined lactating during the spring and summer months (Fig. 67). Fox squirrel females extend their lactation period well into the fall, indicating perhaps a longer breeding season than for gray squirrels.

TABLE XLVIII

SEASONAL LACTATION RATES OF FOX AND GRAY SQUIRRELS, SPEARS STUDY AREA, 1970-1972

Age	Winter Lactating		Spring Lactating		Summer Lactating		Fall Lactating		Total Lactating	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Fox Squirrel										
Juvenile										
Shot	0	1	0	39	0	11	0	10	0	61
Trapped	0	0	0	10	0	1	0	1	0	12
All	0	1	0	49	0	12	0	11	0	73
Subadult										
Shot	0	10	0	10	0	12	2	10	2	42
Trapped	0	27	1	10	0	1	0	0	1	38
All	0	37	1	20	0	13	2	10	3	80
Adult										
Shot	0	10	29	15	10	6	12	12	51	42
Trapped	8	26	38	9	2	0	0	2	48	37
All	8	36	67	24	12	6	12	14	99	79

TABLE XLVIII (continued)

Age	Winter Lactating Yes	Winter Lactating No	Spring Lactating Yes	Spring Lactating No	Summer Lactating Yes	Summer Lactating No	Fall Lactating Yes	Fall Lactating No	Total Lactating Yes	Total Lactating No
Total	8	74	68	93	12	31	14	35	102	232
Gray Squirrel										
Juvenile										
Shot	0	2	0	42	0	10	0	7	0	61
Trapped	0	4	0	3	0	0	0	0	0	7
All	0	6	0	45	0	10	0	7	0	68
Subadult										
Shot	1	6	2	15	1	18	0	26	4	65
Trapped	1	15	2	9	0	1	0	4	3	29
All	2	21	4	24	1	19	0	30	7	94
Adult										
Shot	0	10	29	15	10	6	2	12	41	43
Trapped	3	5	5	0	0	0	0	0	8	5
All	3	15	34	15	10	6	2	12	49	48

TABLE XLVIII (continued)

Age	Winter Lactating Yes	Winter Lactating No	Spring Lactating Yes	Spring Lactating No	Summer Lactating Yes	Summer Lactating No	Fall Lactating Yes	Fall Lactating No	Total Lactating Yes	Total Lactating No
Total	5	42	38	84	11	35	2	49	56	210

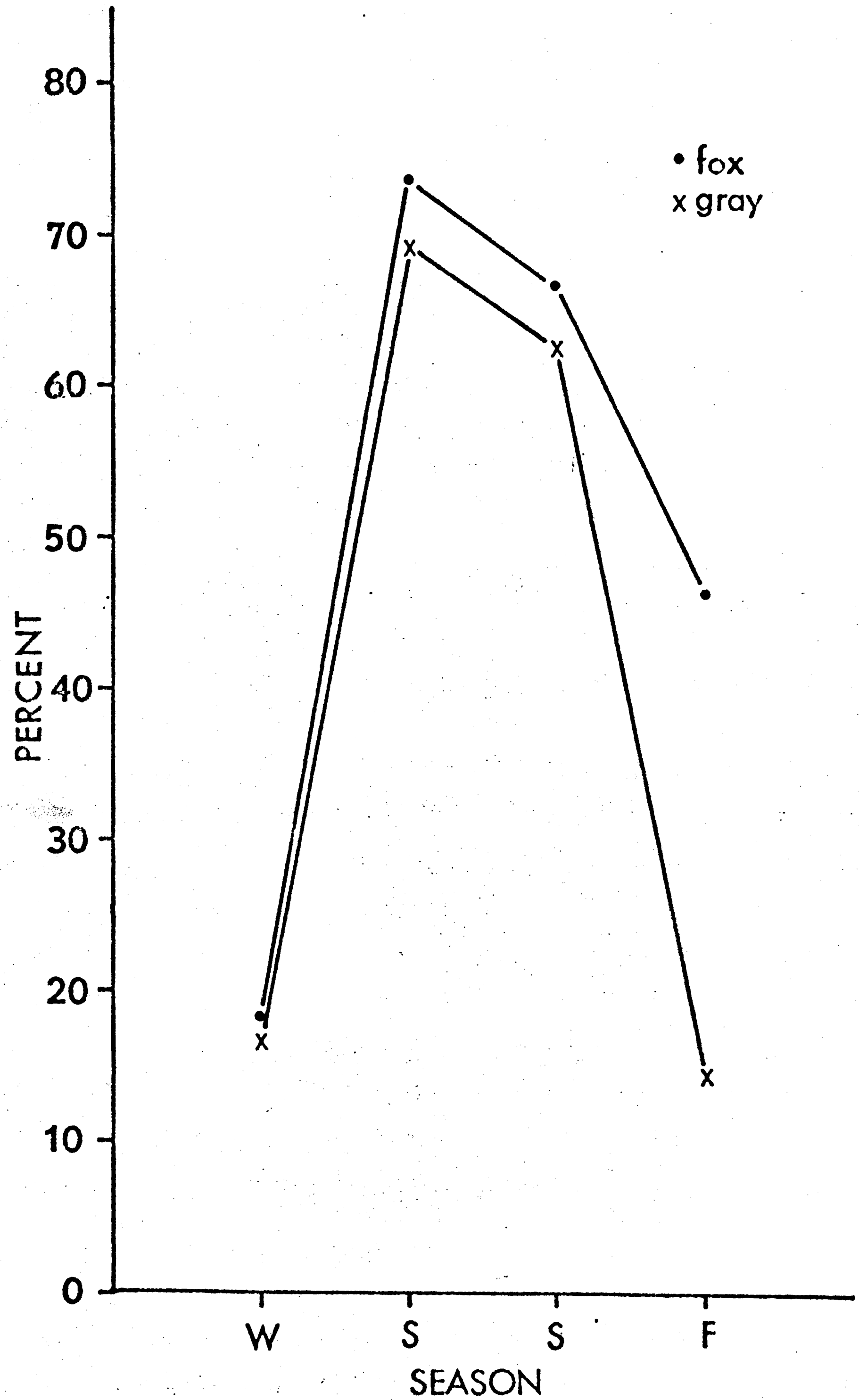

Figure 67. Percentage of Adult Female Squirrels Lactating, Spears Study Area, 1970-1972.

CHAPTER VIII

HARVEST AND MANAGEMENT OF FOX AND GRAY SQUIRRELS IN OKLAHOMA

Introduction

The successful management of fox and gray squirrels depends on integrating biological information with the desires of the sportsman. Increasing demands for more recreational hunting underscore the need for intensive management of fox and gray squirrels.

This chapter provides needed information on the current harvest and management of squirrel populations, particularly along the Deep Fork of the North Canadian River in east-central Oklahoma. Management of tree squirrels in other states and potential management options that may exist for tree squirrels in Oklahoma are reviewed. Information on squirrel harvest and management was collected from August 1968 through August 1973.

Methods and Materials

A synopsis of past regulations and laws dealing with squirrel hunting in Oklahoma was compiled from Oklahoma Department of Wildlife Conservation records and summaries of laws enacted by the state legislature. Estimates of hunter effort and harvest along the Deep Fork of the North Canadian River were gathered through hunter check stations at the Okmulgee Public Hunting Area and in interviews with hunters encountered along the Deep Fork throughout the hunting season. Five waterproof cans containing hunter questionnaires were placed at prominent locations along roads frequented by squirrel hunters to gain information on hunter activity and squirrel harvest in the Deep Fork drainage. Correspondence with other states having huntable populations of fox and gray squirrels provided an overview of squirrel management practiced in other areas in comparison to that being done in Oklahoma.

Computer simulation was used to predict the effect variations of the opening dates of squirrel seasons would have on the total population of an area similar to that of the Spears Study Area. This proposed model was developed on California State University, Fresno, Control Data Corporation (CDC) 713 Series Cathode Ray Tube Terminal, using FORTRAN IV subset EXFOR. The model was transmitted through CSUF's CDC 3150 compiler to CSU, Northridge's CDC 3170 computer which did the actual calculations for the model. All calculations were done with biological data collected from the Spears Study Area. Information in existing literature supplemented my data where necessary.

Categories of biological information used in the program include:

(1) cohort statistics
(2) cyclic mortality rates
(3) seasonal mortality rates
(4) number of offspring per breeding female
(5) sex ratios at birth of litter
(6) percent of breeding females that conceive/breeding cycle/age class
(7) number of cycles a cohort is in system
(8) hunting mortality impact on population growth
(9) immigration and emigration indexes
(10) density index

The output for the model was a CDC Series 92417 matrix printer containing a heat-sensitive print head. Output consisted of a tabular accounting of population status per cycle detailed by sex-and-age ratios, reproductive performance, and mortality rates for each group within the population, and total population on the theoretical study area for each cycle. Graphic display of any of the computed population statistics was an option built into the computer program by the investigator.

Results and Discussion

Oklahoma Squirrel Harvest and Hunter Effort

Data collected by the Oklahoma Department of Wildlife Conservation on the state-wide harvest of squirrels were analyzed and are presented in Table XLIX. As shown by Table XLIX, Oklahoma hunters have in the past 15 years, from 1958 to 1972, harvested more than a million squirrels

TABLE XLIX

ESTIMATED FOX AND GRAY SQUIRREL (*SCIURUS NIGER* AND *S. CAROLINENSIS*) HARVEST IN OKLAHOMA, 1958 to 1972[a]

Year	Total Harvest	Number of Squirrel Hunters	Average Kill Per Hunter
1958	1,906,759	122,330	15.6
1959	2,095,273	120,418	17.4
1960	753,139	62,289	11.9
1961	1,356,464	74,347	16.9
1962	917,873	66,034	13.9
1963	538,410	53,308	10.1
1964	648,586	54,503	11.9
1965	907,598	65,768	13.8
1966	1,043,086	63,993	16.3
1967	869,414	64,401	13.5
1968	1,067,070	61,895	17.2
1969	843,728	72,028	11.7
1970	818,338	71,784	11.4
1971	841,776	67,752	12.4
1972	966,207	66,635	14.5
Average	1,038,181	72,499	14.3

[a]Data from unpublished reports of the Oklahoma Department of Wildlife Conservation, Oklahoma City.

annually. The average Oklahoma squirrel hunter takes 14 squirrels per season, one of the highest averages in the United States.

Squirrels receive the second highest percent of the total hunting effort expended on species in Oklahoma, 15 percent, in contrast to 31 percent for quail and 13 percent for rabbits (Ellis 1972:26). The average licensed sportsman hunted squirrels 6.4 days annually and actually hunted for squirrels an average of 5.1 hours in each of those days (Ellis 1972:21-24). According to Ellis (1972:48) 45.2 percent of the people hunting squirrels had difficulty in obtaining access to land areas on which to hunt. Hunters in Oklahoma were willing to drive an average one-way distance of 28.8 km to hunt squirrels (Ellis 1972:14). Only crows (*Corvus brachyrhynchos*) were hunted closer to home; 17.9 km of one-way driving.

Because of woodland distribution patterns, more of the squirrel harvest occurs in the eastern one-half of the state, although local areas in western Oklahoma can provide good hunting for fox squirrels (Duck 1951). Although hunters in eastern Oklahoma often prefer squirrel hunting over quail hunting, few hunters in western Oklahoma seriously hunt the available squirrels there.

Squirrel hunting regulations enacted by the Legislature since 1909 have changed little in 63 years. The present season extends from 15 May to 1 January and allows a daily bag limit of six squirrels (Table L).

TABLE L

HISTORICAL SUMMARY OF THE STATUS OF SQUIRREL MANAGEMENT AND SQUIRREL POPULATIONS IN OKLAHOMA, 1890 TO 1968

Year	Comments
1890	Oklahoma Territorial Government officially established.
1895	First game and fish laws passed by the Territorial Government. The killing of wild game and insectivorous birds was prohibited, except that quail, prairie chicken, and wild turkey seasons were set from 1 November to 1 February and doves and plover were legal game from 1 August to 31 December. No specific mention was made of squirrels in this legislation. The Indian Territory listed no seasons for wildlife; indicating a lack of any restrictions on hunting in this portion of Oklahoma (Anon. 1955b:16).
1907	Oklahoma became a state.
1909	Game laws were enacted by the First Legislative Session. Squirrel season was set by the Legislature, as it is today, not by the Oklahoma Wildlife Conservation Commission. First hunting license required in Oklahoma.
1932	Recommendation No. 10 in Game and Fish Department Biennial Report: Squirrel-bag limit (10 in 1930) be reduced to 6 a day (present bag limit). Open season on squirrels established from 1 August to 1 January (Anon. 1932:50).
1935	HB 323 passed to give the Wildlife Conservation Commission power to set some game seasons although squirrel seasons still governed by legislative act.
1935-1944	Squirrel season opened 15 May, closed on 1 January, with bag limits of 10 squirrels per day, no possession limit; total length of season 231 days.
1938	It is thought that a shorter season for squirrels would be beneficial in many parts of Oklahoma. Problem exists in that the legislative act sets the season (squirrel) (Anon. 1938:58).

TABLE L (continued)

Year	Comments
1945	There was an unprecedented abundance of both red (fox) and gray squirrels in 1944 and this year, 1945, may equal last year's crop of this game animal. . . . (Anon. 1945:13).
1945-1950	Squirrel season opened 15 May, closed 31 December, with bag limit of 10 squirrels per day and no possession limit; total season length 230 days.
1946	Good squirrel season reported (Kendal 1946:7).
1946	Results of Game and Fish Department survey indicated a density of 1.18 squirrels per acre on 77 acres sampled in 18 counties (Kendall 1946:10-11).
1951	Spring squirrel population up over squirrel population of 1950 (Temple 1951). Bad drought caused the closing of fall hunting seasons until November. Squirrel daily bag reduced from 10 to 6 animals (Anon. 1955a:12).
1953	Poor squirrel year due to severe drought throughout Oklahoma (Barker 1954:2).
1955	M. H. Whisenhunt completed his study "The breeding season and the hunting season of squirrel in Oklahoma." Good mast crop but squirrel population remained below normal this year (Stanphill 1955:3).
1958	Oklahoma Department of Wildlife Conservation begins collecting game harvest estimates with a statewide hunter questionnaire survey.
1958-1959	Squirrels plentiful (1958) near Antlers in Pushmataha County (Anon. 1959a). . . . more squirrel along river and creek bottoms than at any time in the past ten years (Johnston County) (Anon. 1959b). Squirrel hunting exceptionally good (Anon. 1959c).
1959	Ten percent more squirrels taken in 1959 than during 1958; 75 percent of Oklahoma's squirrel harvest occurs in eastern Oklahoma; little interest in hunting fox squirrels in many western areas of the state (Williamson 1960:10-11).
1960	Squirrel season below normal (Anon. 1961:2).

TABLE L (continued)

Year	Comments
1961	Squirrel hunting has seldom, if ever, been better than it was reported during the past fall (1961), according to reports from game rangers (Anon. 1962a). There were the most squirrels we have had for years in Creek County in 1961 (Oliver 1962:22). The 1961 squirrel season was termed the best in 30 years or more in many sections of the state, particularily in eastern Oklahoma. . . . (Anon. 1962b).
1962	Low population of squirrels reported (Anon. 1963).
1964	More young squirrels in hunters' bag this year; squirrel population is on the upswing although the squirrel population is still low (Williamson 1964:11; 1965).
1965	More squirrels in woods in summer of 1965 than in the past 2 or 3 years (Williamson 1965).
1966	The 1966 population of squirrels is higher than at any time since 1959 (Williamson 1966).
1967	With the initiation of a fall hunting season on rabbits, squirrels in Oklahoma now experience the longest hunting season of any game animal in Oklahoma.

Since 1967, the squirrel hunting season has been longer than the season on any other game animal in Oklahoma, and is the longest state-wide season in the United States (Table LI), if other states lacking specific seasons are excluded. Throughout the United States, the average squirrel season is about 109 days (range 32-365) and daily bag limits average 6 squirrels (range 4-12).

Management of Squirrels in Other States

Considerable variation exists between states in the opening and closing dates of hunting seasons on squirrels. Most states open their squirrel seasons in October (36 percent), September (23 percent) or November (17 percent). Most states close their seasons in January (34 percent), December (23 percent), November (23 percent), or February (11 percent). Little conformity exists between geographically contigous states, indicating perhaps that social factors, particularly hunting traditions, rather than biological considerations, determine when squirrel seasons will open and close.

Data on harvest, hunting popularity, and management problems of tree squirrels within the respective states are presented in Table LII. The breakdown of 34 specific management problems mentioned in correspondence with management agencies were: loss of habitat (40 percent); underutilization of resource and lack of hunter interest

TABLE LI

TREE SQUIRREL HUNTING REGULATION IN THE UNITED STATES 1968-1972

State	Season Dates		Days in Season	Bag Limits		
	Opening	Closing		Daily	Possession	Season
Alabama	15 Oct.	11 Jan.	89	8	8	none
Arkansas	15 May 1 Oct.	15 June 31 Dec.	123	8	16	none
Colorado	1 Oct.	31 Jan.	123	5	10	none
Connecticut	17 Oct.	9 Jan.	85	8	none	40
Delaware	23 Nov. 15 Sept.	16 Dec. 31 Oct.	23 47 =70	4	none	none
Florida	11 Nov. 11 Nov.	18 Feb. 25 Feb.	99 106	12	none	20 gray 4 fox
Georgia	15 Aug. 15 Oct.	3 Sept. 27 Feb.	158	10	none	none
Illinois	1 Aug. 1 Sept.	15 Nov. 15 Nov.	107 76	5	10	none
Indiana	15 Aug. 11 Nov.	12 Oct. 16 Nov.	63	5	none	none
Iowa	12 Sept.	31 Dec.	111	6	12	none
Kansas	1 June	31 Dec.	214	5	10	none
Kentucky	16 Aug. 20 Nov.	31 Oct. 31 Dec.	117	--	--	--

TABLE LI (continued)

State	Season Dates		Days in Season	Bag Limits		
	Opening	Closing		Daily	Possession	Season
Louisiana	3 Oct.	10 Jan.	100	8	16	none
Maine	1 Oct.	30 Nov.	61	4	8	none
Maryland	5 Oct.	31 Jan.	118	6	12	none
Massachusetts	20 Oct.	30 Nov.	42	5	10	20
Michigan	15 Sept.	10 Nov.	57	5	10	25
Minnesota	26 Sept.	31 Dec.	97	7	14	none
Mississippi	10 Oct.	9 Jan.	122	8	16	none
Missouri	30 May	31 Dec.	216	6	12	none
Nebraska	1 Sept.	31 Jan.	122	7	21	none
New Hampshire	1 Oct.	1 Nov.	32	5	none	none
New Jersey	7 Nov. 14 Dec.	5 Dec. 6 Feb.	79	5	none	none
New York	1 Oct. 1 Nov.	31 Jan. 31 Jan.	123 92	5 5	-- --	-- --
N. Carolina	15 Oct.	31 Jan.	108	8	16	75
N. Dakota	19 Sept.	31 Jan.	104	5	10	none
Ohio	11 Sept.[a] 11 Sept.[b]	14 Nov.[a] 26 Dec.[a]	65	4	8	none

[a]private-land hunting season

[b]public hunting area season

TABLE LI (continued)

State	Season Dates		Days in Season	Bag Limits		
	Opening	Closing		Daily	Possession	Season
Oklahoma	15 May	1 Jan.	232	6	12	none
Pennsylvania	15 Oct. 26 Dec.	28 Nov. 16 Jan.	63	6	none	none
Rhode Island	20 Oct.	31 Jan.	113	--	--	--
S. Carolina	22 Nov.	15 Feb.	85	10	none	none
S. Dakota[c]	1 Jan.	31 Dec.	365	none	none	none
Tennessee	29 Aug.	15 Nov.	79	6	12	none
Texas[d]	--	--	--	--	--	--
Vermont	24 Sept.	10 Nov.[e]	48	4	8	none
Virginia	--	--	--	6	12	none
W. Virginia	12 Sept. 10 Oct.	2 Jan. 2 Jan.	113 85	6	12	none
Wisconsin	5 Oct.	31 Jan.	118	5	10	none

[c]not considered a game animal, so is unprotected

[d]very complex regulation, too detailed and variable to summarize

[e]attempting to extend season to 31 Dec. to utilize more fully the resource

TABLE LII

TREE SQUIRREL HARVEST AND HUNTING POPULARITY IN THE UNITED STATES

State	Average Harvest Years of Record	Total	Recent Hunter Harvest Year	Number	Per Year	Per Trip	Popularity Ranking	Management Problems
Alabama	--	--	1972	2,105,950	13	--	--	bot flies, nuisance. Loss of habitat (conversion to pure stands of pine) worst problem
Arkansas	--	--	--	--		--	1 or 2	loss of habitat through clearing and killing of hardwoods
Colorado	5	7,000	1972	5,000(?)	2.9	.9	low	underutilization of resources
Connecticut	--	--	1972	85,000	5.0	--	4th	lack of hunter interest; underharvest; gypsy moth damage to habitat
Delaware	--	--	1972	97,259	7	--	2nd	loss of habitat due to urbanization; nuisances
Florida	--	--	1972	(±144,900) 1,333,000	13.8	--	2nd	loss of suitable habitat; pine monoculture, housing development and orchards

TABLE LII (continued)

State	Average Harvest Years of Record	Average Harvest Total	Recent Hunter Harvest Year	Recent Hunter Harvest Number	Recent Hunter Harvest Per Year	Recent Hunter Harvest Per Trip	Popularity Ranking	Management Problems
Georgia	--	--	1972	1,341,557	10.6	--	3rd	setting of seasons to avoid bot fly infestations; loss of habitat and decline in hunter interest
Illinois	14	2.8 million	--	--	n=14	--	1 or 2	conflicts with timber management; forests being cleared at rapid rate
Indiana	29	1,400,000	1968	1,600,000	--	.52	2	reduction in habitat; changes in land use patterns
Iowa	10	1,175,289	1972	1,172,742	14.0	2.3	3rd in harvest statewide	increased research on management needed
Kansas	--	--	1972	304,000	6.16		5 out of 6 game species - low	insufficient habitat; habitat destruction, loss of shelterbelts
Kentucky	5	1,175,000	--	--	12.1	1.6	averages #1	loss of habitat due to logging; failure to be able to set seasons on biologically sound basis due to public opinion
Maine	--	--	1970	20,611	2.39	--	low	lack of suitable habitat; lack of hunter interest

TABLE LII (continued)

State	Average Harvest Years of Record	Average Harvest Total	Recent Hunter Harvest Year	Recent Hunter Harvest Number	Recent Hunter Harvest Per Year	Per Trip	Popularity Ranking	Management Problems
Maryland	--	--	1971	933,511	8.09	--	1	loss of habitat due to urban development
Massachusetts	--	--	--	--	--	--	low	no management except to preserve prime mast trees on management areas
Michigan	5	778,734	1972	792,690	3.60	--	2 or 3	maintenance of suitable habitat; squirrel hunting is growing in popularity
Minnesota	3	166,997	1972	163,991	--	--	?	damage complaints main problem
Missouri	6	2,608,505	1972	3,155,052	14.45	1.69	1 or 2	need more flexibility in season setting; habitat losses
New Hampshire	--	--	--	--	--	--	low	need increased hunter interest in hunting squirrels
New Jersey	--	--	1972	192,085	3.24	4(?)		--
N. Carolina	--	--	1972	2,072,110	10.56	--	1	--
N. Dakota	14	11,000	1971	26,000	4.20	.93	low	--

TABLE LII (continued)

State	Average Harvest Years of Record	Total	Year	Recent Hunter Harvest Number	Per Year	Per Trip	Popularity Ranking	Management Problems
Ohio	--	--	1962	1,400,000	4.58	.88	1	--
Oklahoma	14	1,043,322	1972	841,776	12.40	--	2	loss of habitat; need access to lands
Pennsylvania	--	--	1971	2,500,000	--	--	--	need to improve hunter harvest
Rhode Island	--	18,000 20,000	--	--	4.00	--	102	lack of hunter interest; nuisance problems
S. Carolina	--	--	1966	1,473,393	11.88	--	2 or 3	destruction of habitat
S. Dakota	--	--	--	--	--	--	light	unprotected animal, no information available
Tennessee	--	1.5 to 2 million	1969	757,000	--	--	1 or 2	underharvest of squirrels except in woodlots; loss of hunter access to woodlands
Texas	--	6 million	--	--	15.00	--	#1 in East Texas	management of hardwoods in Texas
Vermont	--	--	--	--	--	--	--	little work done; 1974 survey hunter attitude; no research planned

TABLE LII (continued)

State	Average Harvest Years of Record	Total	Recent Hunter Harvest Year	Number	Per Year	Per Trip	Popularity Ranking	Management Problems
Virginia	--	--	1969	2,933,420	11.10	--	--	waste due to warbles; land use and conflict with forestry management
West Virginia	--	--	1970	1,432,016	8.02	--	1	loss of squirrels due to bot fly infection; timber management; unutilized recreation potential
Wisconsin	--	--	1972	1,400,000	9.30	--	4	underutilized resource

(33 percent); nuisance problems and damage (9 percent); loss due to bot fly (Cuterebra sp.) infestation (9 percent), and need for increased research on squirrels and setting of squirrel seasons on a biological basis (5 percent).

Characteristics of Deep Fork Squirrel Hunters

No usable data on squirrel hunters were obtained from unmanned check stations. The waterproof cans containing the questionnaires were either ignored, destroyed, or if the survey form was filled out, it was done with exaggerated answers.

Information obtained from check stations operated at the entrance to the Okmulgee Public Hunting Area and from other contact with hunters elsewhere along the Deep Fork River is summarized in Table LIII. The counties bordering the Deep Fork contain about 23 percent of Oklahoma's resident population, 18.4 percent of its licensed hunters, but only 1.82 percent of its public hunting lands (Table LIV).

The typical sportsman of this area hunted with one other person, usually with shotgun, in the morning hours, primarily in bottomland forest habitat for squirrels. None of the interviewed hunters utilized dogs in their squirrel hunting during the opening weekend of the season. These hunters actually pursued squirrels about 3 h per trip and usually bagged one or two squirrels during the

TABLE LIII

CHARACTERISTICS OF DEEP FORK SQUIRREL HUNTERS, DETERMINED BY HUNTER INTERVIEWS DURING THE FIRST THREE DAYS OF SQUIRREL SEASON, 1970-1972

Information	Year			
	1970	1971	1972	Total
Number of hunters interviewed	98	96	45	239
Number of hunting parties	60	45	26	131
Average number of hunters per party	1.6	2.1	1.7	1.8
Time hunted squirrels				
Morning	83 (85%)	76 (79%)	36 (80%)	195 (82%)
Afternoon	15 (15%)	20 (21%)	9 (20%)	44 (18%)
Weapons used				
Shotgun	64 (65%)	83 (87%)	44 (98%)	191 (80%)
Rifle	32 (33%)	13 (13%)	1 (2%)	46 (19%)
Bow and arrow	2 (2%)	-- --	-- --	2 (1%)
Hunting effort				
Total hours hunted	252	253	185	690
Total squirrels taken	131	130	138	399
Hours hunted per trip	2.6	2.6	4.1	2.9
Squirrels taken per hour	0.52	0.51	0.75	0.58
Squirrels taken per hunt	1.34	1.35	3.07	1.67

TABLE LIII (continued)

Information	Year			
	1970	1971	1972	Total
Squirrel dog used	0	0	0	0
Type of terrain hunted				
Bottomland forest	87 (89%)	83 (87%)	28 (63%)	198 (83%)
Pecan orchards	10 (10%)	8 (8%)	13 (29%)	31 (13%)
Upland forest	2 (2%)	4 (5%)	4 (9%)	10 (4%)
Distribution of harvest				
Okmulgee public hunting area				
Number of hunters	40	34	6	80
Number of squirrels bagged	28	28	5	61
Total hours hunted	122	96	19	237
Squirrels taken per hour	0.23	0.29	0.26	0.26
Squirrels taken per hunt	0.70	0.82	0.83	0.76
Private lands				
Number of hunters	58	62	39	159
Number of squirrels bagged	103	102	133	338
Total hours hunted	130	157	166	453
Squirrels taken per hunt	1.77	1.65	4.26	2.13
Bag Distribution	Number of Hunters Having Each Size of Bag			
Bag Limit				
0	36 (37%)	22 (22%)	10 (22%)	68 (28%)
1	16 (17%)	16 (13%)	6 (13%)	38 (16%)
2	8 (8%)	16 (11%)	5 (11%)	29 (12%)

TABLE LIII (continued)

Information	1970	1971	1972	Total
	Year			
Bag Distribution Bag Limit	Number of Hunters Having Each Size of Bag			
3	7 (7%)	8 (8%)	2 (4%)	17 (7%)
4	7 (7%)	8 (8%)	4 (9%)	19 (8 %)
5	8 (8%)	16 (16%)	8 (18%)	32 (13%)
6	16 (17%)	12 (12%)	10 (22%)	38 (16%)

TABLE LIV

DISTRIBUTION OF OKLAHOMA HUNTERS AND PUBLIC HUNTING LANDS, 1968, EXPRESSED AS PERCENTAGES BY COUNTY, BORDERING THE DEEP FORK RIVER

County	Percent State Population[a]	Percent Resident Licensed Hunter[b]	Percent Public Hunting Lands[c]
Creek	1.73	2.40	.00
Lincoln	.78	.90	.00
Okfuskee	.51	.50	.05
Oklahoma	18.60	9.72	.00
Okmulgee	1.53	4.88	1.77

[a]1968 Oklahoma Data Book, Bureau Business Research, University of Oklahoma.

[b]Administrative Planning Report #9 (Oct. 10, 1969), Oklahoma Department of Wildlife Conservation, Oklahoma City.

[c]Administrative Planning Report #7, Oklahoma Department of Wildlife Conservation, Oklahoma City.

hunt. Hunters on private lands were about three times more successful in bagging squirrels than were people hunting on the Okmulgee Public Hunting Area.

Twenty-eight percent of those interviewed failed to bag any squirrels while about 16 percent bagged their legal limit of 6 squirrels.

These data support the contention that squirrel hunters on public lands are less successful in bagging squirrels than are those who hunt on private lands (Nixon, et al. 1974). Studies in West Virginia (Uhlig 1955a:152) and Indiana (Allen 1952) found that more than 50 percent of the hunters were unsuccessful in killing squirrels on public lands.

Most squirrel hunting activity along the Deep Fork occurs during the first 2 or 3 weeks of the hunting season. Hunter interest declines during June and July in direct proportion to the increase in daily temperature, poison ivy, ticks, and mosquitos. In late August, squirrel hunters again actively seek squirrels when the squirrel begin cutting green pecans and begin to utilize the ripening acorns of the oaks. Cooler weather and the availability of summer-born litters, preferred by seasoned squirrel hunters for their taste and palatability over the older squirrels, also increase hunter interest in squirrels in late August and September. Light hunting pressure continues in October through 1 January, as many hunters pursue rabbits, waterfowl, bobwhite quail, and white-tailed deer in preference to squirrels during this period. At any time during the hunting season, flooding of the Deep Fork River may make much of the available hunting area near the river unusable by squirrel hunters.

Effect of Hunting on Squirrel Populations

Concern over the possible detrimental effects of Oklahoma's liberal regulations governing the hunting of squirrels is not new. In 1912, Doolin (1912) wrote that, although once plentiful throughout the state, squirrels have been so closely hunted that they are disappearing and should be protected by a closed season from 1 January to 1 July. Whisenhunt also stressed the need for examining Oklahoma's squirrel season opening and closing dates (Anon. 1955a).

A decision regarding the optimum opening and closing dates of Oklahoma's squirrel season is a complex affair. Not only must the biological processes determining squirrel population growth be assessed, but the social impact of the changes, if any, must also be evaluated. Reducing the amount of recreational opportunity by more restrictive hunting regulations must be considered carefully as the tradition of a liberal squirrel season is viewed as a right by many sportsmen of Oklahoma. Spring squirrel seasons occur when other hunting opportunities are low, esthetic aspects are high, and the amount of recreation provided by early squirrel seasons should not be disregarded in consideration of season setting.

Examination of squirrels taken by hunters in 1970-1972 along the Deep Fork of the North Canadian River provided the biological data necessary to estimate the impact of sport hunting on these populations. Table LV summarizes a portion of this information with the remainder being discussed in the chapter dealing with reproductive biology. A simplified model of predicting the impact of hunting on squirrel populations is presented in Table LVI. This loss calculation resembles that used by Brown and Yeager (1945:527). Using their calculation, for every 100 squirrels bagged by hunters along the Deep Fork another 36 animals are estimated to be lost. Of this total projected loss, 60.6 percent is due to fox squirrel mortality while 39.4 percent is contributed by the gray squirrels. These 36 animals represent unborn young not produced by adult females during the summer months and nestling young that die when deprived of their mother. No adjustment in Table LVI was made for crippling loss associated with the hunter harvest. Using this formula, Brown and Yeager (1945) estimated that Illinois was losing about 32 squirrels: 100 bagged.

Hunter Success Along the Deep Fork

Hunting success on squirrels along this portion of the Deep Fork was about the same in 1970 and 1971, but it

TABLE LV

SEX AND AGE RATIOS OF FOX AND GRAY SQUIRRELS KILLED BY HUNTERS, OKMULGEE AND OKFUSKEE COUNTIES, OKLAHOMA, 1970-1972

	Juvenile		Subadult		Adult		Total	
Species	n	%	n	%	n	%	n	%
Female								
Fox	57	32.2	36	20.3	84	47.5	177 (182)[a]	
Gray	65	36.7	68	38.4	44	24.9	177 (184)[a]	
Totals	122	14.3	104	12.2	128	15.0	354 (366)[a]	41.5
Male								
Fox	73	24.7	55	18.6	168		296 (301)[a]	
Gray	91	44.6	71	34.8	42	20.6	204 (213)[a]	
Totals	164	32.8	126	25.2	210	42.0	500 (514)[a]	

[a]Sex but not age determined for the squirrel

TABLE LVI

CALCULATED LOSS IN UNBORN AND SUCKLING YOUNG PER 100 SQUIRRELS BAGGED IN THE DEEP FORK STUDY AREA, MAY THROUGH SEPTEMBER, 1970-1972

Types of Loss by Species	Number per 100 Squirrels (51 fox squirrels: 49 gray squirrels)
Mature, potentially breeding, females	
Fox squirrels (24.8) X (51) = 12.65	20.25
Gray squirrels (15.5) X (49) = 7.60	
Pregnant	
Fox squirrels 3.8% of 12.65 mature females = .481	.96
Gray squirrels 6.3% of 7.60 = .479	
Lactating	
Fox squirrels (12.65) X (53.8) = 6.81	10.93
Gray squirrels (7.60) X (54.2) = 4.12	
Unborn young	
Fox squirrels (.481) X 3[a] 1.443	2.88
Gray squirrels (.479) X 3[a] 1.437	
Total unborn young lost 2.88	

[a]Estimated average number of young per litter determined by examination of corpora lutea present in ovaries of adult females.

TABLE LVI (continued)

Types of Loss by Species		Number per 100 Squirrels (51 fox squirrels: 49 gray squirrels)
Suckling young		
Fox squirrels (6.81) X (3) =	20.4	32.80
Gray squirrels (4.12) X (3) =	12.4	
Total suckling young lost	32.8	
Total loss		35.68

increased markedly in 1972 (Table LVII). Hunter success doubled in 1972 with 3.1 squirrels being taken on the opening weekend of the season. Squirrels killed per gun hour increased about 47 percent, up from 0.51 per hour to 0.75 squirrels per hour of hunting. Hunters also hunted longer on the average in 1972 when squirrels were apparently more abundant or susceptible to harvest.

There appears to be a positive correlation (r=.72, 12df, P=.01) between pecan production in Oklahoma one year and the overall squirrel harvest of the next year (Fig. 68). No significant correlation between current pecan harvest and current squirrel harvest was indicated (r=-0.36). If such a past-pecan year relationship does exist, this may produce a general predictive idea of value in setting squirrel seasons in Oklahoma. More detailed information on country-wide pecan production and squirrel harvest by county is needed to further test the value of the predictive success of this relationship.

Crippling Loss Associated With Hunting Tree Squirrels

Based on records kept by selected hunters, including myself, an indication of the crippling loss occurring during the hunting of tree squirrels was estimated (Table LVIII). On 121 hunts, 370 squirrels were bagged and another 34 believed lost, either wounded and escaped or

TABLE LVII

HUNTER SUCCESS DURING 1970-1972 HUNTING SEASONS FOR FOX AND GRAY SQUIRRELS, OPENING WEEK OF THE HUNTING SEASON

Year	Total Number of Hunts	Total Hours Hunted	Average Hours Hunted	Squirrels Taken		
				Total	Per Gun Hour	Per Each Hunt
1970	98	252	2.57	131	0.52	1.34
1971	96	253	2.64	130	0.51	1.35
1972	45	185	4.11	138	0.75	3.07
Total	239	690	2.89	399	0.58	1.67

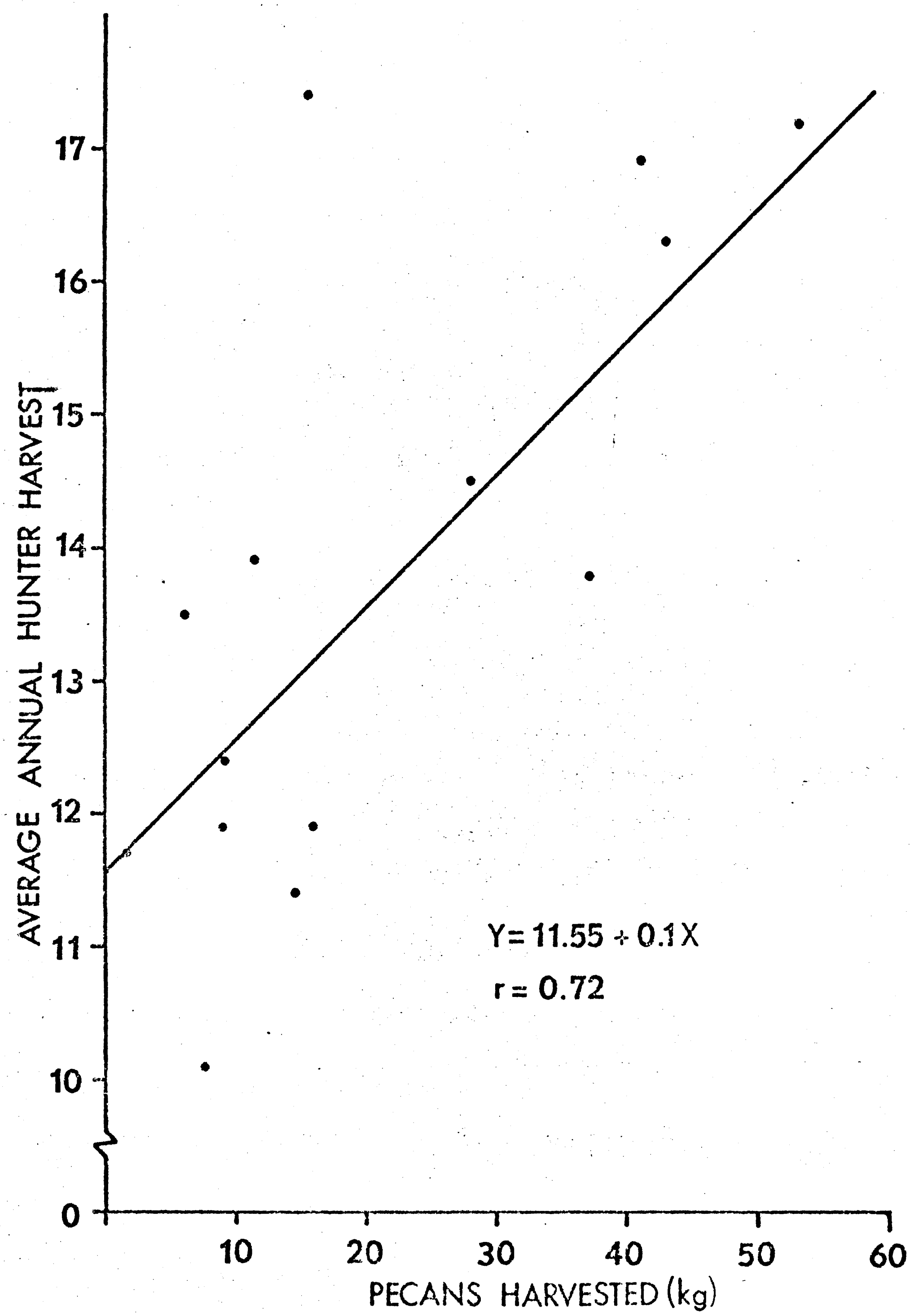

Figure 68. Correlation of Past Years Pecan Harvest and Current Year Average Hunter Harvest of Tree Squirrels in Oklahoma, 1958-1971.

TABLE LVIII

HUNTING LOSSES OF FOX AND GRAY SQUIRRELS ALONG THE DEEP FORK OF THE NORTH CANADIAN RIVER IN OKMULGEE AND OKFUSKEE COUNTIES, 1970-1972

Month	Bagged			Known Lost		
	Fox	Gray	All	Fox	Gray	All
December	13	8	21	0	0	0
January	2	2	4	0	2	2
February	3	0	3	0	0	0
	18	10	28	0	2	2
March	3	10	13	1	0	1
April	23	9	32	0	1	1
May	46	34	80	7	5	12
	72	53	125	8	6	14
June	5	17	22	0	1	1
July	5	4	9	1	0	1
August	31	35	66	4	5	9
	41	56	97	5	6	11
September	30	22	52	1	2	3
October	21	29	50	3	1	4
November	8	10	18	0	0	0
	59	61	120	4	3	7
Totals	190	180	370	17	17	34

killed but not retrieved. This loss was equivalent to an additional 9.2 percent of the overall harvest.

Seasonal differences in crippling loss must be considered. The loss during the months of May through September, coinciding with the existence of a dense growth of vegetation in bottomland forest areas, was 11.4 percent (26 squirrels lost for 229 bagged) while the crippling rate was only 5.7 percent (8 squirrels lost for 141 bagged) from October through December. The hindrance of vegetation providing escape cover, into which wounded squirrels rapidly disappear, and which may deflect shot pellets from shotguns, may increase this crippling rate accordingly. Based on this sample, no gross difference between the crippling rate for grays (9.4 percent), versus that for fox squirrels (8.9 percent), is indicated.

The crippling rates calculated for data taken along the Deep Fork approximate those reported in other studies. A crippling loss of between 10 to 15 percent probably occurs on most squirrels hunts (Atkeson 1958, Atkeson and Hulse 1952).

Population Simulation

Models for projecting changes in population densities have been written for several species of big game, primarily moose (*Alces alces*) and deer, and for turkeys (Davis 1967, Henny, et al. 1970, Dean 1972, Lobdell, et al. 1972, Lomnicki 1972). However, no existing program included sufficient flexibility to reflect accurately the population changes that a population of tree squirrels undergoes during the time that one of its cohorts survives.

Such a decision-making model for population fluctuation was developed as an aid to determining the long-term effects of an early squirrel season, starting 15 May, versus a hunting season opening 1 October. An indication of the detrimental effects of an early squirrel season are shown in Table LVI. However, not all squirrels dying because of hunting activity during the early squirrel season would survive until 1 October even if not hunted.

Calculations dealing with population dynamics are often difficult to understand in simulation models. Table LIX presents the coding scheme used for major variables used in this simulation work. After the data in Table LIX had been provided, they were entered into the terminal and simulation calculations were begun. The computer program developed for this simulation problem is on file at The Computer Center, California State University, Fresno.

The calculations are done on a breeding-cycle basis, so that time lags representing differential mortality rates and reproductive rates can be entered into the program. Population status is reported at the end of each breeding cycle. The basic equation for this estimate is:

$$POP(i) = HIST(i,1) * (1 + MIGRAT(i,1) - MIGRAT(i,2)) \quad (1)$$

TABLE LIX

DEFINITION OF VARIABLES USED IN POPULATION SIMULATION

Variable	Data
Hist(i,1)	= Total population of cohort i
Hist(i,2)	= Male population of cohort i
Hist(i,3)	= Female population of cohort i
Hist(i,4)	= Accumulative survival of offspring; unless experiment is done in laboratory, birth survivorship should equal zero
Hist(i,5)	= Age of cohort i
Hist(i,6)	= Mortality level of cohort i
i	= Cohort identity, maximum of 10 historical cohorts
Season	= Number of breeding cycles in seasonal cycle
Cymort(j)	= Seasonal mortality for each cycle of j of season
j	= Number of seasons range from 1 to 40
Index	= Number of survivorship cycles cohort is in system
C(k)	= Survivorship rates in the form of (1 - rate)
k	= Number of cycles ranging from 1 to Index
Den	= The number of elements which one unit of study area can hold without causing damage to the habitat
Units	= Number of biological units or area in study plot
Denunits	= Theoretical maximum carrying capacity of study area
Migrat(k,1)	= Immigration into system for cohort k in decimal equivalents
Migrat(k,2)	= Emigration out of system for cohort k in decimal equivalents
Migrat(k,3)	= Male ratio of migrational factors in cohort k
Migrat(k,4)	= Female ratio of migrational factors in cohort k
Brats	= Number of offspring per breeding female
Stud	= Male ratio of offspring
Bitch	= Female ratio of offspring
Adult Breed	= Percentage of females bred to conceive offspring
Birth	= Birth mortality of new cohorts
Ages	= Number of breeding cycles female bred in system
Age(1,1)	= Cycle number
Age(1,2)	= Percent of females to breed at age 1
1	= Ages range from 1 to ages
Number	= Number of breeding cycles to run
Iyear	= Year to start cycle 1
Icpy	= Number of breeding cycles per year

for each cohort i, POP(i) would be the cohort population after the migrational factors have been considered. If the results of Equation 1 give the total population after migrational effects, Equations 2 and 3 would give the total number of males and females that are to be considered before mortality.

POP MALE(i) = HIST(i,2) * ((1 + MIGRAT(i,1)
- MIGRAT(i,2)) * MIGRAT(i,3)) (2)

POP FEMALE (i) = HIST(i,3) * ((1 + MIGRAT(i,1)
- MIGRAT (i,2)) * MIGRAT(i,4) (3)

After the new population has been calculated, the mortality should be calculated to estimate the breeding stock for the new cohort to be conceived. The major mortality will be the same for the male population, female population, and total population. The major mortality affecting the population is the survivorship rate and seasonal mortality. These equations:

POP(i) = POP(i) - POP(i) * (CYMORT(i) + (C(j)/ICPY)) (4)

POP MALE(i) = POP MALE(i) - (POP MALE(i)
* (CYMORT(i) + (C(j)/ICPY)) (5)
* RATE MALE)

POP FEMALE(i) = POP FEMALE(i) - (POP FEMALE(i)
* (CYMORT(i) + (C(j)/ICPY)) (6)
* RATE FEMALE)

calculate the new population after mortality. From these new female populations the new cohort is conceived. The number of offspring from each cohort is dependent on the number of females in the cohort, female conception rate, the number of offspring per female, and the breeding rate.

POP NEW = POP NEW + (POP FEMALE(i) * BRAT
* AGE(i,2) * (BREED)) (7)

The new cohort is then subject to birth mortality, which is the major mortality affecting the new population.

POP NEW = POP NEW - (POP NEW * BIRTH) (8)

The male and female ratios of the new cohort are calculated by multiplying the total cohort by these ratios:

POP NEW MALE = POP NEW * STUD (9)

POP NEW FEMALE = POP NEW * BITCH (10)

Density-dependent populations require an additional set of equations where Denunits are considered. This set of equations first tests to determine if the total population for that cycle is greater than the calculated density. If not, density equations are not considered. If they are, then Equations 11-15 are processed.

POP EXCESS = POP TOTAL - DENUNITS (11)

POP(i) = POP(i) - (POP EXCESS * .5) (12)

POP MALE(i) = POP MALE(i) - (POP EXCESS * .5
* RATE MALE) (13)

POP FEMALE(i) = POP FEMALE(i) - (POP EXCESS
* .5 * RATE FEMALE) (14)

POP EXCESS = POP EXCESS - (POP EXCESS * .5) (15)

These equations start with the newest population and run to the oldest population.

The combined equation for estimation of population changes with differing hunting strategies is: (16)

TOTAL POPULATION = Σ[(HISTORY(j,1) * (HISTORY(j,1)
* (CYMORT(i)/ICPY + SEASONAL(1))]
+ [Σ POP(ii,1) - (POP(ii,1))
* (CYMORT(i)/ICPY + SEASONAL(1))]
+ [(Σ HISTORY(j,3) + Σ POP(ii,3))
* BRAT] * BIRTH MORTALITY
* AGE(i,2) * ADULT BREED

where:

k = cycle being analyzed

j = 1 to number of history records

i = cycle cohort is in system

ii = 1 to number of cycles previously processed

Specific Assumptions and Parameters Used in Simulation

The biological assumptions and their justifications accepted in constructing the model are as follows:

(1) The initial population of squirrels estimated to be on the area just prior to the spring breeding season was 300. Data obtained from livetrapping on the Spears Study Area indicated that this density is probably present on good squirrel habitat in east-central Oklahoma.

(2) Examination of corpora lutea from sectioned ovaries indicated that the average breeding female had a conception rate of three offspring.

(3) Sex ratio of the litter at birth was believed to be 50:50.

(4) Two reproductive periods occur in both the fox and gray squirrel populations in eastern Oklahoma, as in the rest of North America (MacClintock 1970).

(5) Mortality of young squirrels during the first three months of their life was assumed to be 50 percent of the cohort size (Barkalow, et al. 1970).

(6) Mortality of the remaining young squirrels until 1 year of age was assumed to be 25 percent of the surviving cohort (Barkalow, et al. 1970).

(7) Mortality of all squirrels 1 year and older was assumed to be 50 percent of the surviving cohort (Barkalow, et al. 1970).

(8) The percent of females in each age class in the population believed to be breeding was: juveniles, 0 percent; subadults, 10 percent; adults, 95 percent.

(9) The number of breeding females producing two litters per year: juveniles, 0 percent; subadults, 0 percent; adults, 40 percent.

(10) Cohort mortality was distributed in hunting by: males, 60 percent; females, 40 percent.

(11) The maximum density that a squirrel population was assumed to tolerate without disruptive social behavior

and/or emigration taking place was six squirrels per acre (Sanderson and Berry 1973).

(12) Population changes were calculated for 20 cycles, or 10 years, to indicate potential density changes in squirrel populations that might occur under these given assumptions.

(13) Within reason, environmental conditions were assumed to fluctuate within "average" limits throughout the 20 cycles; whereas, in fact, this assumption may not be met in actual ecological situations.

(14) No input of data on immigration or emigration was provided because this information was lacking and not provided by field investigation as originally planned. In essence, the Spears Study Area was treated as a closed system as far as the existence of other squirrels outside of its boundaries were concerned.

(15) Hunting mortality was assumed to be an additional 10 percent mortality added to existing mortality rates that function in unexploited squirrel populations. It has the greatest impact by removing nursing females, causing the subsequent assumed loss of nestlings as the result of the death of the mother and the loss of potential young animals contained by pregnant females. The loss of the potential future reproductive input of these future breeding females on changes in projected growth curves is particularly important.

Implications of Population Simulation

Projected population composition, sex ratios, mortality rates, and total population for squirrels subjected to no hunting, and for populations subject to hunting seasons starting 15 May to 1 October as computed by the simulation program, are presented in Tables LX, LXI, LXII, and LXIII. Using this approach, the addition of 10 percent mortality due to hunting to the nonhunting mortality shows dramatically how hunting may limit the growth of the squirrel population (Fig. 69).

However, the results of the different hunting strategies are less evident. If it is correct that almost all of the hunting effort for squirrels occurs in the spring, as appears to be the case in many Deep Fork areas, then an expected annual average population size of 318 (± 8) would be maintained on the area (Table LXI).

But, by splitting the hunting mortality into two equal portions in which the May-season time period is credited with 5 percent of the total hunting mortality and the early fall months of September-October are given the remainder, an average population of 286 (± 4) would be maintained on the area (Table LXII).

By keeping the season closed until 1 October the expected benefits of saving nursing females with nestlings and unborn young did not materialize (Table LXIII). The

TABLE LX

PROJECTED POPULATION DENSITIES OF UNEXPLOITED TREE SQUIRREL POPULATIONS IN EASTERN OKLAHOMA

Breeding Cycle	Current Population			
	Total	Males	Females	Births
1	278	103	117	58
2	319	98	120	101
3	358	107	140	111
4	370	112	158	100
5	397	111	170	116
6	446	116	188	141
7	496	127	214	155
8	541	138	240	164
9	598	152	262	185
10	666	168	290	209
11	736	187	321	229
12	811	208	355	250
13	897	229	391	279
14	993	253	433	309
15	1,097	280	479	341
16	1,212	310	530	376
17	1,341	342	586	417
18	1,483	379	648	462
19	1,638	419	716	508
20	1,812	463	792	563

TABLE LXI

PROJECTED POPULATION DENSITIES OF TREE SQUIRREL POPULATIONS RESULTING FROM AN EARLY SQUIRREL SEASON, 15 MAY, IN EASTERN OKLAHOMA

Breeding Cycle	Current Population			
	Total	Males	Females	Births
1	278	103	117	58
2	319	98	120	101
3	291	89	126	75
4	252	69	121	61
5	279	65	126	87
6	316	71	141	103
7	292	65	148	82
8	271	59	139	77
9	312	66	144	105
10	346	80	160	110
11	315	75	157	85
12	295	65	148	85
13	339	72	156	114
14	370	87	170	115
15	338	80	168	92
16	314	69	157	90
17	355	77	161	117
18	388	91	177	120
19	352	83	175	95
20	330	72	164	95

TABLE LXII

PROJECTED POPULATION DENSITIES OF TREE SQUIRREL POPULATIONS RESULTING FROM AN EARLY SQUIRREL SEASON, 15 MAY, WITH PARTIALLY DEFERRED HUNTING MORTALITY IN EASTERN OKLAHOMA

Breeding Cycle	Current Population			
	Total	Males	Females	Births
1	253	95	110	48
2	266	80	106	80
3	275	79	115	81
4	260	72	120	67
5	257	63	122	73
6	271	58	127	86
7	277	61	131	85
8	278	63	132	81
9	283	64	133	84
10	288	65	135	86
11	291	66	136	86
12	294	67	138	87
13	297	67	139	88
14	300	68	140	89
15	300	69	140	88
16	303	69	141	90
17	305	70	142	90
18	307	70	143	91
19	310	70	145	92
20	313	71	146	92

TABLE LXIII

PROJECTED POPULATION DENSITIES OF TREE SQUIRREL POPULATIONS RESULTING FROM A LATER SQUIRREL SEASON, 1 OCTOBER, IN EASTERN OKLAHOMA

	Current Population			
Breeding Cycle	Total	Males	Females	Births
1	229	86	104	39
2	218	64	93	61
3	255	67	103	85
4	261	73	118	71
5	231	57	115	59
6	225	46	112	69
7	260	54	119	89
8	281	66	132	85
9	256	61	127	69
10	242	53	119	70
11	273	59	125	91
12	298	70	137	91
13	272	64	136	74
14	254	56	127	74
15	288	62	132	96
16	316	74	145	98
17	286	68	142	77
18	266	59	132	76
19	302	65	138	100
20	330	77	151	102

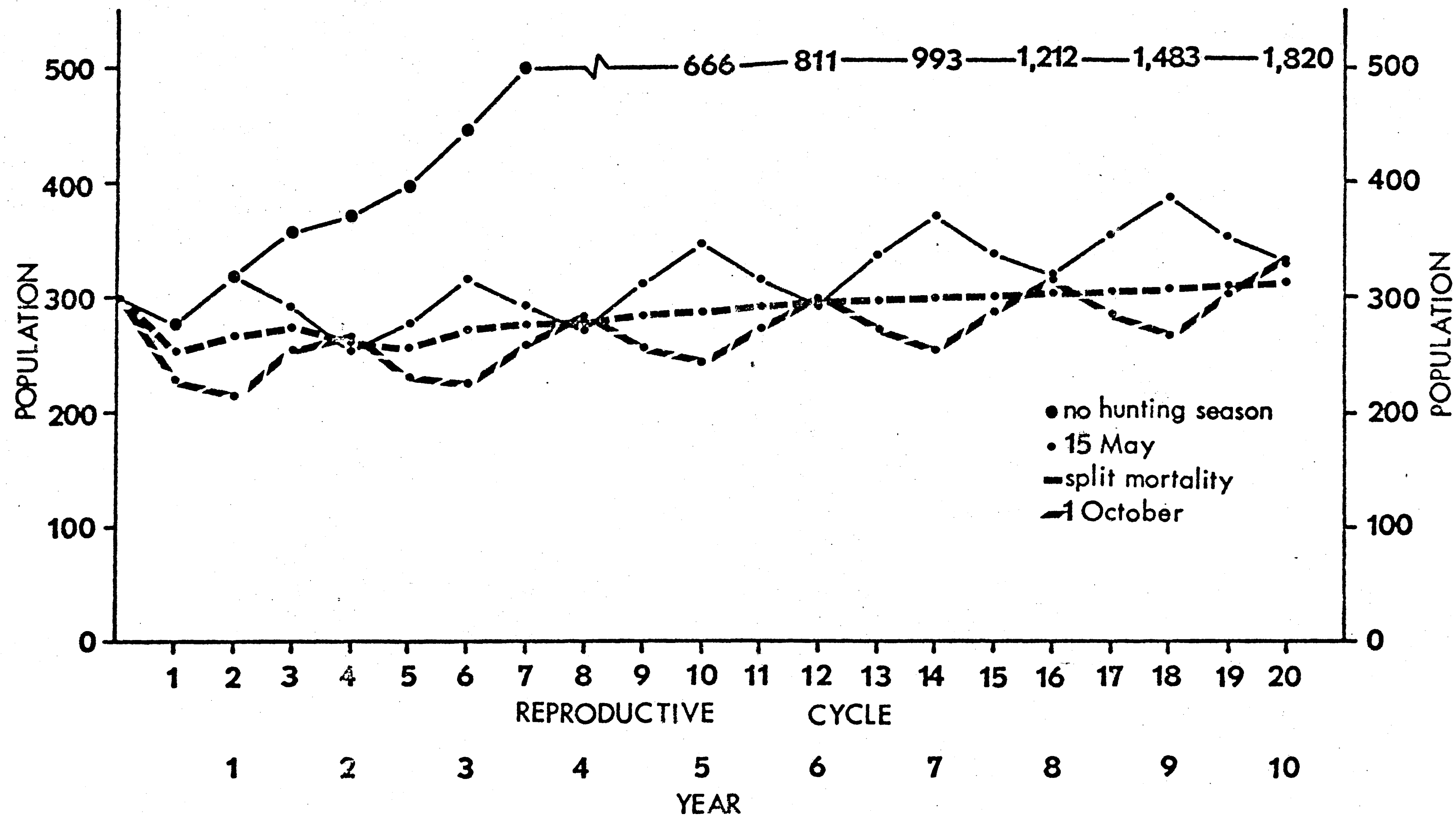

Figure 69. Comparison of Effect of Early Opening of Squirrel Season (15 May) with a Later Opening Date (1 October).

late opening of the squirrel season resulted in the lowest average projected population for the area, 267 (± 7).

Based on this computer simulation work, it is apparent that the early squirrel season opening on 15 May does not result in greatly reduced squirrel populations and in fact may produce the most squirrel density for the area. If the squirrel season is delayed in opening until 1 October there will not be an increase in availability of squirrels and the additional recreational time offered to the sportsman by the early season will be lost. Consequently, the current 15 May season appears adequate for management purposes. Refinement of the biological assumptions associated with this model may change these conclusions. Many other biologists have recommended later opening dates for tree squirrel seasons (Table LXIV).

Based on the evaluation of computer simulation and harvest data, the opening of squirrel seasons in Oklahoma on 15 May is not considered to be detrimental at this time. However, if new or more exact data on specific biological assumptions become available, it may be necessary to reassess this conclusion.

TABLE LXIV

HUNTING RECOMMENDATIONS BASED ON SQUIRREL RESEARCH

State	Reference	Current Opening Date	Recommended as the Most Biologically Sound Opening Date
Illinois	Brown and Yeager (1945:528)	north: 1 Sept.-16 Nov. central: 15 Aug.-30 Oct. southern: 15 July-15 Oct.	15 Sept.-15 Nov. 15 Sept.-15 Nov. 1 Sept.-31 Oct.
Indiana	Allen (1952:110)	20 Aug.-20 Oct.	1 Nov.-1 Jan.
Kansas	Packard (1956:62)	15 June-30 Nov.	1 Sept.-10 Dec.
Ohio	Nixon, et. al 1974	2nd week of Sept.	after 15 Sept.
Oklahoma	Doolin (1912)		1 July-1 Jan.
	Duck and Fletcher (1944:106)	15 May-1 Jan.	16 May-30 June 16 Oct.-14 Dec.
	Whisenhunt (1955:12)	15 May-1 Jan.	1 May-15 July 15 Oct.-15 Dec.
Texas	Goodrum (1967:34)	--[a]	15 May-15 June 15 Oct.-10 Dec.

[a]Too many county regulations to summarize. See Goodrum (1967) for details on any specific county.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The primary objectives of this study were to determine the current status and distribution of fox and gray squirrels in Oklahoma and to determine the relative population densities of these squirrels in major habitat types in east-central Oklahoma. Once this information on the natural history of these species was collected, management recommendations were formulated.

In reviewing the records of past and present squirrel distribution in Oklahoma, it became obvious that the fox squirrel was more widely distributed than the gray squirrel and it occurs throughout the state except in the Panhandle region. It occupies a broad spectrum of habitat types throughout the state and disrupts its stereotyped image of a dweller of only the forest edge and open woodlands by being abundant in the dense bottomland forests in east-central Oklahoma. Fox squirrels probably have extended their distribution in Oklahoma in response to man's afforestation work.

In contrast, the gray squirrel's distribution in Oklahoma is decreasing and it is now recorded only eastward of the 97th meridian. It appears that the distribution of gray squirrels in Oklahoma will continue to be reduced. Destruction of the dense bottomland forest, the preferred habitat for gray squirrels in east-central Oklahoma, is proceeding at a rapid rate. Representative portions of this bottomland habitat need to be preserved as a representative ecological type before there is none left to serve us as ecological guideposts in our management restoration efforts. Acquisition and preservation of existing bottomland forests appear a necessity if gray squirrel populations are to be maintained in many local areas of eastern Oklahoma.

The spatial distribution of fox and gray squirrels within remaining woodland habitats has not been adequately explained. Fox and gray squirrels may compete inter-specifically with this competition preventing gray squirrels from utilizing the open pecan orchards in east-central Oklahoma. On the Spears Study Area the only portion of the pecan orchard that gray squirrels utilized were those areas still having a dense brush fringe along the orchard's edge; portions of the orchard lacking these brushy areas were not used by gray squirrels. Maintenance of the brush fringes and brush patches within pecan groves provides a remnant habitat that gray squirrels will utilize. Without this cover, only fox squirrels will occupy the open pecan orchards. Intensive study is needed of the behavioral aspect of the failure of gray squirrels to occupy open pecan orchards. The entire orchard area supported an abundant fox squirrel population. No gray squirrels were found in the post oak-blackjack oak upland forest. Fox squirrels were common in the dense bottomland forest areas that also supported abundant populations of gray squirrels.

Ecologically, the remaining bottomland areas are now recovering from intensive logging, grazing, and man's disruption from the 1930's and perhaps now in the 1970's are regaining a vestige of their former character. Fox squirrels may have invaded these areas in the 1930's when the density of vegetation was reduced. Now, a deme of fox squirrels may have adapted to this atypical habitat and is flourishing in it. Additional study of this aspect of distribution of these two squirrel species is needed.

The watershed of the Deep Fork of the North Canadian River purportedly contains some of the best squirrel habitat remaining in Oklahoma. Review of literature dealing with this 370 km watercourse, discussions with long-term residents of the area, travel along much of the river and establishment of study areas within it (Fig. 1) provided data for the assessment of its ecological conditions. The apparent key to maintenance of the bottomland forest along the Deep Fork is the occurrence of periodic flooding. This flooding has prevented the conversion of this bottomland to agricultural uses in Creek, Okfuskee, and Okmulgee Counties. Analysis of aerial photographs taken from 1939 through 1970 of four sections of land adjoining the Spears Study Area indicate that from 1896 through 1974, woodland cover on these sections decreased from 67.7 percent to 43.2 percent. A rapid loss of woodlands in this area has occurred since 1970. In 1971, bottomland forest made up only 3.2 percent of the total forest cover in the counties bordering the Deep Fork; it now probably makes up less. This woodland loss and/or conversion from bottomland forest to open, intensively managed pecan orchards is most devastating to the gray squirrels in that they disappear from these new habitat types. Fox squirrels remain on the sites, at least in token numbers, but with the destruction of den sites in the open pecan orchard, fox squirrel populations also plummet. Conditions in the Spear's pecan orchard probably represented ideal habitat for fox squirrels because of the numbers of den trees left in it, 6 per 0.4 ha, although den trees were more abundant in the bottomland forest. The bottomland forest had an estimated den tree density of 48 potential dens per 0.4 ha. The paucity of den trees in the post oak-blackjack oak uplands may be a serious limiting factor for fox squirrels. Elms were predominantly the potential den trees in the bottomland whereas pecans were the obvious possibility in the pecan orchard. Post oak was the major den tree utilized in the post oak-blackjack oak forest.

The unique combination of soil type, vegetation patterns, and past historical use by man have combined to produce the existing ecological conditions on the Spears Study Area. In the past 30 to 40 years, the study area has been transformed from a forested area supporting several small farms and their associated field crops into a consolidated ranch managed exclusively for producing pecans and grazing domestic stock.

Four major habitat types occur on the study area: pasture-brush, post oak-blackjack oak forest, pecan orchard, and bottomland forest (Fig. 20). Post oak dominates the post oak-blackjack oak forest although black oak and blackjack oak are also common members of this forest type. Soils supporting post oak-blackjack oak forests are sandier and lower in fertility than soils supporting the bottomland forest and pecan orchard types. Because of the obvious differences in soil type, moisture conditions and plant composition, two subtypes of bottomland forest were recognized: wet bottomland dominated by green ash and swamp privet and dry bottomland forest dominated by elms and oaks. Many other species of trees occasionally occur in the dry bottomland woodland. The bottomland forest is the most varied of the habitats encountered on the Spears Study Area and contains the greatest diversity of wildlife. The largest habitat type on the study area was the pecan orchard consisting of a virtual monoculture of pecan trees. Overall tree density on the forested area of the study area was 38.8 stems per 0.4 ha.

Counts of leaf nests on 41.7 ha of the study area indicated that generally the forest type with the least number of den trees had the most active leaf nests although the negative correlation (r=-.65) was not statistically significant.

Home ranges and population density estimates for squirrels were determined. Trapping and handling of fox and gray squirrels affected their future catchability, violating the assumption of equal catchability among all members of the population. The sex ratio of livetrapped fox squirrels on the Spears Study Area was 100 females: 115 males whereas a ratio of 100 females: 119 males was obtained for the gray squirrels. Neither estimate was statistically different from a hypothesized 50:50 sex ratio. A comparison of sex and age ratios obtained from livetrapped squirrels and animals shot by hunters revealed no statistical difference between these two samples.

Trapping success was related to environmental conditions with fewer squirrels being captured during the colder portions of trap periods. No statistically significant correlation between higher temperatures and lower trap success on the study was obtained although such a negative relationship seems indicated.

In this study, home ranges were calculated for 43 fox squirrels. Adult male fox squirrels had significantly larger minimum home ranges than did the adult female fox squirrels. They had an average home range of 2.87 ha versus a home range of 0.44 ha for the adult females. The general shape of the minimum home range was distinctly noncircular. The home range of adult males was almost four times as long as wide whereas the maximum length:width ratio for adult females was 1:0.42.

Little movement of tagged squirrels out of the study area was indicated. Only 1.8 percent of the squirrels tagged on the study area were found outside its borders. Male fox squirrels were more likely to change habitat types than were the female fox squirrels. No gray squirrels were recovered in a habitat type other than bottomland forest or ecotone, such as the brush fringe along the Deep Fork River. Male fox squirrels traveled almost twice as far as did the female fox squirrels to seek shelter after their release at the trap site.

Efforts to obtain population estimates on the area and failure to recapture adequate numbers of previously marked squirrels resulted in low precision for the population estimates that were obtained. Assumptions usually stated for mark-recapture techniques were probably only partially met, and both contagion and heterogeneity may affect the population estimates. The Eberhardt formula for an estimate of population based on the maximum likelihood estimation (MLE) for the geometric distribution and regression techniques for a geometric distribution produced unrealistically high population estimates. The Schnable method was used to estimate population densities when sequential trapping was used and the unmodified Petersen Index was also used where applicable. An overall density of one squirrel per 0.4 ha was estimated to occur on the area. Hunters harvested one squirrel per 0.89 ha on the area.

Monthly collections of squirrels were made along the Deep Fork of the North Canadian River in Okmulgee and Okfuskee Counties. Physical measurements were taken and age classes were constructed by which the general population dynamics of the species were described. A total of 442 fox squirrels and 355 gray squirrels were necropsied during the study. All measurement data were subsequently transcribed and analyzed with a CDC 3150 computer at The Computer Center, California State University, Fresno.

Analysis of eye lens weights indicated that juvenile fox squirrels had eye lenses weighing less than 30 mg, subadults lenses weighing 31 to 41 mg, and adults lenses weighing more than 41 mg. Gray squirrel juveniles had lenses weighing less than 27 mg while subadult lenses weighed from 28 to 39-41 mg and adults had a lense weight of more than 41 mg. These lens weights match approximately those given by other investigators. Unfortunately, known-age squirrels were not available from this study, so the accuracy of this lens distribution could not be determined. Use of a microwave oven to dry eye lenses was unsuccessful because the rapid drying charred the lenses. Seasonal variability in the body weights of squirrels was present with squirrels generally losing weight in the summer months.

Reliance on any one physical feature to establish age classes or cohorts of unknown-age animals is often unsuccessful. Because two distinct breeding seasons exist for squirrels, animals should fall into one of k classes or cohorts if the selection of physical attributes is made properly. An attempt was made to combine several morphometric values into a useable age index from which a more precise determination of age could be determined. After Equation 4 was developed, age index values and frequency distributions for these age index values were constructed using total length, eye lens weight, occipio-nasal length, and total weight. A total of 90 frequency diagrams were generated by the computer program developed for this aging approach. Unfortunately, the frequency distributions for morphometric factors do not all result in emphasizing differences between cohorts in the population. The combinations utilizing total length, total weight, and eye lens weight appear by inspection to have the greatest promise for the development of a useable age index. Larger samples and known-age animals are needed to confirm this interpretation. Based on this approach, no apparent gain over the use of eye lens weights only for aging tree squirrels was apparent so the eye lens aging technique was retained.

Information on the breeding biology of fox and gray squirrels was collected from May 1970 through May 1972. The external appearance of the scrotal sac of the fox and gray squirrel males was adequate to distinguish between juveniles and subadult-adult age classes. Based on physical measurements, male squirrels are least active sexually during the summer and fall months and most active in the winter and spring periods. The Cowper's gland shows the greatest seasonal change in size of any of the male reproductive organs measured. It is smallest in the fall and becomes the largest in the succeeding months. Changes in the morphometrics of subadult male reproductive organs followed the same general pattern as that of the adult males whereas juveniles exhibited no matching pattern of size changes.

Estimates of the fertility of female fox and gray squirrels were obtained from counts of corpora lutea present in the ovaries, pigment scars visible on the uterine wall, number of embryos, and counts of the number of young in litters of squirrels at their natural den sites. The mean ovulation rate for adult fox squirrels was 3.0 (1SE=0.29) and 3.0 (1SE=0.25) for adult female gray squirrels. An average foetal rate of 3.14 (1SE= 0.33) was estimated from fox squirrel material while a foetal rate of 3.4 (1SE=0.25) was indicated from examination of gray squirrel material.

Examination of the mammary glands of squirrels provided an indication of lactation rates. Of the adult female fox squirrels, 55.6 percent were found to be lactating at some time during the year while 50.5 percent of the adult female gray squirrels examined were lactating. Two distinct peaks of lactation occurred in both the fox and gray squirrels, with most of the squirrels examined lactating during the spring and summer months. Fox squirrels extend their lactation period well into the fall, indicating perhaps a longer breeding season than occurs for the gray squirrel group. The breeding seasons of both the fox and gray squirrels appear longer than those reported for other geographical areas.

The successful management of fox and gray squirrel depends on integrating biological information with the desires of the sportsman. A synopsis of past regulations dealing with squirrel hunting in Oklahoma was compiled and estimates of hunter effort and harvest along the Deep Fork were gathered through hunter check stations at the Okmulgee Public Hunting Area and interviews with hunters encountered along the Deep Fork during the hunting season. Correspondence with other states having huntable populations of fox and gray squirrels provided an overview of squirrel management practiced in other areas in comparison to that being currently conducted in Oklahoma. Computer simulation was used as an aid in determining the appropriateness of the current opening date of 15 May for the squirrel season in Oklahoma.

Squirrels are popular with Oklahoma hunters. More than one million squirrels are harvested annually statewide. The average Oklahoma squirrel hunter takes 14 squirrels per season. This average harvest is one of the highest in the United States. Regulations governing squirrel hunting in Oklahoma have changed little in the past 63 years. The present season, one of the longest in the United States traditionally opens 15 May and extends until 1 January. Each hunter is allowed a daily bag limit of six squirrels.

The typical Deep Fork squirrel hunter hunted with one other person, usually with a shotgun, in the morning hours, primarily in bottomland forest habitat for squirrels. These hunters actually pursued squirrels about 3 h per trip and usually bagged one or two squirrels during the hunt. Hunters on private lands were about three times more successful in bagging squirrels than were people hunting on the Okmulgee Public Hunting Area. Twenty-eight percent of those interviewed failed to bag any squirrels while about 16 percent bagged their legal limit of six squirrels. Most squirrel hunting activity along the Deep Fork occurs during the first 2 or 3 weeks of the hunting season. In late August, squirrel hunters again actively seek squirrels when these animals begin cutting green pecans and utilizing ripening acorns. Light hunting pressure continues from October through 1 January, as many hunters pursue other species of wildlife in preference to squirrels. At any time during the hunting season, flooding of the Deep Fork may make much of the available hunting area unusable by squirrel hunters. There appears to be a positive correlation between pecan production in Oklahoma the preceding year and the current squirrel harvest. If such a relationship does exist, it may be of predictive value in setting squirrel seasons in Oklahoma.

Based on records kept by selected hunters, including myself, a crippling loss of about 10 percent occurs, but this loss rate varies seasonally. More squirrels are lost when dense vegetation is present than later on in the fall when it becomes less dense.

A decision regarding the optimum opening date of Oklahoma's squirrel season is complex. Examination of squirrels taken by hunters in 1970-1972 along the river provided biological data necessary for estimating the impact of sport hunting on these populations. Preliminary calculations indicated that for every 100 squirrels being bagged by hunters along the Deep Fork, another 36 animals are estimated to be lost (Table LVI). These 36 animals represent unborn young not produced by adult females during the summer months and nestling young that die when deprived of their mother.

A decision-making model for population fluctuation was developed to compare the long-term effects of an early squirrel season, starting 15 May, versus a hunting season opening 1 October. The calculations are based on the breeding cycle so that time lags representing differential mortality rates and reproductive rates can be entered into the program. Hunting mortality was assumed to be an additional 10 percent mortality being added on top of existing mortality rates estimated for an unhunted squirrel population. The addition of this 10 percent mortality dramatically limits population size (Fig. 69). However, the results of the different hunting strategies are less evident. If the biological data used in this model are reasonably correct, there appears to be no real benefit in opening the Oklahoma squirrel season 1 October. The earlier squirrel season, opening 15 May, does not result in greatly reduced squirrel populations and may in fact produce the highest average squirrel density over a span of time.

The trend in squirrel management in Oklahoma must be one of increased intensity. Reduction of available woodlands makes it necessary to produce more squirrels on our remaining woodland areas. Acquisition and preservation of existing bottomland forests appears mandatory if gray squirrel populations are to be maintained in many local areas in Oklahoma. Maintenance of the brush fringes and brush patches within pecan groves provides a remnant habitat that gray squirrels will utilize. Intensive study is needed of the behavioral aspect of the gray-fox squirrel interaction and failure of gray squirrels to utilize open pecan orchards. Utilization of artificial nest boxes in post oak-blackjack oak forests, and in some bottomland areas lacking in adequate den trees could dramatically increase the production of tree squirrels in these areas. If safety permits, the use of .22 rimfire rifles over shotguns may result in a reduction in the crippling loss associated with hunting squirrels.

Introducing fox squirrels into the cottonwood groves along the rivers in the Panhandle portion of the state may establish fox squirrel populations in these areas. These animals are found in neighboring Kansas and Texas counties under the same ecological conditions. Wildlife managers should be able to develop populations of fox squirrels in the Oklahoma Panhandle once an initial introduction is established.

Production of tree squirrels in the post oak-blackjack oak uplands as well as in bottomland areas could be dramatically increased by use of artificial nest boxes. The abundance and suitability of den trees and food on respective forest sites must be determined before extensive programs in artificial shelter construction are established. Using artificial nest boxes in western Oklahoma windbreaks and woodlots where den sites may be lacking could also increase markedly the fox squirrel population in the western areas of the state.

Fox and gray squirrels represent a considerable recreational resource within Oklahoma. If intensively managed, they will produce a quality outdoor experience for a large number of people experiencing an outdoor adventure. A successful squirrel hunter is an esteemed member of the sportsman's society in Oklahoma and is often locally recognized for his skills. However, the neglect of the habitat needed for squirrels and virtually no management of these species may result in the loss of much if not all of this recreational potential. This neglect will rob future generations of potential squirrel hunters and watchers of the opportunity to practice their woodcraft on these species unless an intensive management program for squirrels is implemented in Oklahoma.

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VITA

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