AS ASSESSMENT OF DAMAGE TO PECANS BY WILDLIFE IN CENTRAL OKLAHOMA

By

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AN ASSESSMENT OF DAMAGE TO PECANS BY

WILDLIFE IN CENTRAL OKLAHOMA

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PREFACE

The purpose of this study was to develop a method whereby wildlife damage to pecans could be accurately measured and to determine the species responsible for the majority of damage. The relationship between oak mast production and pecan damage was also investigated and recommendations for control and further research made. Funds for this study were provided by the Oklahoma Cooperative Wildlife Research Unit and the Oklahoma State University Agricultural Experiment Station.

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF STUDY AREA	8
Climate	8
Topography, Soils, and Geology	8
Vegetation	10
METHODS AND MATERIALS	13
Study Site Selection	13
Wildlife Species Census	13
Oak Mast Production	15
Pecan Mast Production	17
Pecan Damage	20
Wildlife Damage	21
Insect Damage	22
Source of Damage Unknown	22
Stomach Content Analysis	23
RESULTS	24
Wildlife Species Census	24
Relative Oak Mast Production	32
Pecan Mast Production	32
Wildlife Damage	35
Caching Loss	38
Insect Damage	38
Source of Damage Unknown	41
Stomach Content Analysis	41
DISCUSSION	44
Species Causing Damage	44
Blue Jays	45
Common Crows	45
Woodpeckers	46
Squirrels	48
Other Species	49
Insect Damage	50
Damage from Unknown Sources	50

Page

Oak Mast Production 51
Management Recommendation 52

SUMMARY AND CONCLUSIONS 54

LITERATURE CITED 58

APPENDIXES 63

APPENDIX A - MEAN WEIGHT (GRAMS) OF 25 INDIVIDUAL PECANS FROM 23 SAMPLE TREES, 1979 64

APPENDIX B - DENSITY (NUMBERS PER HECTARE) OF AVIAN SPECIES SEEN IN THE PECAN ORCHARD DURING TIME-AREA COUNTS, FALL AND WINTER 1978-79, AND FALL AND WINTER 1979 66

LIST OF TABLES

Table | Page

1. Categorical ranking of mast producing capacity based on potential yields of acorns produced in a growing season (Sharp 1958) 16

2. Relative abundance (number of tracks) of mammalian species utilizing the pecan orchard during the fall of 1979 25

3. Mean densities (birds per 100 hectares) of blue jays in the pecan orchard and adjacent oak forests during consecutive 10-day periods during pecan ripening and harvesting periods of 1978 and 1979 26

4. Mean densities (birds per 100 hectares) of red-bellied woodpeckers in the pecan orchard and adjacent oak forests during consecutive 10-day periods during pecan ripening and harvesting periods of 1978 and 1979 28

5. Mean densities (birds per 100 hectares) of red-headed woodpeckers in the pecan orchard during consecutive 10-day periods during pecan ripening and harvesting periods of 1978 and 1979 30

6. Mean densities (individuals per 100 hectares) of eastern fox squirrels in the pecan orchard and adjacent oak forests during consecutive 10-day periods during the pecan ripening and harvesting periods of 1978 and 1979 31

7. Condition of pecans collected from seed traps and open ground plots beneath sample trees, fall and winter 1978-79 33

8. Condition of pecans collected from seed traps and open ground plots beneath sample trees, fall and winter 1979 34

Table Page

9. Estimates of number of harvestable kilograms of pecans from sample trees by the nut trap and ground plot methods compared to actual number of kilograms of pecans harvested 36

10. Estimates of the percent of damage and harvest of the total pecan production from 69 ha pecan orchard and the economic value of each based on an average price of 29 cents per kilogram of pecans 37

11. Estimated number of kilograms of pecans cached from 69 ha pecan orchard by blue jays, red-bellied woodpeckers, and red-headed woodpeckers, fall and early winter, 1979 40

12. Percent frequency of occurrence of major food items of blue jays, common crows, red-bellied woodpeckers and red-headed woodpeckers collected in 3 pecan orchards in Central Oklahoma during pecan ripening and harvesting periods of 1978 and 1979 43

LIST OF FIGURES

Figure		Page
1.	Location of study area in eastern Lincoln County, Oklahoma	9
2.	Distribution of 4 general plant associations in the study area	11
3.	Arrangement of seed traps under sample tree	19
4.	Temporal occurrence of wildlife damage, fall and early winter 1979-80. Shaded area represents harvesting period	39

INTRODUCTION

The commercial production of pecans (Carya illinoensis) has increased progressively in this country during the past 50 years. Today it is one of the most important native horticultural crops in the United States, with a total annual production over 90 million kilograms (Shafer and Bailey 1978). There are approximately 20 cultivars of major importance grown, plus the native pecan which is usually smaller. Approximately 85 percent of the estimated 1 million pecan trees in Oklahoma are of the small native types (Taylor pers. comm. 1978) and comprise approximately one-half of the commercial production of pecans in the United States (Brison 1974).

Pecans are native to the United States occurring naturally in the river and stream valleys of Texas, Oklahoma, Arkansas, and Louisiana (Toole 1956). Planting of improved cultivars has extended this range throughout many of the southeastern states and as far west as Arizona, where pecans are now a commercially important crop (Brison 1974).

Oklahoma currently ranks fourth among pecan producing states, with 7 million kilograms harvested in 1978 and 11 million kilograms harvested in 1977. Commericial production in Oklahoma averages approximately 7 million kilograms annually. During 1967, a record high of 24 million kilograms of pecans were harvested in Oklahoma (Taylor pers. comm. 1977). According to Hinrichs (pers. comm. 1977), Oklahoma could easily produce 34 to 36 million kilograms of pecans annually if orchard were well

managed. At the current (1979) average wholesale price of 50 cents per pound, the state pecan crop has a potential of 40 million dollars annually.

The inherent erratic production cycle of pecans results in drastic annual fluctuations in yield (Brison 1974). During years of low productivity, pecans are particularly vulnerable to the deletory effects of disease and depredation (Murray 1975). Extensive research has been conducted on the effects and prevention of disease and insect damage to pecan trees and nuts (Barnes 1973, Coppock 1966, Hinrichs and Bieberdorf 1953, Hinrichs and Thomson 1955, Hinrichs et al. 1944). The use of insecticides throughout the growing season appears to control insect damage (Hinrichs pers. comm. 1977). There is however, little information in the literature concerning damage caused by vertebrate species or their control, in spite of the fact that damage to pecans from this source has long been recognized (Aldous 1944, Baumgartner 1939, Foreman 1924). The loss of pecans to wildlife species, particularly birds, is a major problem for many growers. McDowell and Pillsbury (1959) reported that orchards and tree plantations were rated as principal areas of damage by 12 states in returns from questionnaires sent to state wildlife agencies to evaluate crop damage caused by wildlife.

Pecan growers in Oklahoma estimate their annual losses to wildlife to be 0.9 million kilograms. In extreme and local cases, wildlife may destroy the entire crop of an orchard (Hinrichs pers. comm. 1977). In 1976, a record low of 0.5 million kilograms of pecans were harvested in Oklahoma. Pecan damage by wildlife was estimated by many growers to be as high as 30 percent of the total crop (Couch, Taylor pers. comm. 1978). Acorn production was also poor in 1976. During 1977, acorn production

was high and wildlife damage was reported by pecan growers to be the lowest since 1965 (Couch pers. comm. 1978).

Control of wildlife damage is poorly developed and generally unsuccessful. Shooting is the most common method of control, although the use of acetylene exploders and poison baits are also used (Couch pers. comm. 1977). In Oklahoma, control of this damage is carried out by the individual growers.

Several avian species, including commons crows (Corvus brachyrhynchos), blue jays (Cyanocitta cristata), and red-bellied woodpeckers (Centrus carolinus) are known to consume pecans (Aldous 1944, Bannon 1921, Davison 1942, Martin et al. 1951, Murray 1975, Wilson 1974). Raccoons (Procyon lotor), white-tailed deer (Odocoilieus virginianus), eastern fox squirrels (Sciurus niger), and gray squirrels (S. carolinensis) also consume pecans (Barber 1954, Baumgartner 1954, Martin et al. 1951, Murray 1975, Wilson 1974, Yeager and Elder 1945, Yeager and Rennels 1943). The major vertebrate depredators in Oklahoma are common crows, blue jays and eastern fox squirrels (Taylor pers. comm. 1978).

Blue jays are considered by many growers to be the most destructive and most difficult wildlife species to control. Damage begins in September when the pecan nuts begin to ripen and continues throughout the fall and winter months, with heaviest damage apparently during October and November when migrating flocks of blue jays pass through Oklahoma. The majority of the damage caused by blue jays appears to occur in a north-south corridor through the central portion of the state (Couch pers. comm. 1977).

Blue jays prefer the small pecans (Couch pers. comm. 1977). This

size allows the jay to grasp the pecan and break it open to remove the nutmeat. Jays have been observed removing pecans from the trees and caching them, but are rarely seen taking pecans from the ground (Couch, Hinrichs pers. comm. 1977, Murray 1975). Blue jays in Louisiana were reported by Murray (1975) to be responsible for an average annual loss of 0.43 percent of the total crop. Murray (1975), however, sampled only cultivars which produce large pecans which are less desireable to blue jays, and considered the loss of pecans due to caching behavior as negligible. The caching behavior of blue jays is well documented but poorly understood (Arnold 1938, Goodwin 1976, Hardy 1961, Laskey 1942, Rand 1937), and it is possible that a significant percentage of the pecans lost to jays are removed from the orchard.

The common crow is a well known depredator of many cultivated crops and has long been recognized as a serious source of pecan loss (Aldous 1944, Good 1952, Hoffman 1924, Kalmbach 1951, Lemairie 1950). Murray (1975) found crows were a major pecan depredator in Louisiana, causing an average annual loss of 6 percent of the total crop. Losses as high as 50 percent have been attributed to large flocks of crows wintering in the vicinity of pecan orchards in Louisiana (Wilson 1974).

Crows prefer the large, thin-shelled, pecans. These are generally taken from the ground after the nuts have ripened (Couch pers. comm. 1977). Crows have also been observed caching pecans (Murray 1975).

Control of crows has met with reasonable success with the use of acetylene exploders, shooting, Av-alarms, and Avitrol baits. Although this problem is by no means solved, control measures can alleviate this problem to some extent and reduce the loss of pecans to the grower (Wilson 1974).

Fox squirrels are known depredators of a variety of cultivated crops including pecans (Barber 1954, Baumgartner 1939, Martin et al. 1951). Though damage to pecans by squirrels is common, generally it is considered not to be as serious as damage caused by jays or crows. Squirrels begin to consume large numbers of pecans in late August while the pecans are still green and have been observed removing pecans from the orchard (Barber 1954, Couch pers. comm. 1978). Damage by squirrels is controlled by shooting, trapping, and removal of nest trees (Hinrichs pers. comm. 1977). The popularity of squirrels as game animals often protects them, causing their activities in the orchard to be tolerated, and provides a convenient means of control (Murray 1975).

Martin et al. (1951) list a total of 25 species of birds and mammals known to use pecans as a food source. Other avian species occurring in central Oklahoma known to consume pecans are the common flicker (Colaptes auratus), the red-headed woodpecker (Melanerpes erythrocephalus), the wild turkey (Meleagris gallopavo), and the bobwhite (Colinus virginianus) (Cypert and Webster 1948, Martin et al. 1951, Murray, 1975, Sutton 1967). Wood ducks (Aix sponsa) and mallards (Anas platyrhynchos) have also been observed taking pecans when orchards become flooded (Couch pers. comm. 1978).

Several mammalian species are also reported to be incidental pecan consumers. These include the eastern wood rat (Neotoma floridana), field mice (Peromyscus sp.), the eastern cottontail (Sylvilagus floridanus), and the coyote (Canis latrans). Damage from these species is generally considered insignificant or negligible (Martin et al. 1951, Murray 1975). Domestic livestock may also consume pecans which have fallen from the trees. Removal of cattle and hogs from the orchard

prior to ripening of the pecans will eliminate damage from this source (Murray 1975).

It is possible that the extent of wildlife damage to pecans is inversely proportional to the quantity of natural acorn production. Acorns are an important fall and winter food for many species of wildlife (Baker et al. 1945, Jackson 1976, Christisen and Korschgen 1955, Dalke et al. 1942, May et al. 1939, Stollberg 1950). According to Downs (1944), mast of the acorn crop is consumed by wildlife species, except during years of heavy mast production. Many wildlife species causing extensive damage to pecans rely heavily upon oak mast as a food resource. When oak mast production fails, these birds and mammals seek an alternate food source (Good 1959, Harlow et al. 1975). Pecan orchards in Oklahoma generally border on oak forests. The planting and clearing of pure stands of pecan trees provides a concentrated and easily exploitable food source for animals that prefer acorns.

There is little doubt wildlife in Oklahoma is responsible for a significant percentage of the loss of pecans to commercial growers each year. However, the extent of this damage is unknown. Considering the monetary value, economic potential of pecans, and the cost of wildlife control measures, a method was needed to accurately differentiate damage from wildlife, insects, and weather in order to determine the significance of loss due to caching behavior of jays and crows.

The purpose of this study was to develop a method whereby wildlife damage to pecans could be accurately measured and to determine which species were responsible for the majority of damage. This study also served to give insight into the relationship between pecan damage and oak mast production and provide preliminary information for further

research on the control of wildlife pecan depredation.

Specific objectives were to (1) determine the current year production and damage to pecans by wildlife, insects, and other sources, (2) determine the relative abundance of oak mast production in the forest adjacent to the pecan orchard, and (3) determine densities of wildlife species suspected of causing damage in the pecan orchard and the adjacent oak forests.

DESCRIPTION OF STUDY AREA

The study was conducted in eastern Lincoln County, Oklahoma on a privately owned pecan orchard, approximately 8.8 km southwest of Stroud (Fig. 1). The orchard is located in the floodplain of Dry Creek, a tributary of the Deep Fork River.

Climate

The climate of the study area is characterized by pronounced day-to-day changes in weather but only gradual seasonal changes. Spring and autumn months are mild with warm days and cool nights; summers are usually long and hot, and winters comparatively mild and short. The mean annual temperature is 16°C. Average daily maximum temperatures range from 8.8°C in January to 35°C in July, while daily minimum temperatures average -2.2°C in January and 21°C in July. The average annual precipitation is 94 cm. May receives the largest portion of rainfall with 15 percent of the annual precipitation. The annual growing season of the study area averages 210 days (OWRB 1971).

Topography, Soils, and Geology

The soils of the study area are composed of Port-Pulaski and Darnell-Stephenville associations. Soils of the pecan orchard are deep, nearly level Port loamy clay and Rosebuck clay. Both soil types were described as frequently flooded, the Port clays being well drained and the Rosebuck clays being poorly drained. The soil of the area

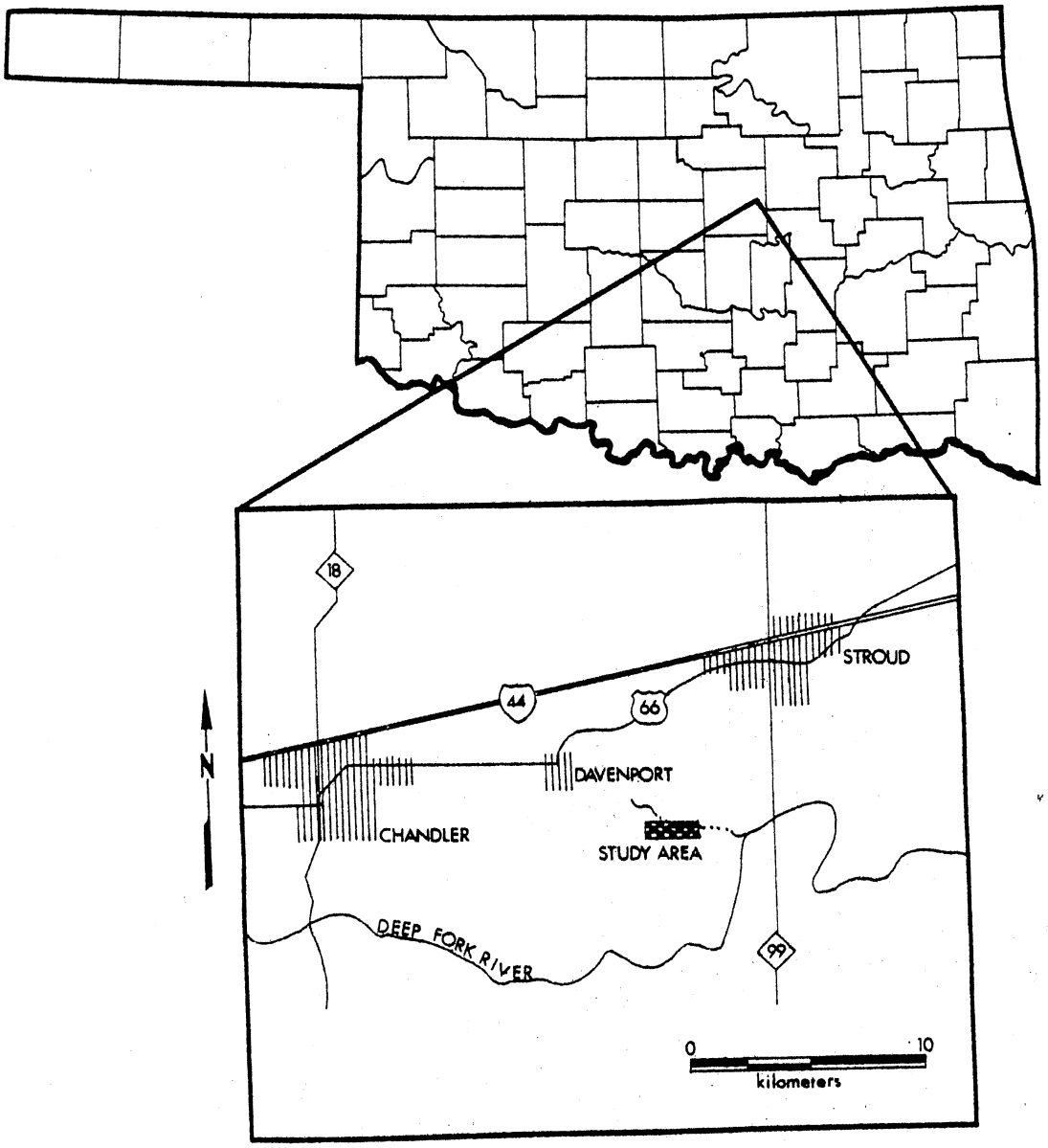

Figure 1. Location of study area in eastern Lincoln County, Oklahoma.

surrounding the pecan orchard is composed primarily of gently to strongly sloping Pulski and Darnell-Stephenville fine sandy loams (SCS 1970).

Vegetation

According to Bailey (1976) the study area is included in the Oak + Bluestem Parkland ecoregion and lies in the Postoak - Blackjack Forest vegetation type of Duck and Fletcher (1943).

The natural climax vegetation of the study area is bottomland hardwood forest. Dominant woody vegetation along Dry Creek is composed of hackberry (Celtis sp.), sycamore (Platanus occidentalis), hickories (Carya sp.), oaks (Quercus sp.) and buckbush (Symphoricarpus orbiculatus). Herbaceous vegetation is dominated by broad-leaf Uniola (Uniola lateralis), poison ivy (Rhus radicans) and greenbriar (Smilax sp.). Clearing of vegetation for crop and pasture land has created a mosaic of 4 general plant associations: pecan orchard, bottomland hardwood forest, tamegrass pasture, and upland forest (Fig. 2). The remaining bottomland hardwood forest, approximately 39 ha, is restricted to areas directly adjacent to Dry Creek.

The area of native and planted pecans totaled 69 ha, scattered throughout 194 ha. Approximately 90 percent of the pecan trees in the orchard were native trees. The herbaceous ground cover is dominated by bermudagrass (Cynodon dactylon), ironweed (Veronia baldwinii), and smartweed (Polygonum sp.). This vegetation is mowed several times throughout late summer and early autumn and cattle grazed in the orchard throughout the year.

Upland forest, dominated by post oak (Quercus marilandica),

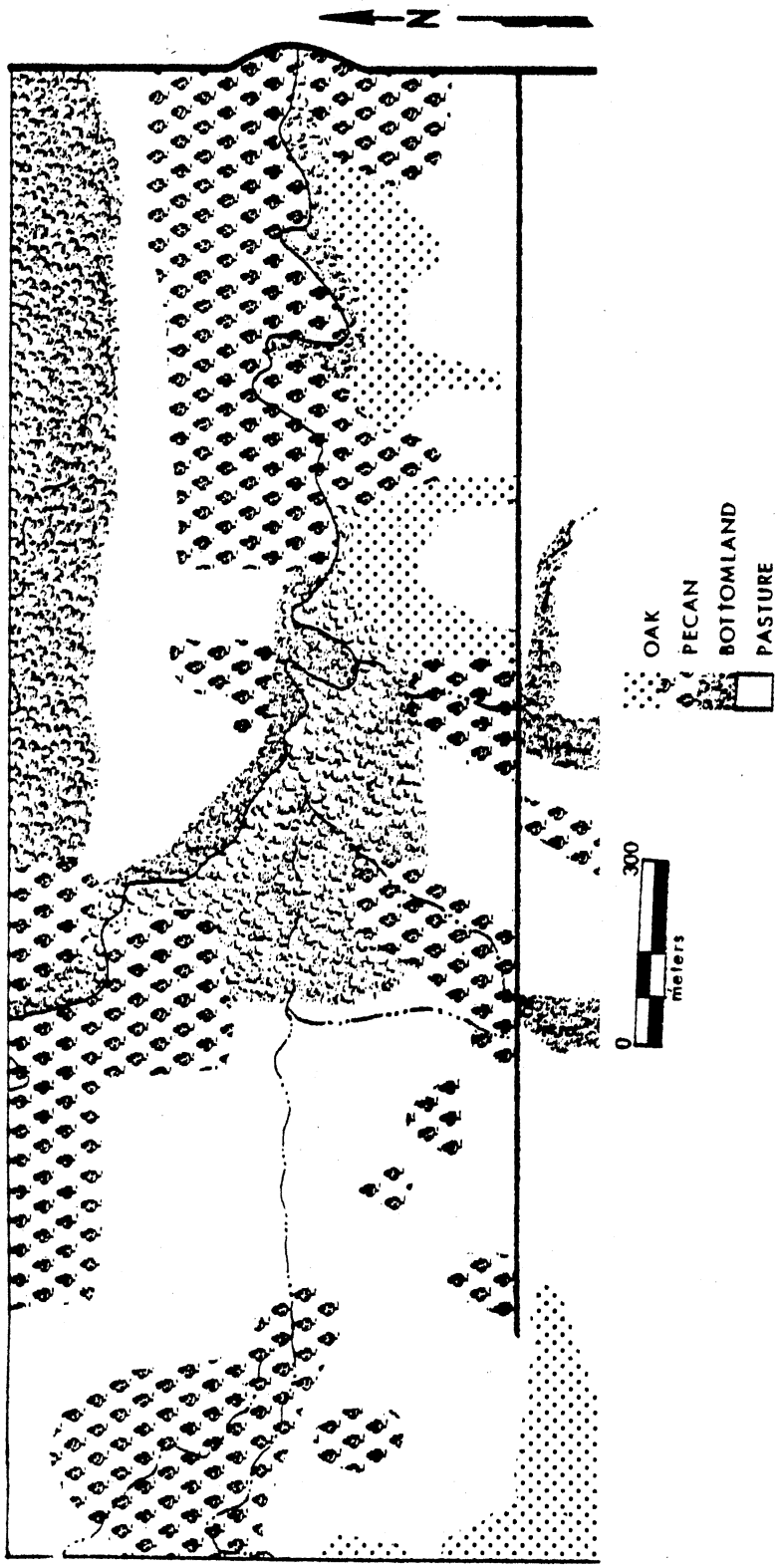

Figure 2. Distribution of 4 general plant associations in the study area.

blackjack oak (Quercus stellata), and eastern red cedar (Juniperus virginianus), covered approximately 20 ha of the study area. The remaining area, approximately 75 ha, was bermudagrass pasture.

METHODS AND MATERIALS

Study Site Selection

Five privately owned pecan orchards were considered as potential study areas. Each orchard was evaluated by ground reconnaissance, review of aerial photographs, and landowner interviews. The pecan orchards were evaluated on the following criteria: (1) owner management strategy, (2) geographical location, (3) composition of pecan types, and (4) proximity of oak forest.

The pecan orchard near Stroud, Lincoln County, Oklahoma, was selected as the study site because: (1) it is managed for maximum production, (2) it is located within an area of the state reported to incur heavy losses of pecans to wildlife, particularly blue jays, (3) it is composed of approximately 90 percent native pecan trees, and (4) it is bordered by oak forest within at least 0.8 km.

Wildlife Species Census

Bird species and squirrel densities in the pecan orchard and the adjacent oak forest were estimated using a circular plot method similar to those described by Buffard and Hein (1978), Fowler and McGinnes (1974), and Goodrum (1940). Twelve circular plots were located within homogeneous vegetation types, 7 within the pecan orchard and 5 within oak forest. Each plot was 75 m in radius and marked at 25 m intervals in the 4 cardinal directions with orange wooden stakes to allow

observers to make accurate distance judgements. Observations were made from the center of the plot. Location and number of all bird species and squirrels observed within the plot during 15-minute count-periods were recorded on grid maps. Weather conditions and time were recorded at the start and finish of each count.

According to Emlen (1971) the major source of error in bird census work is observational bias, influenced by such variables as observer experience, weather, and time of day. Bias caused by weather and the daily activity patterns of birds were minimized by conducting counts only during the first 4 hours of daylight, when no precipitation was occurring, and when the wind speed was less than 40 km per hour. The effect of human disturbance was minimized by preceding each count with a 15-minute waiting period at the observation point.

Two technicians in addition to the author were employed to assist with collection of census data. The technicians were selected on the basis of their bird identification skills. Test counts were conducted to synchronize and improve the identification ability of the technicians and observational biases were minimized by having each site sampled several time by each observer.

Census counts were conducted at each site at least once every week during the fall and early winter of 1978 and 1979. In addition, bi-weekly counts were conducted during the summer 1979. Densities of bird species and squirrels were calculated by using the ratio of number of individuals of each species observed to the area of the plot. Mean densities were calculated for consecutive 10-day periods beginning in late August. The null hypothesis, no difference in species density between years and habitat type, were tested using paired t-test at 95

percent significance level (Steel and Torrie 1960).

The relative abundance of mammalian species was determined during the fall of 1979 by monitoring the movement of animals into and out of the orchard. Monitoring of animal movement was accomplished by use of a track-sign count method similar to that described by Brabander (1977) and Giles (1971). Eighteen track-sign plots, each 3X1 m, were established along two sides of an 11 ha section of the pecan orchard at random. Plots were created by clearing vegetation from the ground with a gasoline-powered tiller. Conflicts with management practices of the landowner prevented the placement of the track-sign plots throughout the orchard. Sand from the creek bottom was spread over each plot to aid in detectability of tracks and to reduce bias in detectability due to differences in soil texture. Plots were checked each week, the number of tracks of each species present counted, and raked smooth. The relative abundance of each species was determined by the total number of individuals of each species detected in all track-sign plots.

Oak Mast Production

The method described by Sharp (1958) was used to determine the relative abundance of oak mast production in the area adjacent to the pecan orchard. The outermost 60 cm of 20 lateral and terminal branches of sample oak trees were inspected (during November 1978 and August 1979) and the number of acorns present counted. Branches of the black oak group, excluding the current year growth, bearing 32 or more acorns and branches of the white oak group bearing 24 or more acorns were considered 100 percent yield (Sharp 1958). A categorical rating (Table 1) was used to describe the current year production of oak mast.

Table 1. Categorical ranking of mast producing capacity based on potential yields of acorns produced in a growing season (Sharp 1958).

Rank	Proportion of maximum (%)
Bumper	76 to 100
Good (heavy)	51 to 75
Fair (medium)	26 to 50
Poor (light)	10 to 25
Trace	less than 10
None	no acorns observed

Sample trees were selected at random using the point-centered quarter method described by Cottam and Curtis (1956). Ten transect lines, each 150 m in length with points 10 m apart, were established in areas of oaks. Five transect lines were also established in the bottomland forest. Moody (1953), working on mast production of upland trees in Louisiana, found top producing blackjack oaks and post oaks to be at least 20 cm in diameter at breast height (dbh). These two species were the dominant oaks within the study area. Only trees with a dbh of 20 cm or more were sampled.

Results of the 2 surveys are not directly comparable due to the seasonal difference in the timing of the surveys, but give indications of oak mast production during respective years. Sharp (1958) suggested August as the optimum time to conduct such surveys, prior to the loss of acorns to wildlife and the natural dropping of acorns as they ripen.

Pecan Mast Production

Estimates of pecan production were obtained by sampling pecans which had fallen from randomly selected pecan trees. Sampling was accomplished using 2 methods, open ground plots and nut traps. Similar methods of sampling mast production have been described by Downs and McQuilkin (1944) and Murray (1975).

Sampling of pecans from randomly selected trees was conducted during the pecan ripening and harvesting periods of 1978 and 1979. Sampling was not begun until mid-October 1978 due to delays in securing nut traps, after many pecans had ripened and fallen from the trees. Sampling in 1979 was begun in early August prior to the occurrence of pecan ripening. Sampling was terminated at the completion of harvest.

The harvesting of pecans was begun in early November each year. The 1978 harvest was delayed by rain in late November and ice and snow in January and February 1979. The 1979 harvest was delayed only occasionally by inclement weather and equipment failure. Harvest of pecans and collection of data was completed in mid-March 1979 and early January 1980.

Eight nut traps and 8 open ground plots, each covering an area of 0.096 square meters, were established under each sample tree. Figure 3 demonstrates the arrangement of traps underneath each tree. Open ground plots were located between the nut traps. The arrangement was designed to eliminate any bias due to differential production within the tree. Nut traps consisted of 57 liter metal cans, anchored with metal stakes. An orange-colored nail was used to mark the center-point of each ground plot. The total area sampled underneath each tree was constant at 0.767 square meters. As a result, the percent of the crown area of each tree sampled varied due to differences in size of crown areas. Twenty-three trees were sampled in 1978 and 21 trees were sampled in 1979.

Traps and plots were inspected each week, beginning the second week of October in 1978 and the first week of August in 1979. Pecans found in the traps and plots were removed and counted in 1 of 4 categories: (1) well-developed and apparently sound, (2) wildlife damaged, (3) insect damaged, and (4) source of damage unknown. Estimates of production for each method were made for each sample tree from the total number of pecans sampled.

During the 1979 field season 2 additional parameters were measured to obtain estimates of the number of harvestable pecans from each sample tree. Well developed pecans were marked with a small spot of indelible

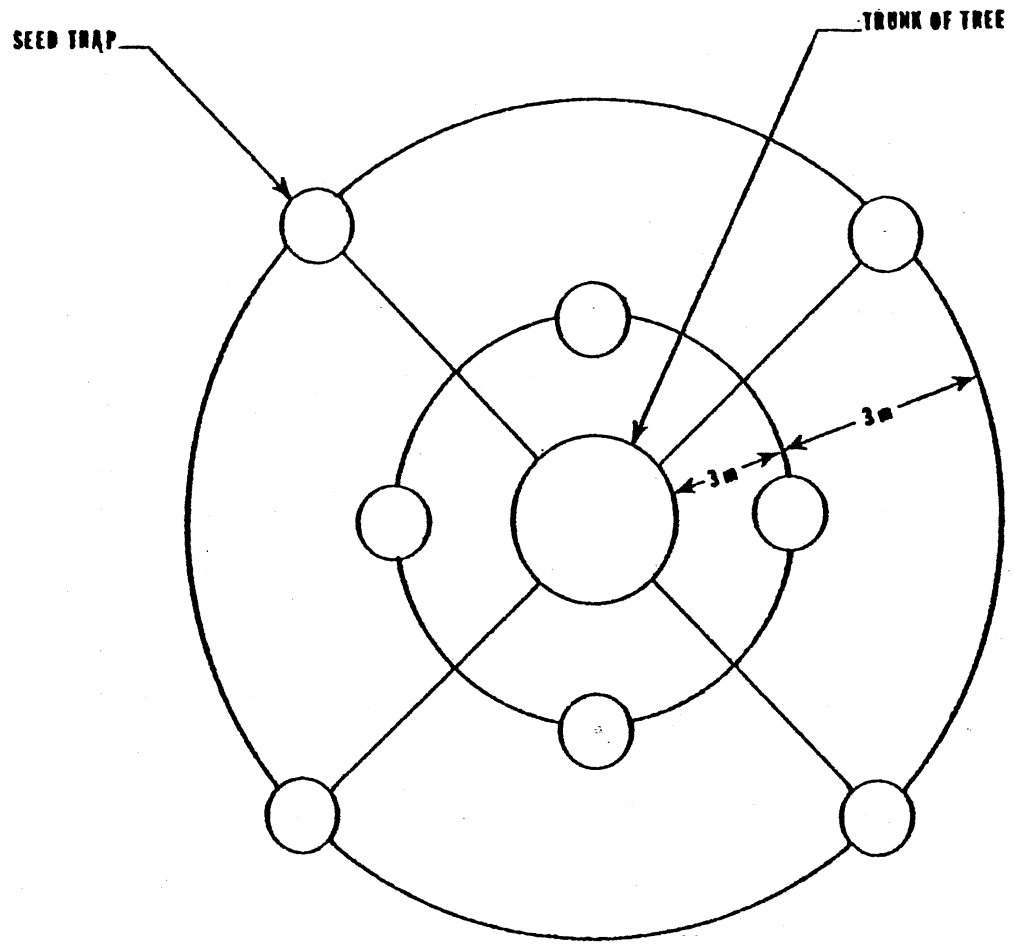

Figure 3. Arrangement of seed traps under sample tree.

ink and left in the traps until the next inspection. The number of marked pecans missing gave an estimate of pecan loss from the plots and traps between inspections. Ground plots were also inspected after harvest of individual sample trees to estimate the number of pecans remaining on the ground. The estimated number of pecans harvested equaled the number of well-developed pecans less the number of marked pecans lost and pecans left after harvest. The mean weight of individual pecans from each sample tree (Appendix A) was determined to estimate the number of kilograms of pecans produced by sample trees. The accuracy of both methods were tested by comparing the actual number of kilograms of pecans harvested from each sample tree with the estimated number of harvestable kilograms of pecans.

Pecan Damage

Estimates of the percent total production of (1) well-developed pecans, (2) wildlife damaged pecans, (3) insect damaged pecans, and (4) pecans damaged by unknown sources were based on the ratio of the number of pecans in each category to the total number of pecans sampled. Ninety-five percent confidence intervals for estimated percentage of total production for each category were calculated using the formula:

$$\frac{y_i}{x_i} \cdot 100 \pm \frac{(1 - f)}{n\bar{x}^2} \cdot \frac{\Sigma(y_i - R \cdot x_i)^2}{n - 1} \cdot 100,$$

where n equals the number of sample trees, y_i equals the number of nuts in each category on the i^{th} tree and R equals the percent of the total of each category (Cochran 1977). The value f represents the percent of the total number of pecan trees in the orchard sampled. This value in

the present study was considered zero due to the small sample size.

Wildlife Damage

Fragments of pecans found in the nut traps and ground plots showing teeth marks or bird bill probings were considered damaged by wildlife. The number of marked pecans missing from the nut traps and ground plots were considered damaged by wildlife. These numbers represented the loss of pecans to wildlife at the sample trees.

During the 1979 field season, 373 15-minute flightline counts were conducted between late September and late December to estimate the loss of pecans due to the caching behavior of jays, crows, and woodpeckers. Three observation points were selected, adjacent to established flightlines, to estimate the number of pecans being removed from the orchard by jays, crows, and woodpeckers. Observation periods were 15 minutes long and conducted throughout the day to determine diurnal activity patterns of the birds. Birds flying out of the orchard were counted and classified into 1 of 3 categories: (1) with pecan, (2) without pecan, and (3) possession of pecan undetermined. The number of birds flying into the orchard was also counted.

Flightline counts were conducted at least once each week beginning in late September and continued through December. Counts were conducted continuously during the first 4 hours of daylight and then during 1 to 2 hour periods through the remainder of the day.

Flightline data were graphed as time of day (x) versus number of trips (y) for each day counts were conducted. The formula, $y = a + bx$, where a equals the y intercept and b the slope of the line, was used to

determine the line that best fit the data (Steel and Torrie 1960). The area of the triangle formed by this line was an estimate of the number of trips made for any given day. The estimated number of trips per day divided by the estimated number of birds using the flightline equaled the average number of trips per bird. This information was expanded for the entire orchard and an estimate of the number of pecans cached per species was obtained. These calculations and estimates were produced for consecutive 10-day periods of 21 September through 20 December.

Estimates of total pecan weight cached by each species were made by estimating the total number of trips made out of the orchard with a pecan by each bird and multiplying by an average of the total number of birds using the orchard during consecutive 10-day periods. Observations of blue jays indicated that as many as 3 pecans could be carried at a time. Although blue jays were observed carrying more than one pecan per trip out of the orchard, only one pecan per trip was used to calculate caching loss.

Insect Damage

Pecans found in nut traps and ground plots with weevil emergence holes, black spots on the shuck, or black shriveled kernel were considered damaged by insects.

Source of Damage Unknown

The source of damage of pecans found in nut traps and ground plots without signs of insect damage and apparently not well-developed was unknown. This included imperfectly developed, deformed, aborted or

with the shuck remaining on the nut.

Stomach Content Analysis

During pecan ripening and harvesting periods of 1978 and 1979, common crows, blue jays, red-bellied woodpeckers, and red-headed woodpeckers were collected in or adjacent to 3 pecan orchards in Central Oklahoma. Stomach contents of birds collected were analyzed to determine the frequency of occurrence of autumn food items, particularly pecan and oak mast. Birds were collected at the study area, the Oklahoma State University Pecan Experiment Station near Sparks, Lincoln County, and a privately owned orchard near Luther, Oklahoma County.

Birds were frozen as soon after collection as possible and returned to Stillwater, where contents of the gizzard, proventriculus, and esophagus were removed. Individual food items were separated with forceps and identified visually with the aid of a dissecting scope.

RESULTS

Wildlife Species Census

Results of the wildlife species censuses conducted in the pecan orchard during the fall and winter of 1978 and 1979 indicated the presence of 44 avain and 10 mammalian species. Estimated densities (individuals per 100 hectares) of avian species encountered are contained in Appendix B. Relative abundance of mammalian species in the orchard is presented in Table 2.

Paired t-tests showed no significant difference ($P > .05$) between mean densities of blue jays in the pecan orchard (Table 3) during the field seasons of 1978 and 1979. Seasonal patterns of blue jay densities were similar during both years. Blue jay densities were low during early September, gradually increasing to peaks of 283 birds per 100 hectares in mid-October of 1978 and 346 birds per 100 hectares in early November of 1979. Densities of blue jays gradually declined thereafter. No blue jays were observed in the pecan orchard or adjacent areas during the summer months of 1979. Mean densities of blue jays in the adjacent oak forest were significantly higher ($P < .05$) than in the pecan orchard during both 1978 and 1979. However, mean densities of blue jays in the oak forest were significantly higher ($P < .05$) in 1978, than in 1979 while there was no significant difference ($P > .05$) in total mean densities of blue jays in the study area between 1978 and 1979.

Red-bellied woodpecker densities (Table 4) in the pecan orchard

Table 2. Relative abundance (number of tracks) of mammalian species utilizing the pecan orchard during the fall of 1979.

Species	Relative abundance
Eastern fox squirrel	48
Coyote/domestic dog	8
Raccoon	7
Unknown	6
Eastern cottontail	5
Nine-banded armadillo	2
White-tailed deer	1
Beaver	1
Striped skunk	1

Table 3. Mean densities (birds per 100 hectares) of blue jays in the pecan orchard and adjacent oak forests during consecutive 10-day periods during pecan ripening and harvesting periods of 1978 and 1979.

Period		1978			1979		
		Oaks	Pecans	Total	Oaks	Pecans	Total
August	1-10				0	0	0
	11-20				0	0	0
	21-31				11	19	30
September	1-10	0	14	14	8	45	53
	11-20	63	34	97	57	28	85
	21-30	153	127	280	113	57	170
October	1-10	358	231	589	396	170	566
	11-20	623	282	905	233	89	322
	21-31	257	150	407	299	255	554
November	1-10	208	127	335	580	347	927
	11-20	62	93	155	102	137	239
	21-30	113	0	113	71	113	184

Table 3. (Continued)

Period	1978			1979		
	Oaks	Pecans	Total	Oaks	Pecans	Total
December 1-10	170	26	196	76	98	174
11-20	178	28	217	32	65	97
21-31	208	42	250	71	32	103
Total mean	200	96	296	143	97	240
Standard deviation	164	90	235	165	98	254

Table 4. Mean densities (birds per 100 hectares) of red-bellied woodpeckers in the pecan orchard and adjacent oak forests during consecutive 10-day periods during pecan ripening and harvesting periods of 1978 and 1979.

Period		1978		1979	
		Oaks	Pecans	Oaks	Pecans
August	1-10			0	94
	11-21			28	71
	21-31			45	38
September	1-10	0	92	81	96
	11-20	13	57	42	75
	21-30	34	103	88	133
October	1-10	47	118	79	75
	11-20	113	113	35	57
	21-31	10	69	57	79
November	1-10	38	170	127	99
	11-20	21	67	79	81
	21-30	0	38	50	96
December	1-10	28	70	63	63
	11-20	19	71	49	57
	21-31	38	57	28	73
Total mean		97	87	57	79
Standard deviation		223	37	31	23

were relatively constant during both 1978 and 1979 and were not significantly different ($P > .05$). Red-headed woodpecker densities (Table 5) were significantly higher ($P < .05$) in the pecan orchard during 1979. Densities increased gradually throughout each field season. No red-headed woodpeckers were observed in the adjacent oak forest.

Numbers of crows in the pecan orchard during the 1979 field season, as estimated from flock size counts, ranged from 4 to 48. Crows were observed in the orchard throughout the field season but large numbers were present only in late December. They were observed in the adjacent oak forest generally in late afternoon and large numbers were present in the vicinity of the study area throughout the field season, utilizing an adjacent pecan orchard. Densities of crows in the pecan orchard during 1978 and 1979 are listed in Appendix B, however, these estimates are considered low due to difficulties in observing crows for accurate census data.

Eastern fox squirrel densities (Table 6) in the pecan orchard were highest in early August 1979 (84 per 100 hectares). Densities decreased sharply in late August and remained relatively constant. During both field seasons, densities of squirrels increased sharply in late December. Squirrel densities in the pecan orchard were significantly higher ($P < .05$) during 1979. While in the adjacent oak forest densities were relatively constant during 1978 and significantly lower ($P < .05$) than in 1979.

Results of track-sign plot census data showed eastern fox squirrels to be the most abundant mammal utilizing the pecan orchard between 22 September and 22 December 1979. Coyotes and raccoon were the second

Table 5. Mean densities (birds per 100 hectares) of red-headed woodpeckers[a] in the pecan orchard during consecutive 10-day periods during pecan ripening and harvesting periods of 1978 and 1979.

Period		1978	1979
August	1-10		0
	11-20		0
	21-31		0
September	1-10	0	0
	11-20	17	38
	21-30	35	90
October	1-10	46	170
	11-20	14	129
	21-31	61	151
November	1-10	57	248
	11-20	70	146
	21-30	38	79
December	1-10	74	179
	11-20	99	97
	21-31	13	97
Total mean		52	90
Standard deviation		34	80

[a]not observed in adjacent oak forests.

Table 6. Mean densities (individuals per 100 hectares) of eastern fox squirrels in the pecan orchard and adjacent oak forests during consecutive 10-day periods during the pecan ripening and harvesting periods of 1978 and 1979.

Period		1978		1979	
		Oaks	Pecans	Oaks	Pecans
August	1-10			0	57
	11-20			28	85
	21-31			0	47
September	1-10	0	14	8	45
	11-20	31	17	14	28
	21-30	57	0	19	23
October	1-10	0	5	0	13
	11-20	0	0	7	24
	21-31	10	8	12	13
November	1-10	0	14	0	7
	11-20	5	10	23	16
	21-30	28	0	14	14
December	1-10	70	44	0	13
	11-20	0	0	0	49
	21-31	0	0	42	8
Total mean		17	9	11	29
Standard deviation		25	13	13	23

most abundant mammals. Coyotes were observed eating pecans on one occasion.

Relative Oak Mast Production

Oak mast production in areas adjacent to the pecan orchard were estimated to be 8.0 percent of the total possible production during 1978 and 5.6 percent of the total possible production during 1979. Based on the categorical rating (Table 1) developed by Sharp (1958), relative oak mast production in the study area was traced during both years. Production during 1978 was presumed to higher than indicated by survey results, since surveys were conducted late in the year after some mast had dropped.

Pecan Mast Production

The number of pecans collected from nut traps was less than the number collected from ground plots during 1978. Nut traps were secured to the ground with 3 metal stakes during 1979 and a sample of 24 traps were covered with hardware cloth to prevent the disturbance or entry of the traps by cattle or wildlife. Paired t-tests of these data showed no significant difference ($P > .05$) between the number of pecans in traps with hardware cloth and traps without hardware cloth. The number of pecans collected from nut traps was also lower than the number collected from ground plots during 1979. Condition of pecans sampled from traps and plots during 1978 and 1979 are presented in Tables 7 and 8 respectively.

During 1978 well-developed pecans were an estimated 67.5 percent of the total pecan production by the ground plot method and 77.5 percent by

Table 7. Condition of pecans collected from seed traps and open ground plots beneath sample trees, fall and winter 1978-79.

Condition	Plots	Traps
Well-developed		
No. of pecans	850	445
Mean per tree	36.9	19.4
Standard deviation	34.8	11.6
Percent of total	67.5 ± 2.73	77.5 ± 2.38
Wildlife damaged		
No. of pecans	382	109
Mean per tree	16.6	4.7
Standard deviation	22.3	5.2
Percent of total	30.3 ± 2.52	19.5 ± 3.01
Insect damaged		
No. of pecans	5	1
Mean per tree	0.2	0.1
Standard deviation	0.4	0.2
Percent of total	0.4 ± 0.01	0.0 ± 0.01
Unknown source of damage		
No. of pecans	23	5
Mean per tree	1.0	0.2
Standard deviation	1.9	0.7
Percent of total	1.8 ± 0.07	0.9 ± 0.08
Total sample		
No. of pecans	1260	560
Mean per tree	54.8	24.4
Standard deviation	56.5	14.4
Percent of total	100.0	100.0

Table 8. Condition of pecans collected from seed traps and open ground plots beneath sample trees, fall and winter 1979.

Condition	Plots	Traps
Well-developed		
No. of pecans	954	688
Mean per tree	46.5	34.7
Standard deviation	40.7	26.7
Percent of total	66.3 ± 7.72	76.4 ± 4.55
Wildlife damaged		
No. of pecans	352	176
Mean per tree	12.9	6.4
Standard deviation	20.8	10.5
Percent of total	19.7 ± 6.46	16.1 ± 4.48
Insect damaged		
No. of pecans	67	25
Mean per tree	3.1	0.3
Standard deviation	4.2	4.5
Percent of total	4.7 ± 4.11	2.9 ± 0.19
Unknown source of damage		
No. of pecans	65	11
Mean per tree	2.9	1.3
Standard deviation	4.2	1.2
Percent of total	4.5 ± 0.23	1.3 ± 0.02
Total sample		
No. of pecans	1438	900
Mean per tree	65.4	41.4
Standard deviation	54.6	34.7
Percent of total	100.0	100.0

the nut trap method. Two additional parameters were measured in 1979 to estimate the number of harvestable pecans on each sample tree. Analysis of marked pecan data showed that 15.8 percent of the marked pecans left in the nut traps were removed by wildlife. Inspection of grounds after harvest showed that 1.5 percent of the total production of pecans remained on the ground after completion of harvest. Estimates of the number of kilograms of pecans harvestable from each sample tree from both the nut trap and ground plot methods during 1979 was not significantly different ($P > .05$) from the actual number of kilograms of pecans harvested (Table 9). Adjusted estimates of the percent of total production of harvestable pecans, sources of pecan damage, and the economic value of each for the 1979 pecan crop is presented in Table 10.

Wildlife Damage

Damage to pecans by wildlife during the 1978 pecan ripening and harvesting period (Table 7) was estimated to be 19.5 percent of the total pecan production by the nut trap method and 30.3 percent of the total pecan production by the ground plot method. The difference between the two methods was believed to be a result of disturbance to the traps by cattle and wildlife. Damage to pecans from all sources (Table 7) during this period was 21.4 percent of the total pecan production by the nut trap method and 33.5 percent of the total pecan production by the ground plot method. Damage to pecans by wildlife during 1979 (Table 8) was estimated to be 16.1 percent of the total pecan production by the nut trap method and 19.7 percent by the ground plot method.

Table 9. Estimates of number of harvestable kilograms of pecans from sample trees by the nut trap and ground plot methods compared to actual number of kilograms of pecans harvested.

Sample tree	Ground plots	Nut traps	Actual harvest
A	44.35	17.25	0.00
B	-	25.76	21.32
C	48.82	43.15	44.45
D	35.84	26.45	36.74
E	19.65	15.96	20.41
F	14.25	11.98	15.88
G	56.71	51.26	58.97
H	24.80	38.70	31.75
I	36.32	36.32	34.02
J	46.59	35.32	41.73
K	15.81	6.15	19.05
L	29.81	24.29	24.49
M	99.30	-	86.18
N	28.75	-	34.93
O	162.50	-	154.22
R	-	74.11	45.36
S	3.58	4.34	5.44
T	12.34	10.42	11.34
U	12.66	4.48	12.70
V	27.54	35.51	27.22
W	5.21	0.00	1.81
X	0.00	0.00	0.00
Y	4.13	2.47	4.54
Z	16.74	15.75	15.88
Mean	32.42	22.84	31.19
Standard deviation	37.02	19.29	33.15

Table 10. Estimates of the percent of damage and harvest of the total pecan production from 69 ha pecan orchard and the economic value of each based on an average price of 29 cents per kilogram of pecans.

	Plots			Traps		
	Kilograms	Percent	Dollars	Kilograms	Percent	Dollars
Actual harvest	28,123.2	63.9 ± 8.07	39,680.00	28,123.2	75.0 ± 4.55	39,680.00
Left after harvest	651.0	1.5 ± 0.13	918.53			
Wildlife damage						
Plot/trap	8,549.8	19.7 ± 6.46	12,063.23	5,521.6	14.7 ± 4.48	7,790.59
Marked loss	2,083.2	4.7 ± 0.34	2,939.26	1,693.2	4.5 ± 0.24	2,389.12
Caching loss	436.3	1.4 ± 0.30	904.58	436.3	1.7 ± 0.8	904.58
Total wildlife loss	11,069.3	25.8 ± 7.10	15,907.07	7,856.0	21.0 ± 5.52	11,084.29
Insect damaged	1,996.4	4.7 ± 4.11	2,816.77	1,030.7	2.8 ± 0.19	1,454.27
Source of damage unknown	1,996.4	4.5 ± 0.23	2,816.77	441.7	1.2 ± 0.02	623.23
Total production	4,404.1	100.0	62,139.14	37,451.6	100.0	52,841.73

The temporal occurrence of wildlife pecan damage during the pecan ripening and harvesting period of 1979 is presented in Figure 4. It is evident from these data that approximately 60 percent of the pecan damage by wildlife occurred prior to the beginning of harvesting activities, during the second week of November. After harvest of the pecan crop had commenced, wildlife damage decreased drastically, presumably due to the presence of the grower in the orchard and the reduced number of available pecans.

Caching Loss

Caching loss by birds between 28 October and 2 December 1978 was important. Caching activity during 1979 was first observed in early October, and increased gradually until early November and thereafter decreased. Blue jays were by far the most numerous and active of the bird species caching, and were responsible for approximately 95.8 percent of the estimated caching loss. Red-headed woodpeckers, red-bellied woodpeckers, common flickers, and common crows were also observed carrying pecans out of the orchard. The number of crows and flickers observed caching pecans were not considered important and were not included in the analysis. Table 11 presents estimates of the number of kilograms of pecans cached by each species during the 1979 pecan ripening and harvesting period.

Insect Damage

Estimates of the percent of the total pecan production damaged by insects during 1978 from ground plots and nut traps were 0.4 ± 0.01 and 0.0 ± 0.01 respectively (Table 7). Damage by insects during 1979 was

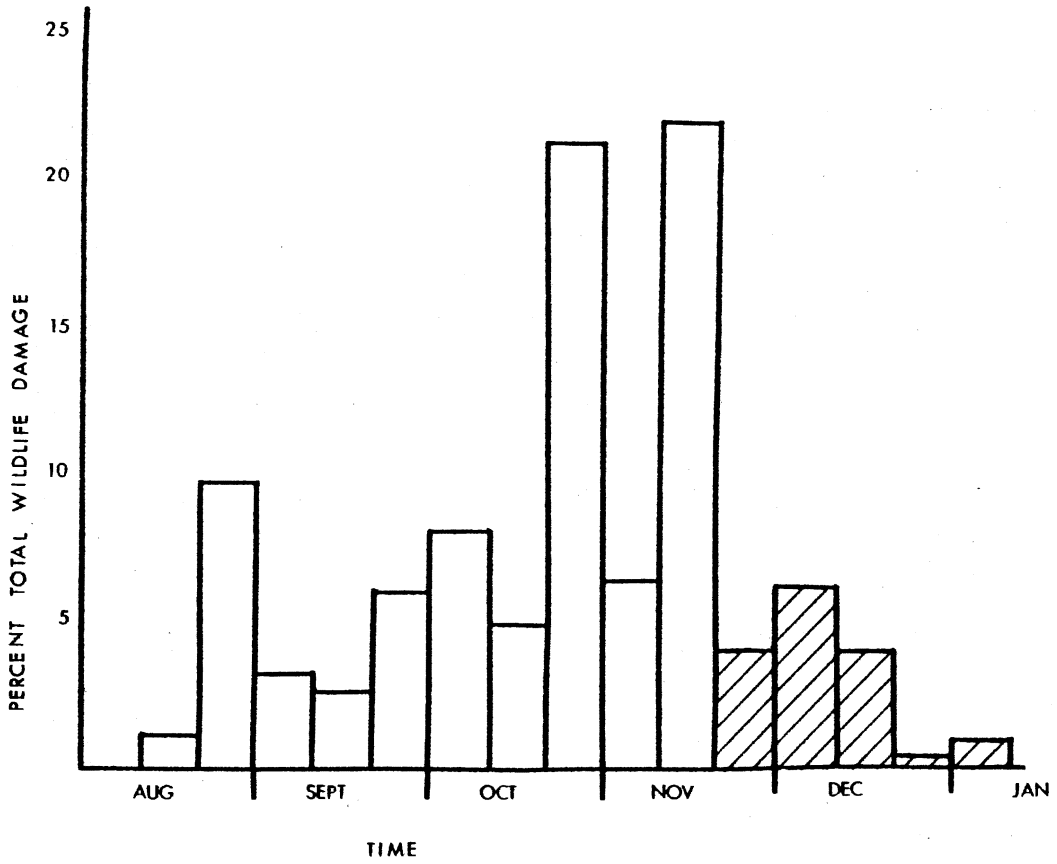

Figure 4. Temporal occurrence of wildlife damage, fall and early winter 1979-80. Shaded area represents harvesting period.

Table 11. Estimated number of kilograms of pecans cached from 69 ha pecan orchard by blue jays, red-bellied woodpeckers, and red-headed woodpeckers, fall and early winter, 1979.

	Blue jay	R-b. woodpecker	R-h. woodpecker	Total
September				
21-30	0.0	0.0	0.0	0.0
October				
1-10	25.2	0.0	0.0	25.2
11-20	67.5	2.8	0.0	70.4
21-31	102.3	8.7	0.6	111.6
November				
1-10	131.4	4.6	2.0	138.0
11-20	62.5	2.9	0.6	204.0
21-30	14.1	2.2	0.1	16.4
December				
1-10	3.9	0.9	0.5	5.3
11-20	2.6	1.0	0.0	3.6
Total	409.5	23.1	3.8	436.4

was estimated to be 4.7 ± 4.11 and 2.9 ± 0.19 percent of the total pecan production from ground plots and nut traps respectively (Table 8). Results of cutting tests showed that less than 0.5 percent of the pecans sampled were either insect damaged or not well-developed.

Source of Damage Unknown

Estimates of the percent of the total pecan production damaged by unknown sources during 1978 from ground plots and nut traps were 1.8 ± 0.07 and 0.9 ± 0.08 respectively (Table 7). Damage from unknown sources during 1979 was estimated to be 4.5 ± 0.23 and 1.3 ± 0.02 percent of the total pecan production from ground plots and nut traps respectively (Table 8).

Stomach Content Analysis

One hundred and seventy two blue jays were collected in and adjacent to pecan orchards in central Oklahoma during pecan ripening and harvesting periods of 1978 and 1979. Analysis of the stomach contents revealed that pecans were present in 14.28 percent of the stomachs of jays collected in 1978 and 32.43 percent collected in 1979. Frequency of occurrence of acorns in the stomachs of blue jays collected in 1978 and 1979 were 24.28 percent and 10.81 percent respectively. In all, pecans and acorns occurred in 39 percent and 43 percent of the stomachs analyzed in 1978 and 1979 respectively. Plant material other than pecans and acorns was present in 33.75 percent of all stomachs analyzed. Insects of the order Coleoptera (beetles and weevils) were the most frequent food items, occurring in 52.9 percent of all stomachs analyzed. Major food items encountered and the frequency of occurrence

of each are listed in Table 12.

Analysis of the stomach contents of 18 common crows collected during the 1978 and 1979 pecan ripening and harvesting periods showed similar composition of food items as blue jays. Pecans were present in 30 percent of the stomachs analyzed in 1978 and 12.5 percent in 1979. Acorns were present in 10 percent of the stomachs analyzed in 1978 but were not present in the stomachs of crows collected in 1979. Plant material other than pecans and acorns were present in 30 percent and 75 percent of the stomachs analyzed in 1978 and 1979 respectively. Orthoptera (grasshoppers and crickets) were the most frequent food type encountered, occurring in 61.11 percent of all stomachs analyzed. Major food items encountered and the frequency of each are listed in Table 12.

Twenty red-headed woodpeckers and 11 red-bellied woodpeckers were collected during the pecan ripening and harvesting period of 1979 in 3 pecan orhcards in central Oklahoma. Analysis of the stomach contents revealed food habits of the 2 species to be similar. Pecans were present in 63.63 percent of the red-bellied stomachs and 60 percent of the red-headed woodpecker stomachs. Acorns were not found in the stomachs of red-bellied woodpeckers and occurred in only 5 percent of the red-headed woodpecker stomachs analyzed. Coleoptera were the most frequent food item encountered in stomachs of red-headed woodpeckers (85 percent), while pecans were most frequently encountered in the stomachs of red-bellied woodpeckers. Major food items encountered and the frequency of each is presented in Table 12.

Table 12. Percent frequency of occurrence of major food items of blue jays, common crows, red-bellied woodpeckers and red-headed woodpeckers collected in 3 pecan orchards in central Oklahoma during pecan ripening and harvesting periods of 1978 and 1979.

Species	Number of birds	All plant matter	Pecan	Acorn	Vertebrate matter	Total insect matter	Coleoptera	Orthoptera
Blue jays								
1978	98	71.42	14.28	24.28	8.16	85.71	43.87	26.53
1979	74	63.51	32.43	10.81	9.45	89.18	64.86	16.21
Total	172	68.02	22.09	18.60	8.72	87.20	52.90	22.09
Common crows								
1978	10	60.00	30.00	10.00	0	90.00	20.00	70.00
1979	8	75.00	12.50	0	0	87.50	25.00	50.00
Total	18	66.66	22.22	5.55	0	88.88	22.22	61.11
Red-bellied woodpecker								
1979	11	72.73	63.64	0	0	54.55	36.36	0
Red-headed woodpecker								
1979	20	70.00	60.00	5.00	0	90.00	85.00	5.00

DISCUSSION

Damage by wildlife to native pecans using 2 methods of estimation averaged 26.98 percent and 22.58 percent of the total pecan production on the study area during 1978 and 1979 respectively. Murray (1975) in north-central Louisiana during 1973, found wildlife, primarily the common crow, to be responsible for 6.26 percent loss of the total production of large fruited pecans. The present study was concerned with only native varieties of pecans and is therefore not directly comparable to results of Murray's (1975) study.

The results of this study represent production and damage to native pecans in central Oklahoma and are not intended to be representative of pecan damage throughout Oklahoma. The amount of damage caused by wildlife will vary between orchards and from year to year. Numerous factors, such as, size and location of the orchard, height, density and type of pecan trees, timing of ripening and harvest of pecans, and densities and timing of major migratory movements of pecan depredators may affect the extent of wildlife damage to pecans.

Species Causing Damage

Based on observations during the 1978 and 1979 pecan ripening and harvesting periods and review of pertinent literature, 16 species of birds and mammals occurring in the study area were suspected of causing damage to pecans. Eight species, blue jays, common crows, common

flickers, red-bellied woodpeckers, red-headed woodpeckers, and eastern fox squirrels were considered to be the only species causing significant damage to pecans in the study area. Due to the variety of species and numbers suspected of causing damage to pecans it was not possible to accurately determine the species responsible for damage by inspecting damaged pecans as Murray (1975) had done. Other factors such as, density in the pecan orchard, seasonal occurrence, observations of consumption, and analysis of stomach contents were used to estimate the importance of each species depredating pecans.

Blue Jays

The blue jay appeared to be the most serious depredator of pecans on the study area during both 1978 and 1979. Blue jays were not present in the orchard or the surrounding area prior to late August, although it is a common nesting species and permanent resident in central Oklahoma (Sutton 1967). Blue jays were first observed in the orchard in late August and were observed consuming pecans throughout the pecan ripening and harvesting periods. Peak densities of blue jays occurred prior to the beginning of harvest of the pecan crop and were generally the most numerous of vertebrates consuming pecans. Blue jays were the most active of the avian species caching pecans during both 1978 and 1979 and were responsible for an estimated caching loss of 409.5 kilograms of pecans during the fall and winter of 1979 (Table 11).

Common Crows

Common crows were present in the study area throughout the year and were most numerous in the pecan orchard during December and January.

Crows were observed consuming pecans throughout the pecan ripening and harvesting period and were observed taking pecans from both the trees and the ground. Caching behavior was not considered significant during the 1979 field season and was not as great as blue jay activity during 1978. Damage to pecans by crows during the fall and winter of 1978-79 was considered heavy but during the fall and early winter of 1979 was described as light. Numbers of crows in the vicinity of the pecan orchard were similar during both periods but in 1979 crows did not utilize the orchard to the same extent as in 1978. Crows were observed consuming pecans in an orchard directly adjacent to the study area where the pecan trees were composed primarily of large fruited cultivars of pecans. Crow control measures were not used in the adjacent pecan orchard during 1979, whereas during 1978 crow control measures in the adjacent orchard moved crows into the study area. Alternate food sources in the vicinity of the study area may have also alleviated the amount of damage caused by crows. The frequency of occurrence of pecans in the stomachs of crows collected during 1979 was only 12.5 percent compared to 30 percent during 1978. The frequency of occurrence of total plant material in crow stomachs increased from 60 percent in 1978 to 75 percent in 1979 indicating utilization of a food source other than pecans (Table 12).

Woodpeckers

Damage to pecans by red-bellied woodpeckers and red-headed woodpeckers during pecan ripening and harvesting periods of 1978 and 1979 was considered moderate. Densities of both species in the pecan orchard were moderate (Tables 4 and 5) and both species were observed

consuming and caching pecans throughout the fall and winter. The frequency of occurrence of pecans in the stomachs of woodpeckers collected in 1979 was high (Table 12). Caching loss due to woodpeckers was not as great as that caused by blue jays but may be greater than indicated by the data. Kilham (1958a) in Maryland, and Moskivits (1978) in Florida, found woodpeckers harvesting acorns up to only 100 m from their defended storage areas MacRoberts (1975) found red-headed woodpeckers in Louisiana gathered mast only from within their territories. These studies indicated that much of the woodpecker caching activity in the study area was conducted within the pecan orchard and therefore not recorded by flightline counts.

Actual loss of pecans to red-headed and red-bellied woodpeckers also may be lower than these data indicate due to behavioral characteristics of the 2 species during the fall and winter. During the early fall woodpeckers established winter territories in areas supporting abundant mast (Kilham 1958b, Reller 1972). Much of their activity at this time is devoted to inter- and intraspecific defense of their territories (Kilham 1958b, MacRoberts 1975, Reller 1972, Willson 1970). After winter territories are established, mast and other food items are cached within the territory. Moskovits (1978) found caching activities greatest during October and November, continuing to December only sporadically. Studies by Kilham (1958a, 1963), Moskovits (1978), and Pinowski (1977) found that, following this period of mast harvesting, woodpecker activities shifted to consumption and restoring of cached stores of food.

Squirrels

Although densities of eastern fox squirrels in the pecan orchard were low in comparison to bird densities, damage to pecans by fox squirrels during both 1978 and 1979 were considered heavy. Fox squirrel densities were highest in the pecan orchard during August and were present in the pecan orchard and observed consuming pecans throughout the year. Barber (1954) found that mast of Carya species composed almost the entire diet of fox squirrels during August in Kentucky and was apparently the preferred food item. Squirrels subsisted largely on these nuts until the supply was exhausted (Barber 1954). Cultivated pecan orchards provide excellent fox squirrel habitat with an abundant food supply (Chesemore 1975). Barber (1954) believed food supply was the chief limiting factor for fox squirrels Chesemore (1975) found a positive correlation between pecan production in Oklahoma the preceding year and the current year squirrel harvest. Fox squirrels are also known to cache food items (Baker 1944, Cahalane 1942, Smith and Follmer 1972) and were observed in the study area removing clusters of as many as 5 pecans at a time.

Damage to pecans by gray squirrels was considered negligible. Gray squirrels were seldom seen in the pecan orchard, but were common in the adjacent bottomland forest. Chesemore (1975) found that gray squirrels only utilized densely vegetated borders of pecans orchards and that competition with fox squirrels prevented gray squirrels from utilizing open pecan orchards.

Other Species

Damage to pecans by other species in the study area was considered negligible or insignificant. However, reports of damage by various species of wildlife from pecan growers in Oklahoma warrent discussion of those species.

White-tailed deer were observed in the pecan orchard during both 1978 and 1979 but were not observed consuming pecans. Results of the track-sign plot censuses indicate very low densities of deer in the pecan orchard. Food habit studies of deer in areas where native pecans occur indicate that mast of the genus Carya is not a significant food item of deer (Lay 1965, Segelquist and Green 1968, Segelquist and Pennington 1968). Stegeman (1937) found mast of Carya species to have low palatability and forage value for deer.

Coyotes were observed in the pecan orchard and on one occasion a coyote was observed eating pecans. Track-sign plot data indicate that coyote densities in the pecan orchard were low and food habit studies conducted within the range of native pecans do not include pecans as a food item of coyotes (Ellis 1958, Gipson 1974, Michaelson and Goertz 1977, Tiemeier 1955). Vegetation is not preferred by coyotes (Tiemeier 1955, Gipson 1974) and the abundance of crow and jay carcasses shot by growers and left lying in the orchards would supply an attractive and an easily obtainable food source for coyotes.

Reports by pecan growers in central Oklahoma indicated that significant losses of pecans to raccoons do occur. Raccoons were not observed in the pecan orchard but track-sign plot census data indicated that raccoons did utilize the orchard. Raccoon food habit studies by

Baker et al. (1954), Hamilton (1936), and Kinard (1965) did not list pecans as a food item of raccoons. Raccoons appear to prefer oak mast. It is possible that raccoons were responsible for significant losses of pecans in the study area but there were insufficient data to determine the extent of damage from this source.

Densities in the pecan orchard of other species known to consume pecans were so low as to cause damage from these species to be insignificant in terms of damage to pecan production. These species included pileated woodpeckers (Drycopus pileatus), common flickers, eastern cottontail rabbits, and wild turkeys. The extent of losses of pecans caused by rodents of the genera Neotoma and Peromyscus is unknown.

Insect Damage

Estimates of damage to pecans by insects in this study are actually low. These estimates represent only the damage recognizable between August and the completion of harvest. Much of the damage caused by pecan weevils, pecan nut casebearers and shuckworms occurs prior to the sampling periods used in this study (Smith pers. comm. 1980). Hall (1980), found that weevil damage to pecans may be as high as 28.9 percent of the total pecan production.

Damage from Unknown Sources

Estimates of damage to pecans from unknown sources in this study are also low. Much of the damage to pecans due to drought, nutrition, and disease occurs during the flowering and early fruiting period of pecan nut maturation (Smith pers. comm. 1980), prior to the sampling

periods of this study. Hall (1980) found that approximately 20 percent of the total pecan nut loss was from unknown causes.

Oak Mast Production

The factors effecting damage to pecans by wildlife will vary from year to year and orchard to orchard. The most important factor influencing damage to pecans appears to be the availability of more prefered food. Oak mast in particular is the prefered food of many species that are suspected of causing damage to pecans (Baker et al. 1945, Barber 1954, Jackson 1976, Segelquist and Green 1968). However, the extent of use of other food by a species is dependent upon its availability (Baker et al. 1945, Goodrum 1959). Murphy and Green (1973) found pecans to be a significant fall and winter food of white-tailed deer in Louisiana, being present in 56.2 percent of stomachs analyzed. Pecans were, however, the primary mast producers in the area of the study.

Although differences during 1978 and 1979 between relative oak mast production and damage to pecans by wildlife were not significant enough to establish a definite correlation between pecan damage and acorn production, the frequency of occurrence of pecans and acorns in the stomachs of blue jays collected during 1978 and 1979 gave an indication that an inverse relationship does exist. Frequency of occurrence of acorns in blue jay stomachs decreased from 24.28 percent in 1978 to 10.81 percent in 1979 when oak mast production decreased. The frequency of occurrence of pecans in blue jay stomachs increased from 14.28 percent in 1978 to 32.43 percent in 1979.

Differences in mean densities of blue jays in the study area also

support the suspected relationship between oak mast production and damage to pecans by wildlife. Mean densities of jays in the pecan orchard were significantly higher ($P < .05$) in 1979 when acorn production was low, while the total mean densities of jays in the study area were not significantly different ($P > .05$) between 1978 and 1979.

Management Recommendation

Intensive use of control techniques commonly used by growers in Oklahoma prior to and during periods of peak wildlife depredations may prove the most effective method of control presently available, especially for control of crows. Simultaneous use of acetylene exploders, Avitrol baits, and shooting depredating species was found by Couch (pers. comm. 1979) to be extremely effective in controlling crows.

Wilson (1974) found these 3 techniques to be the most useful in alleviating crow damage in Louisiana. Shooting of birds to reduce numbers is impractical due to cost, time required, and the constant influx of non-resident birds. Shooting to reinforce the effectiveness of gas exploders and occasional movement of exploders is necessary to prevent habituation by birds. The use of Avitrol baits were found by Wilson (1974) to be highly effective, but application should be stringently controlled to avoid affecting non-target species.

Selective harvesting of early ripening pecan trees may be an indirect method to reduce wildlife damage. During the present study, the crop of many early ripening trees suffered severe damage by wildlife prior to harvesting, due to the length of time nuts were avialable for consumption. Beginning harvest operations prior to the time most pecans can be shaken from the tree may also reduce damage by the presence of

the grower in the orchard, frightening animals, especially crows and squirrels, from areas of desired nuts.

Although the relationship between pecan damage and oak mast production is unclear, it is possible that increasing the production of acorns in areas adjacent to the pecan orchard may help reduce damage by wildlife. Flyger and Thoering (1962) found that damage to cultivated crops by deer in Maryland was reduced to some extent by planting crops more desireable to deer around the border of orchards and crop fields. Additional research of the relationship between pecan damage and acorn production and possible implications as a control method is recommended.

Encouragement of hunting and trapping of game and furbearing animals causing damage to pecans can be used, at no expense to the grower, to reduce the numbers of squirrels, deer, and raccoons in the vicinity of the orchard.

SUMMARY AND CONCLUSIONS

An assessment of damage to pecans by wildlife during the pecan ripening and harvesting periods of 1978 and 1979 was made at a privately owned pecan orchard in central Oklahoma. The purpose of the study was to develop a method whereby wildlife damage to pecans could be accurately measured and to determine which species were responsible for the majority of the damage. The relationship between wildlife pecan damage and natural oak mast production in adjacent areas was also investigated. The specific objectives of the study were to (1) estimate the current year production and damage to pecans by wildlife, insects, and other sources, (2) estimate densities of species in the pecan orchard suspected of causing damage, and (3) determine the relative abundance of oak mast production in forest adjacent to the pecan orchard.

Sixteen species of birds and mammals occurring in the study area were suspected of causing damage to pecans. The blue jay, common crow, eastern fox squirrel, and red-bellied and red-headed woodpeckers were the only species believed to cause serious loss of pecans on the study area. The factors used to determine the importance of each species depredating pecans were density in the pecan orchard, seasonal occurrence, observations of pecan consumption, and analysis of stomach contents.

Blue jays appeared to be the most serious source of pecan damage on the study area during both 1978 and 1979. Damage to pecans by common crows on the study area during 1978 was considered heavy, but during 1979 crow damage was considered light due to decreased utilization of the

orchard.

Damage to pecans by eastern fox squirrels in the pecan orchard during 1978 and 1979 was considered heavy. Densities of fox squirrel in the pecan orchard were highest during August and early September and the loss of pecans to squirrels is believed to have been greatest during this time while pecans had not yet ripened.

Damage to pecans by red-bellied and red-headed woodpeckers during 1978 and 1979 was believed to be moderate. However, behavioral characteristics may cause the loss of pecans to these species to be less.

The extent of damage to pecans by raccoons and rodents of the genera Neotoma and Peromyscus is unknown. The loss of pecans to other species of wildlife in the pecan orchard was considered insignificant or negligible.

Although there was insufficient data to establish a definite relationship between pecan damage by wildlife and the relative abundance of natural oak mast production, analysis of stomach contents of blue jays indicate that an inverse relationship between these two factors does exist.

Estimates of the percent of total pecan production lost to wildlife were 30.3 percent by the plot method and 19.5 percent by the trap method during 1978. Estimates of the percent of total pecan production lost to wildlife during 1979 were 25.8 percent and 21.0 percent by the plot and trap methods respectively. The majority of this loss appeared to occur directly from the tree prior to the dropping of pecans. The loss of pecans from the ground appeared to be a minor portion of the total wildlife loss. The loss of pecans due to the caching behavior of jays,

crows, and woodpeckers during 1979, was considered insignificant in terms of total pecan production.

Comparisons of the estimated number of kilograms of harvestable pecans with actual number of harvested kilograms of pecans from sample trees indicated that both methods of estimation of pecan production and damage are accurate. Estimates of production and damage from the open ground plot method tended to be higher while data from the nut trap method were generally lower. The open ground plot method is believed to be better suited for measuring the effectiveness of control techniques. The reduced amount and cost of materials for the ground plots allow for a larger sample size. This method is more convenient to use and does not interfere with orchard maintanence practices or harvest of the pecan crop.

Management recommendations for control of wildlife depredations in pecan orchards include the simultaneous use of techniques now available. Intensive use of acetlyene exploders, poison baits and shooting of depredating birds prior to and during peak periods of depredation is recommended. Shooting to reduce the number of depredating birds is impractical, but should be used occasionally to reinforce the effectiveness of acetylene exploders. Poison baits should be used only with great care to avoid affecting non-target species. Selective harvesting of early ripening pecan trees and encouragement of hunting and trapping in the vicinity of the orchard may also prove effective in reducing the loss of pecans to wildlife.

Numerous factors, such as size and location of the orchard, height, density, and type of pecan trees, and timing of ripening and harvest of pecans, and densities and timing of major migratory movements of pecan

depredators may affect the extent of damage to pecans by wildlife from year to year. The most important factor influencing pecan damage by wildlife appears to be the availability of more preferred foods, especially oak mast, in the vicinity of the orchard. Additional research of these factors and their implications for control of wildlife damage to pecans is highly recommended.

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APPENDIXES

APPENDIX A

MEAN WEIGHT (GRAMS) OF 25 INDIVIDUAL PECANS FROM 23 SAMPLE TREES, 1979

Sample tree	Mean weight	Standard deviation	Variance
A	3.24	0.40	0.16
B	3.49	0.27	0.07
C	2.98	0.23	0.05
D	2.98	0.23	0.05
E	2.81	0.18	0.03
F	2.88	0.29	0.08
G	3.98	0.34	0.11
H	3.04	0.27	0.07
I	3.34	0.22	0.05
J	3.63	0.30	0.09
K	4.24	0.37	0.14
L	2.97	0.25	0.06
M	3.03	0.22	0.05
N	2.87	0.15	0.02
O	2.69	0.30	0.09
R	1.44	0.14	0.02
S	2.27	0.30	0.09
T	3.22	0.20	0.04
U	4.68	0.36	0.13
V	2.82	0.29	0.08
W	3.88	0.31	0.10
Y	4.68	0.36	0.13
Z	3.33	0.22	0.05
Total	3.24	0.71	0.51

APPENDIX B

DENSITY (NUMBERS PER HECTARE) OF AVIAN SPECIES SEEN IN THE PECAN ORCHARD DURING TIME-AREA COUNTS, FALL AND WINTER 1978-79, AND FALL AND WINTER 1979

Species	September'78	October'78	November'78	December'78
Red-tailed hawk (Buteo jamaicensis)	0.02	0.02	-	-
Marsh hawk (circus cyaneus)	-	-	0.03	-
Mourning dove (Zenaidura macroura)	0.04	0.02	0.03	-
Common flicker (Colaptes auratus)	0.05	0.29	0.41	0.23
Pileated woodpecker (Dryocopus pileatus)	0.04	-	0.03	-
Red-bellied woodpecker (Centrus carolinus)	0.90	0.94	0.80	0.67
Red-headed woodpecker (Melanerpes erythocephalus)	0.22	0.49	0.64	0.86
Yellow-bellied sapsucker (Sphyraplicus varius)	-	-	0.08	0.05
Hairy woodpecker (Dendrocopos villosus)	0.02	-	0.05	0.05
Downy woodpecker (Dendrocopos pubescens)	0.05	0.12	0.05	-
Scissor-tailed flycatcher (Muscivora forfic)	0.02	-	-	-
Great crested flycatcher (Myiarchus crinitus)	0.05	-	-	-
Acadian flycatcher (Empidonax virescens)	0.02	-	-	-
Eastern wood pewee (Contopus virens)	0.07	-	-	-
Blue jay (Cyanocitta cristata)	0.73	1.99	0.87	0.29

Species	September'78	October'78	November'78	December'78
Common crow (Corvus brachyrhynchos)	0.27	0.76	0.75	-
Carolina chickadee (Parus carolinensis)	0.58	0.80	1.41	0.18
Tufted titmouse (Parus bicolor)	0.04	0.04	0.08	-
White-breasted nuthatch (Sitta carolinensis)	0.19	0.21	0.13	0.05
Brown creeper (Certhia familiaris)	-	-	0.05	-
American robin (Turdus migratorius)	0.11	0.10	0.54	-
Eastern bluebird (Sialia sialis)	0.50	0.14	0.15	0.05
Blue-gray gnatcatcher (Polioptila coerulea)	0.04	-	-	-
Cedar waxwing (Bombycilla garrulus)	-	0.25	-	-
Starling (Sturnus vulgarus)	-	0.06	0.36	0.09
Yellow-rumped warbler (Dendrocia coronata)	-	0.06	0.03	-
House sparrow (Passer domesticus)	0.02	-	-	-
Eastern meadowlark (Sturnella magna)	-	0.10	0.08	1.08
Red-winged blackbird (Agelaius phoeniceus)	-	-	0.38	-
Northern oriole (Icterus galbula)	0.04	-	-	-

Species	September'78	October'78	November'78	December'78
Common grackle (Quiscalus quiscula)	0.02	-	0.38	-
Brown-headed cowbird (Molothrus ater)	-	-	0.05	0.71
Summer tanager (Piranga rubra)	0.02	-	-	-
Cardinal (Cardinalis cardinalis)	0.04 -	-	0.03	-
American goldfinch (Spinus tristis)	0.05	-	0.23	0.18
Lark sparrow (Chondestes grammacus)	0.16	-	-	-

Species	September'79	October'79	November'79	December'79
Red-shouldered hawk (Buteo lineatus)	0.02	-	-	-
Yellow-billed cuckoo (Coccyzus americanus)	0.05	-	-	-
Common flicker (Colaptes auratus)	0.07	0.23	0.40	0.40
Pileated woodpecker (Dryocopus pileatus)	0.05	0.02	-	-
Red-bellied woodpecker (Centrus carolinus)	1.11	0.70	0.93	0.63
Red-headed woodpecker (Melanerpes erythocephalus)	0.53	1.48	1.93	1.79
Downy woodpecker (Dendrocopos pubescens)	0.19	0.05	0.12	0.17
Great crested flycatcher (Myiarchus crinitus)	0.02	-	-	-
Eastern wood pewee (Contopus virens)	0.05	-	-	-
Blue jay (Cyanocitta cristata)	0.48	1.93	1.95	0.97
Common crow (Corvus brachyrhynchos)	0.33	0.28	0.45	-
Carolina chickadee (Parus carolinensis)	0.50	-	0.50	0.28
Tufted titmouse (Parus bicolor)	0.09	0.26	0.24	0.11
White-breated nuthatch (Sitta carolinensis)	0.19	0.08	0.21	0.28
Brown creeper (Certhia familiaris)	-	0.01	0.02	-

Species	September'79	October'79	November'79	December'79
American robin (Turdus migratorius)	-	0.02	-	-
Eastern bluebird (Sialia sialis)	0.21	0.13	0.66	0.23
Blue-gray gnatcatcher (Polioptila coerulea)	0.02	-	-	-
Starling (Sturnus vulgarus)	-	-	2.48	0.85
Yellow-rumped warbler (Dendrocia coronata)	-	-	0.07	-
House sparrow (Passer domesticus)	0.07	-	-	-
Eastern meadowlark (Sturnella magna)	-	0.01	1.79	0.28
Red-winged blackbird (Agelaius phoeniceus)	-	-	-	0.06
Common grackle (Quiscalus quiscula)	0.02	-	0.38	-
Borwn-headed cowbird (Molothrus ater)	0.02	0.04	-	-
American goldfinch (Spinus tristis)	0.02	-	-	-
Rufous-sided towhee (Pipilo erythrophthalmus)	-	0.05	-	-
Dark-eyed junco (Junco hyemalis)	-	-	0.12	0.11

VITA

Raymond Richard Leppla II

Candidate for the Degree of

Master of Science

Thesis: AN ASSESSMENT OF PECAN DAMAGE BY WILDLIFE IN CENTRAL OKLAHOMA

Major Field: Wildlife Ecology

Biographical:

Personal Data: Born Oklahoma City, Oklahoma, October 17, 1951, the son of Mr. and Mrs. Raymond Leppla; married Bonnie L. Burt, August 3, 1974.

Education: Graduated from Northeast High School, Oklahoma City, Oklahoma, in May 1969; received Bachelor of Science degree in Zoology from Oklahoma State University in 1976; completed requirements for the Master of Science degree at Oklahoma State University, Stillwater, Oklahoma, in July, 1980.

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