THE ECOLOGY AND BEHAVIOR OF BLUE JAYS

IN OKLAHOMA PECAN ORCHARDS

By

GORDON RAYMOND BATCHELLER

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University of Maine at Orono

Orono, Maine

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Thesis Adviser

Dean of the Graduate College

PREFACE

Effective stewardship of wildlife resources requires a biological understanding of those resources. My study was initiated to provide baseline data for management of depredating blue jays in Oklahoma pecan orchards. I concentrated my efforts in 3 major areas of jay biology: population characteristics (numbers and composition), habitat-use patterns, and behavior. It is my hope that management practices stemming from these data will provide a material benefit to Oklahoma pecan growers, and that I will have contributed in a small way to the advancement of the wildlife profession.

Financial support was provided by the Oklahoma State University (OSU) Agricultural Experiment Station through the OSU Department of Horticulture, and by the U.S. Department of the Interior through the Oklahoma Cooperative Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, Wildlife Management Institute, and U.S. Fish and Wildlife Service cooperating).

Dr. John A. Bissonette was my major adviser. His leadership and counsel were deeply appreciated. Dr. Michael W. Smith answered many questions about pecan culture, advised me on a variety of aspects of my study, and served on my committee. Drs. Rudy Miller and John Barclay also served on my committee. I thank them for their improvements to the study proposal and thesis manuscripts. Drs. H. Grant Vest and Paul A. Vohs were instrumental in beginning this project and in initial study design. Their leadership was appreciated. With the help of Dr. W.D. Warde, my study was improved significantly. Dr. Warde provided many hours of counsel on statistical design and analyses. I am indebted for his efforts and patience.

This study would not have been possible without the cooperation of the owners of my study areas. I extend my thanks to Messrs. Richard Couch, Kenton Knorpp, and Everett Ashley for their permission to work on their land.

Personnel of the Oklahoma Cooperative Wildlife Research Unit, fellow graduate students, and several undergraduate volunteers are all thanked for their support, friendship, and assistance. Dr. Frank Schitoskey substituted for Drs. Miller and Barclay at my oral defense. He reviewed the manuscripts and made suggestions for their improvement.

Finally, I thank my wife Mary for her help in every aspect of my graduate work.

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CHAPTER I

INTRODUCTION

This thesis is composed of 3 manuscripts written in formats suitable for submission to scientific journals. These manuscripts are presented as chapters in the thesis and each is complete without additional supporting material. Chapter II, "Blue jay populations and habitat-use in Oklahoma pecan orchards" was written in JOURNAL OF WILDLIFE MANAGEMENT style. Chapter III, "Foraging behavior and time budget of blue jays in Oklahoma pecan orchards" was prepared for the WILSON BULLETIN. Chapter IV, "Blue jay depredations in Oklahoma pecan orchards" was prepared for THE PECAN QUARTERLY.

CHAPTER II

BLUE JAY POPULATIONS AND HABITAT-USE IN OKLAHOMA PECAN ORCHARDS

GORDON R. BATCHELLER, Oklahoma Cooperative Wildlife Research Unit[1/],
Oklahoma State University, Stillwater, OK 74078

JOHN A. BISSONETTE, Oklahoma Cooperative Wildlife Research Unit,
Oklahoma State University, Stillwater, OK 74078

MICHAEL W. SMITH, Department of Horticulture, Oklahoma State
University, Stillwater, OK 74078

Abstract: Density, migration, age and sex composition, and habitat-use of blue jays (*Cyanocitta cristata*) depredating cultivated pecans in Oklahoma were documented in 1978 and 1979. Populations peaked in early October at 4.53 and 3.40 jays/ha, respectively, coinciding with migratory flights and increased nut availability. Although after hatching-year (AHY) males were most abundant ($P<0.10$), differential control is not practical since blue jays are difficult to age and sex in the field. Jays foraged in relatively high nut production areas (cross-sectional trunk area=8.93 m^2/ha) and nonforaged in low production areas (13.40 m^2/ha). Highest nut production sites were not

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[1/] Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Fish and Wildlife Service, and Wildlife Management Institute cooperating.

used since our study area was stocked at 6.16 m^2/ha and maximum nut production in Oklahoma orchards occurs at 6.90 m^2/ha. No relationship was found between foraging activities and distance to vegetative edge ($P>0.10$). A combination of direct (shooting, sound-scare devices) and indirect (early harvest, improved oak mast production) control measures applied simultaneously may minimize damage levels.

J. WILDL. MANAGE.

Key words: blue jay, *Cyanocitta cristata*, pecan, damage, control, habitat-use, time-area counts

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Blue jays depredate cultivated pecans in Oklahoma. Current control techniques, involving the use of sound-scare devices (eg. propane exploders, taped distress calls) and shooting are not satisfactory. We initiated this project to determine jay abundance and habitat-use patterns and to identify the depredating segment of the population in native pecan orchards.

Wildlife damage to pecans has long been recognized (Hoffman 1924, Aldous 1944). Murray (1975) estimated that blue jay damage averaged 0.43% of the total crop in a Louisiana orchard. He did not account for food storage behavior reported in jays (Hardy 1961:88) and only large nut cultivars were sampled. In Oklahoma, pecans become available to depredating blue jays when the shucks split in late September. Blue jays appeared to prefer small native nuts and removed as much as 30% of the total crop in some orchards (Leppla 1980).

We acknowledge the Oklahoma State University Department of Horticulture and Agricultural Experiment Station for their cooperation in administering and financing this project. The Oklahoma Pecan

Growers Association fostered cooperation with orchard owners. H.G. Vest was instrumental in initiation of this study, and P.A. Vohs provided input to the study design. W.D. Warde assisted with experimental design and statistical analyses, and M.H. Batcheller provided invaluable field and lab assistance.

STUDY AREA

The study area was located in central Oklahoma in Lincoln County and comprised 2 managed orchards. Total land area was 194 and 97 ha for orchard 1 and 2, respectively. Total area of pecan grove was 58 and 68 ha. Mean stocking levels, diameter at breast height (DBH, 1.4 m above ground level), and height for the pecan cover type in orchards 1 and 2 were: 61 and 58 trees/ha, 38.7 and 35.0 cm, 14.1 and 14.3 m, respectively. In both areas the orchards were grazed. The remaining habitat types on both areas were a mixture of open field, riparian, and oak upland cover types. Riparian areas were dominated by elms (*Ulmus* spp.), common hackberry (*Celtis occidentalis*), and common honeylocust (*Gleditsia triacanthos*). Post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and eastern juniper (*Juniperus virginiana*) were found on oak upland areas.

Pecans matured in early fall and harvest operations began in late November and terminated by late December. Both orchards were intensively managed for maximum nut production. Management practices included spring and summer pesticide treatments, pruning and thinning, and use of a variety of wildlife control measures including shooting, sound-scare devices, and avicides.

METHODS

Jay population levels were estimated using 2 techniques: time-area counts (TAC's) and a mapped observation method. One 150 m diameter circular plot was established in each of 8 12.1 ha rectangular quadrants on orchard 2. Counts were conducted at approximately 1 week intervals from September to December and 4-8 plots were censused each count day. Censusing began ½ hr before sunrise and ended ½ hr after sunset. Coverage of plots was alternated to avoid biases due to habitat variation within quadrants. Counts were not conducted during severe precipitation or wind.

An experienced observer sat or stood at the plot center and tallied all birds seen or heard in the plot during a 15 min precount period. Following the precount, a TAC was conducted for 15 min. Precount and TAC density indices (jays/ha) were compared with a paired *t*-test and correlation coefficients to evaluate the effect of observer disturbance. Analysis of variance (ANOVA) was used to determine if precount and TAC indices changed during the fall.

The observer remained in each quadrant an additional hour and visual and vocal observations of jays were plotted on study area maps. Only jays within the quadrant where the observer was stationed were tallied. An independent index (mapped observations) to jay abundance (jays/ha) was thus derived and compared to the TAC index. Density indices shown in Table 1, as well as correlations between mapped observations and TAC indices are based on the 1st 4 quadrants or plots covered (½ hr before sunrise-1230) since jays appeared most active at that time. ANOVA was used to evaluate trends in these 2 indices, while Duncan's multiple range test was used to determine which indices differed within years. Between year TAC indices were compared with correlation coefficients to compare timing and pattern of population change each year.

Date and time of occurrence, and size of migratory flocks were recorded. A flock was assumed migrating if it occurred at an altitude of 50+ m, moved in a southerly direction, and continued flying out of sight. Band returns were obtained from U.S. Fish and Wildlife Service records to determine origins of jays recovered in Oklahoma.

Jays were collected to identify the age and sex structure of the depredating population. They were shot from pecan habitat within the orchards and examined in the lab. Jays were sexed internally, aged (Norris 1961, Lamb et al. 1978), and classified as AHY or hatching year (HY). For each age and sex ratio, confidence limits (CL) were computed and χ^2 analysis conducted.

We measured habitat variables in the pecan cover type at jay observation sites. They included tree height and DBH, ground cover height and type (grassy, nongrassy), distance to and type of nearest distinct habitat change (riparian, pasture, upland oak), density of trees, perch size and height, and whether or not pecans occurred within 1 m of the perch. At each site bird behavior recorded included searching for food (SFT), consuming food (CFT), and the nonforaging activities (NFT) calling, preening, and resting.

Data from orchards 1 and 2 were combined, mean habitat variables for each behavior computed, and a _t_-test conducted to detect differences in habitat where a behavior did and did not occur. Chi-square analyses were used to evaluate behavioral associations with fruit availability, ground cover type, and type of nearest distinct habitat change.

Available pecan habitat in both orchards was determined with 67 0.04 ha randomly established circular plots. DBH, height, and number of trees were tallied, means computed and then compared to habitat-use with a *t*-test.

Minimum significance was set at the 10% level except for Duncan's multiple range test and confidence limits (α=0.05). The observed significance level is presented.

RESULTS AND DISCUSSION

Population Estimates

Censusing was conducted 18 and 16 days in 1978 and 1979, respectively. Based on these census days, precount and TAC indices were directly correlated in 1978 (r=0.64, P=0.0001) and 1979 (r=0.57, P=0.0001). In 1978 and 1979 only 1 of 18, and 12 precount indices, respectively, differed from the associated TAC index (paired *t*-tests, P<0.05). Sixteen index comparisons were not made for 1979 since 4 precounts were not conducted. ANOVA of precount indices showed no significant change in population size in 1978 (P=0.2336) and 1979 (P=0.1047) while TAC's did (P=0.0262 and 0.0353, respectively). However, since only 2 precount-TAC comparisons were significantly different it appears that observer presence was not a factor in bird disturbance during precounts. We assume these effects were negligible during TAC's.

Mapped observation and TAC population indices are shown in Table 1. There were significant fluctuations in these indices (ANOVA) in 1978 (P=0.0919 and 0.0310, respectively) and 1979 (P=0.0559 and 0.0892, respectively). Peak TAC density indices were 4.53 and 3.40 jays/ha and occurred 14 Oct 1978 and 6 Oct 1979, respectively. Peak mapped observation density indices were 1.38 and 0.74 jays/ha and occurred 14 Oct 1978 and 3 Nov 1979, respectively. These indices were correlated in 1978 (r=0.91, P=0.0001) and 1979 (r=0.68, P=0.0160), however, mapped observation indices were consistently lower than TAC indices (Table 1). Mapped observations were made by an observer walking throughout each quadrant for 1 hr while other data were collected (eg. habitat-use). Thus, less intensive observations and bird disturbance may have contributed to the differences observed.

Time-area counts without associated precounts, and mapped observations required 1 and 4 man-hours per census day, respectively. Conceivably mapped observations could be reduced 25-50% the normal time commitment by reducing quadrant coverage. Despite the potential time savings, mapped observations require greater effort to traverse quadrants than TAC plot coverage. Since both methods required quadrant or plot establishment, TAC's are recommended without precounts to monitor jay population levels.

A nonsignificant correlation was obtained when 1978 and 1979 TAC's were directly compared (r=0.30, P=0.3480). Since most census dates between years were not coincident, this correlation was based on a maximum of 4 day spacings between 1978 and 1979 dates. However, when these indices were analyzed so that the peak dates coincided, a significant correlation was obtained (r=0.48, P=0.0854). Thus the pattern of fluctuation was similar in both years but was shifted 8 days earlier in 1979.

Migration

Eight ($\bar{x}$ size=8.63 jays/flock) and 11 ($\bar{x}$=12.82) migrating flocks were observed 28 Sep-14 Oct 1978 and 6-11 Oct 1979, respectively. All flights occurred prior to 1020. In both years peak populations were recorded during migration periods which may indicate that many depredating jays were nonresidents. Band returns indicated that blue jays recovered in Oklahoma originated from Arkansas (6 of 33), Iowa (1), Minnesota (7), Missouri (2), Kansas (4), Nebraska (8), North (1) and South Dakota (4).

Age and Sex Structure

A total of 218 jays was collected. Of these 205 could be aged and 137 sexed. The overall age and sex ratios did not differ from unity and were 0.47±0.07 AHY:0.53±0.07 HY (P=0.3628) and 0.55±0.08 male: 0.45±0.08 female (P=0.2005). There were more AHY than HY males (0.60±0.11:0.40±0.11, P=0.0989) and more AHY males than females (0.65±0.12:0.35±0.12, P=0.0139). Ratios between AHY:HY females (P=0.1443) and HY males:females (P=0.5287) did not differ from unity.

We were unable to determine if these ratios were due to 1) the actual population age and sex structure, 2) differential shooting vulnerability, or 3) differential use of the pecan crop based on behavioral factors. AHY females may not be as abundant as AHY males due to high female mortality associated with reproduction. No data are available to suggest age and sex vulnerability differences, however, most migratory jays appear to be subadults (Pitelka 1946, Hardy 1961:87). Thus a dominance hierarchy (AHY males dominant) may have operated to surpress subadult activity in the orchards. Theoretically, depredations may be reduced by controlling AHY males, however, differential control is not practical since blue jays are difficult to age and sex in the field.

Habitat-use Analysis

Habitat-use of 89 (1978) and 62 (1979) jays was analyzed. Since only 10 of 24 between year habitat-use comparisons showed significant differences ($P<0.10$), the data were combined to maximize sample size (Table 2). Areas where jays searched for food were characterized by trees with a large DBH ($P=0.0070$) and small perches ($P=0.0944$), and low density (trees/ha) ($P=0.0007$) far from a distinct habitat change ($P=0.0666$). They consumed food on larger perches than were used for other activities ($P=0.0845$) and were found in relatively dense areas ($P=0.0079$) when nonforaging. All other comparisons of habitat variables where a behavior did and did not occur were not significant ($P>0.10$).

The mean (±95% CL) DBH (36.53±3.42 cm), height (14.29±1.06 m), and density of trees (58.8±8.19 trees/ha) in the pecan habitat type was compared (*t*-test) to habitat used. All activities were performed in trees larger (DBH) than the average ($P=0.0003$, 0.0436, 0.0146 for SFT, CFT, NFT activities, respectively). They consumed food in trees shorter than the average ($P=0.0436$) and nonforaged in areas denser than the average ($P=0.0010$). Searching and nonforaging activities were not performed in trees above or below the average height ($P>0.10$), and there was no preference for habitat differing in density than the average ($P>0.10$) for searching and consuming activities.

No data are available to explain tree height preferences. High nut production may occur in areas relatively far from adjacent habitat types due to reduced competition and this may explain the prevalence of searching activities in these areas. Perch size preferences (Table 2) occurred since nut production is highest on the crown periphery (Mielke et al. 1978) where perches are smallest, and relatively large perches are required for nut consumption.

Pecan yield is inversely proportional to cross-sectional trunk area (a function of DBH and stand density) and in Oklahoma, maximum production occurs at 6.90 m^2/ha (Hinrichs 1978). Average cross-sectional trunk area of the study area was 6.16 m^2/ha but all activities occurred in suboptimal nut production areas (8.93, 12.17, 13.40 m^2/ha for SFT, CFT, NFT activities, respectively). However, it is evident that searching activities took place in areas of relatively high nut yield while nonforaging activities occurred in areas of relatively low nut yield. Nut consumption activities occurred in areas intermediate in nut production (12.17 m^2/ha).

Searching activities were associated with the presence of fruit ($\underline{P}$=0.0001) but consumption ($\underline{P}$=0.5444) and nonforaging activities ($\underline{P}$=0.2030) were not. The latter activities frequently occurred in trees different than the former activity or in areas of the same tree where nuts were not produced. All 3 activities were independent of the type of nearest distinct habitat change ($\underline{P}$=0.4700, 0.6940, 0.1404 for SFT, CFT, NFT activities, respectively). Similarly, Virgo (1971) found that bird damage to cherries in Ontario was independent of the type of habitat surrounding the orchards. Searching activities of jays were associated primarily with the grass ground cover type ($\underline{P}$=0.0771) but consuming and nonforaging activities were not ($\underline{P}$=0.3207 and 0.1639, respectively). This may be related to low grass vigor in high density sites and overgrazing.

MANAGEMENT IMPLICATIONS

Shooting and the use of sound-scare devices appear to be the most successful direct control measures currently employed. Typically these methods are applied sporadically during the depredation season (Sep-Dec) resulting in ineffective control. Since blue jay populations peak in early October, direct control should be most intensive at that time to be cost effective. Time-area counts without associated precounts should be used to document peak population levels.

Darrell Sparks (pers. comm.) reported that early harvest of pecans reduced blue jay depredations in Georgia. Adoption of a similar regime would reduce nut availability and could result in substantial reduction of depredations in Oklahoma orchards.

Management of orchard characteristics (eg. tree height, DBH, stand density) may not be practical since recommendations based on habitat-use data would be inconsistent with maximum nut production management. For example, increasing cross-sectional trunk area may reduce searching activities but it would also reduce nut yield. Leppla (1980) suggested an inverse relationship between acorn yields in oak upland forests adjacent to pecan orchards and jay depredation levels. Goodrum et al. (1971) reported a linear increase in acorn yield with bole size and a curvilinear increase in yield with crown size from blackjack oaks in east Texas and Louisiana. Sharp and Sprague (1967) indicated that white oaks (<u>Quercus</u> spp.) in closed canopies produced acorns only on branches exposed to sunlight. Thinning of blackjack-post oak stands adjacent to pecan orchards to release dominant trees should increase acorn production and could reduce damage levels.

Maximum reduction in jay depredation levels may result from several direct and indirect control procedures applied simultaneously. Additional research should be designed to evaluate the effects of these procedures on jay population and damage levels.

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Table 1. Blue jay mapped observation and time-area count (TAC) density indices (jays/ha) in a central Oklahoma pecan orchard during Fall 1978 and 1979 based on 4 quadrants or plots (½ hr before sunrise-1230).

	1978 Jays/ha[1/]			1979 Jays/ha	
Date	Mapped observation	TAC	Date	Mapped observation	TAC
19 Sep		1.42[b]	7 Sep	0[c]	0[b]
22		0.57[b]	15	0.23[a,c]	0.57[b]
26	0.35[b]	0.99[b]	22	0.16[a,c]	0.43[b]
29	0.70[a,b]	1.13[b]	28	0.58[a,b]	0.29[b]
3 Oct	0.80[a,b]	1.70[b]	6 Oct	0.53[a,b]	3.40[a]
5	0.91[a,b]	2.55[a,b]	13	0.41[a,b,c]	1.42[a,b]
10	1.05[a,b]	2.55[a,b]	19	0.39[a,b,c]	0.85[b]
14	1.38[a]	4.53[a]	20		0.57[b]
17	0.68[a,b]	2.12[a,b]	26	0.49[a,b,c]	1.42[a,b]
26	0.43[b]	0[b]	3 Nov	0.74[a]	1.98[a,b]
2 Nov	0.49[b]	0.28[b]	13	0.31[a,b,c]	0.43[b]
10	0.64[a,b]	0.99[b]	23		1.56[a,b]
18	0.31[b]	0.71[b]	27	0.29[a,b,c]	0.71[b]
21		0.43[b]	15 Dec	0.06[a,c]	0[b]
1 Dec	0.43[b]	0.14[b]			
2	0.35[b]	0.85[b]			
14	0.27[b]	0.57[b]			

[1]Indices with same letter (within years and for each method) are not significantly different (Duncan's multiple range test, $P>0.05$).

Table 2. Blue jay habitat-use patterns in central Oklahoma pecan orchards for 3 behavioral activities during Fall 1978 and 1979.

Activity[1/]		Tree ht. (m)	DBH (cm)	Ground cover ht. (cm)	Distance to change vegetation (m)	Density (trees/ha)	Perch diameter (cm)	Perch ht. (m)
SFT	$\bar{x}$	14.2	45.3	30.5	84.1	55.5	4.5	9.0
	N	71	71	68	71	71	71	71
	P[2/]	0.2274	0.0070	0.6953	0.0666	0.0007	0.0944	0.1281
CFT	$\bar{x}$	12.7	41.5	32.0	59.8	90.2	6.4	7.2
	N	37	37	35	37	37	37	37
	P	0.3418	0.7645	0.3560	0.1699	0.9550	0.0845	0.1161
NFT	$\bar{x}$	13.8	41.6	34.0	73.6	98.5	5.5	8.4
	N	119	119	106	119	118	119	119
	P	0.3553	0.6039	0.3935	0.8215	0.0079	0.3444	0.6009

[1]SFT=searching food food in tree, CFT=consuming food in tree, NFT=nonforaging activities in tree.

[2]Observed significance level under H_o:no difference between habitat variables where behavior did and did not occur.

CHAPTER III

FORAGING BEHAVIOR AND TIME BUDGET OF BLUE JAYS IN OKLAHOMA PECAN ORCHARDS

GORDON R. BATCHELLER, JOHN A. BISSONETTE
MICHAEL W. SMITH

Blue Jays (Cyanocitta cristata) are common Oklahoma birds (Sutton 1967) and are especially abundant in cultivated pecan orchards during fall. Their foraging activities in these areas may result in 30% loss of the total pecan crop of some orchards (Leppla 1980). Few data are available describing these activities (Bannon 1921, Bailey 1928). Arnold (1938) and Bent (1946) provided reviews of Blue Jay life history and Hardy (1961) described qualitatively several aspects of Blue Jay breeding and nonbreeding behavior. However, few quantitative data describe Blue Jay ecology and behavior. This situation provides a unique opportunity to examine a relatively poorly studied species in an environment with a superabundant food resource.

In this paper, we detail Blue Jay time budgets and foraging activities in Oklahoma pecan orchards. These data should facilitate development of nonlethal methods of control. Batcheller et al. (in press) provided a discussion of management aspects of this study but those will not be considered here.

STUDY AREA

The study area was located on 2 managed native pecan orchards in Lincoln County, central Oklahoma. Orchard 1 (O1) was 194 ha and orchard 2 (O2) 97 ha in size, and contained 58 and 68 ha of pecan grove, respectively. Orchard floors were maintained as pasture, and the remaining vegetative types consisted of a heterogeneous mixture of open field, riparian, and oak upland cover types. Elms (*Ulmus* spp.), common hackberry (*Celtis occidentalis*), and common honeylocust (*Gleditsia triacanthos*) dominated the riparian areas. Oak upland areas consisted primarily of post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and eastern juniper (*Juniperus virginiana*). Topography of riparian and pecan grove habitat types was relatively flat, but gently rolling in pasture and oak upland areas.

Both orchards were intensively managed for maximum nut production. Management practices included spring and summer pesticide treatments, pruning and thinning, and wildlife control. Harvest operations were conducted during fall after the pecan crop matured.

METHODS

Field work was conducted from Sep 1978 to Dec 1979. Each orchard was divided into 12.1 ha rectangular quadrants (16 in O1, 8 in O2). Each of these quadrants was traversed during 1 of 8 90 min periods/day (½ hr before sunrise-½ hr after sunset). Thus 2 field days were required for O1. The sequence of coverage was alternated to compensate for between-quadrant habitat differences. Unless indicated differently, the data reported herein are for the pecan grove habitat type only.

Ten behavioral activities were described for time budget analyses (Table 1). The amount of time spent in each activity was timed with a stopwatch to the nearest second. Jays were located by visual and vocal cues and each jay was observed for as long as possible. The percentage of time spent in each activity was computed for each bird and the mean percentage of time calculated for 3 intervals (1=1 Aug-30 Sep, 2=1-30 Oct, 3=1 Nov-30 Dec) and periods (1=<10:30, 2=10:30-14:30, 3=>14:30). These data were analyzed with the general linear models (GLM) and ANOVA procedures of SAS79 (Helwig and Council 1979). Duncan's multiple range test (α=0.05) was used to test for differences between means.

For each interval, behavioral indices (BI) were computed by dividing the total number of jays observed performing an activity by the total number of jays observed. These proportions are indices to the relative number of jays engaged in specific behavioral activities (ie. BI=1.0 means all jays performed that specific behavior). Confidence limits were computed (α=0.05) (Steel and Torrie 1960:353) and interval trends were tested with χ^2.

Activity patterns were determined by comparing (paired *t*-test) jay population density indices (jays/ha) at different times of the day (Table 2). Indices were derived from time-area counts consisting of 8 150 m diameter circular plots (1 per quadrant) established in O2. A 15 min census of all birds seen or heard within each plot was made (Batcheller et al. in press). We assumed that density reflected jay activity levels.

Each time a jay was observed searching for pecans, 1 nut was removed from that tree to determine food size preferences. No effort was made to randomize nut selection but we assumed uniform nut size within the tree. Partially consumed nuts found under pecan trees, and nuts dropped by jays were also collected. Nut length and width were measured with a vernier caliper to the nearest 0.20 mm. Mean nut size selected by jays was derived from these data.

Group size frequencies were determined by estimating number of jays seen or heard in "cohesive" groups. Cohesive refers to a group apparently flying and/or foraging together. Migrating flocks (altitude>50 m, southerly movement) were not tallied.

Blue Jay food storage activities occurred along well defined flight lines between pecan grove and oak upland habitat. Systematic flight line counts (15 min) were made in 1979 (none during interval 1). Since the number of nuts carried by each bird was estimated, 4 variables were derived from these data: pecan-flights/min (number of jays flying out of the orchard/min with at least 1 nut), nuts/jay (number of nuts removed/jay/flight), nuts/min (number of nuts removed/min), and flights/min (total number of jays flying out/min with or without a nut).

RESULTS

Foraging activities.-Blue Jays occur in Oklahoma pecan orchards all year but are most abundant in early October (Batcheller et al. in press). The period of peak abundance coincided with high nut availability and depredation levels (Leppla 1980).

Foraging activities began when pecan husks split longitudinally revealing the nut; 22 Sep 1978 and 15 Sep 1979. Reduction of foraging activities in late fall was directly related to initiation of harvest operations. Harvest was initiated 11 Nov 1978 and 13 Nov 1979, and was completed in late December and early December, respectively.

Blue Jays searched for food by scanning the foliage from a perch or by actively moving throughout the tree. Jays held pecans between their feet on relatively large perches ($\geq$6.4 cm) (Batcheller et al. in press) and fractured the shells by hammering it with their beak. The nut meat was usually consumed on that perch, but typically the nut was dropped prior to complete consumption of the available meat. Bill-wiping usually followed consumption activities. Nuts infected with insect larvae (eg. Curculio caryae) were discarded. Vocalizations during searching and consumption activities were rare.

Following natural nut fall and initiation of harvest operations, nut availability on the ground increased. At this time foraging activities in these areas also increased. Most jays centered ground searching activities near 1 or 2 pecan trees and typically consumed nuts collected from the ground in these trees. Ground cover height was low (<10 cm) making nuts highly visible from tree and ground vantage points. Nonforaging and consumption activities on the ground were rarely observed (Table 4).

Activity patterns.-The mean number of jays/ha observed for all plots in early morning, late morning, morning, afternoon, early afternoon, and late afternoon are shown in Table 2. Highest activity levels occurred in early morning in both years ($P<0.02$). There was no difference in activity levels between early and late afternoon for either year ($P<0.80$).

Our data support Franzreb's (1977) suggestion that bird censuses be conducted during early morning hours due to high activity levels. In pecan orchards, low activity levels following early morning may be due to a combination of increased human activity and adverse weather conditions. Since pecan groves are relatively open habitats, little cover from high winds is provided.

Time budget.-Detailed observations of 187 and 185 jays were made in 1978 and 1979, respectively. The mean length of continuous observation per bird was 55.75 sec in 1978 and 55.37 sec in 1979.

Since the effects of time period were significant (ANOVA, $P<0.05$) for only 2 behaviors in 1978 (SFG, F) and 2 in 1979 (NFG, F), time budget data were pooled over periods and summarized for intervals only (Table 3). In both years for all intervals; searching, consumption, and nonforaging activities in trees combined accounted for 73.2-95.1% of the time budget while flying accounted for 4.5-14.7%. The remaining time was spent on the ground. Caching behavior was not observed in pecan groves (see caching behavior and flight-line count section). This was probably due to poor ground cover conditions and absence of a suitable substrate for construction of a cache site.

Significant fluctuations occurred in both years only for searching in tree activities ($P<0.0002$). As discussed later, this is a reflection of nut availability. In 1978, this activity increased significantly from interval 1-2 ($P<0.05$) but remained relatively constant from interval 2-3 ($P>0.05$). In 1979, foraging times in trees were relatively high (>50%) and constant ($P>0.05$) for intervals 1 and 2, but decreased significantly from interval 2-3 ($P<0.05$). In 1979, nonforaging activities in trees increased from intervals 1-3 ($P=0.0005$), but was relatively constant in 1978 ($P=0.1110$). There were significant increases in the proportion of time spent searching for food on the ground and flying in 1979 ($P=0.0027$ and 0.0460, respectively) but not in 1978 (P=0.5975 and 0.5502, respectively). In 1979, jays spent a greater proportion of their time searching for food in trees than in 1978 (except interval 3). They spent less time in nonforaging activities in trees in 1979 than in 1978.

Behavioral indices.-Blue Jay behavioral indices (±95% CL) are shown in Table 4. They do not sum to 1.0 since each bird may perform more than 1 behavior. Most birds either searched for and consumed pecans in trees, or engaged in nonforaging activities in trees. Observations of jays on the ground were rare, and may be due to lack of cover in these areas.

In 1978, the percentage of birds searching for pecans in trees increased from interval 1-2 then decreased slightly ($P<0.001$). In 1979, the percentage of birds in this activity declined during the fall ($P<0.001$). In both years, the proportion of jays engaged in nonforaging activities in trees increased during the fall (both $P<0.05$). However, the BI for consumption of food in trees was constant throughout the fall (both $P>0.05$) in 1978 and 1979. A significantly larger proportion of jays were engaged in ground searching activities during interval 3 of 1979 ($P<0.001$); in 1978, this activity was constant ($P>0.05$). Significant fluctuations in the flight BI were seen in 1978 ($P<0.0001$) but not in 1979 ($P>0.05$).

Caching behavior and flight-line counts.-Caching behavior was not time budgeted since we were unable to distinguish when flights out of the orchard with a pecan resulted in caching. Many of these flights were undoubtably food storage bouts. "Pecan flights" occurred along distinct corridors at varying intensities throughout the fall. Two flight-lines each were identified in O1 and O2. They occurred in areas where the pecan grove habitat type abutted oak upland areas or where the distance between these 2 habitats was within approximately 100 m.

Caching flights terminated in oak upland areas approximately 50-500 m from the nearest pecan grove habitat type. Infrequent vocalizations in these areas, and dense understory vegetation contributed to a small sample size of caching Blue Jay observations ($\underline{N}$=6).

Nonforaging activities in oak trees occurred in the understory and usually preceded a food storage bout. Pecans were cached in the forest litter following soil probing, presumably to create a depression for cached nuts. Activities on the ground were brief (<1 min) in comparison to nonforaging activities (1-3 min). On 1 occasion (5 Oct 1979), a group of 3 Blue Jays was observed in caching activities within 5 m of each other. Following caching, nonforaging behavior in trees or flight occurred. No jays were observed recovering nuts.

A total of 46 flight line counts was conducted. Although the total number of nuts carried by each bird in a flight-line was estimated, attempts to confirm the accuracy of these were not successful. However, our estimates were conservative and the values presented here should be considered minimal. The overall means for each of the derived variables were: pecan-flights/min=0.29 (SD=0.35), nuts/jay=0.82 (0.59), nuts/min=0.35 (0.46), and flights/min=0.41 (0.45). Since nuts/min>pecan-flights/min, the overall tendency was for Blue Jays to remove more than 1 nut/flight. They are capable of removing 3 native pecans at 1 time (1 each in throat, mouth, and bill).

The effects of interval and period were significant for all variables ($\underline{P}$<0.05) except nuts/jay ($\underline{P}$=0.2068). Thus, the amount of nuts carried per trip was relatively constant throughout the fall and during the day, but the number and intensity of flights varied for both.

Group size.-Group size frequencies included no migrating birds. Blue Jays were most frequently observed as single birds (106 of 149) (Table 5). The largest group size was 8 on 6 Oct 1979. A χ^2 test was conducted to determine if group size was related to any of the 10 different behavioral categories (Table 1). Although significant relationships were found between group size, flying ($P<0.10$), and aggressive behavior ($P<0.0001$), the χ^2 tables were very sparse so we were not justified in making conclusions based on these alone. Twenty-four of 60 (40%) of flying groups observed occurred in group sizes >1. However, the majority of jay groups observed in flight (excluding migratory flights) occurred singly (36 of 60=60%). Only 6 aggressive interactions were observed during the study and group sizes for these interactions varied from 1 (interspecific aggression)-6 (intraspecific aggression). Interspecific interactions primarily involved red-headed woodpeckers (*Melanerpes erythrocephalus*).

Nut size.-Ninety-seven nuts were collected following observation of a foraging Blue Jay during the study. Sufficient data are available only for nuts removed from trees where jays were observed foraging (class 1 nuts), and for nuts collected from the ground that through circumstantial evidence (ie. cracked open, nut meat removed) appeared damaged by jays (class 2) (Table 6). Measurements for class 2 nuts are tabulated only if both length and width could be determined. Mean length varied from 23.94-27.82 mm and mean width varied from 14.22-15.46 mm. Between year tests for nut size were not conducted since weather and/or horticulture practice differences may have contributed to nut size differences. No class 2 nuts were collected in 1978. In 1979, class 1 nuts were longer then class 2 nuts ($\underline{P}<0.05$), but there was no difference in width between these 2 classes ($\underline{P}>0.10$). If class 1 nuts represent a random sample of available food, these findings may indicate that Blue Jays prefer relatively small pecans. However, the range of pecan sizes available on our study area was relatively low (class 1 CV for length=13.07%), so it is uncertain if food preferences can be inferred from these data.

DISCUSSION

The pecan crop matured 22 Sep 1978 and 15 Sep 1979. The early maturing crop of 1979 may have contributed to the large percentage of birds searching for food in trees during interval 1 of that year (BI=85±16%). This contrasted with 5±7% in 1978 for these activities during interval 1. In all cases, at least 50% of the jays observed were engaged in tree nonforaging activities and in both years the pattern differed over the 3 intervals, with nonforaging activities highest in interval 3. Nut availability is lowest at this time so there appears to be an inverse relationship between availability and nonforaging activities. In 1979, ground searching activities were not observed until interval 3 when 25±10% of the birds were seen foraging on the ground. In 1978, these activities were relatively constant ($\underline{P}>0.05$) throughout the fall. Harvest operations were initiated 11 Nov 1978 and 13 Nov 1979, but were much more intensive in 1979 (increased manpower and machinery). Thus increased availability of nuts on the ground may account for the observed relationship.

The mean percent of time spent in flight was constant in 1978 but not in 1979 (Table 3). However, the percent of birds observed in flight differed over intervals in 1978 but not in 1979, and may have been due to the relative abundance of pecans on the orchard floor. In 1978, there was a low density of nuts on the ground due to low intensity harvest operations during interval 3. Thus jays spent more time in trees and flying between trees to locate nuts. In 1979, due to high intensity harvest operations during interval 3, nut abundance on the ground was high and a smaller proportion of birds were engaged in flight activities since ground activities were also high.

The proportion of birds consuming food in trees was relatively constant throughout the fall (Table 4). Once a jay successfully removed a pecan from a tree or the ground (SFT, SFG), there were essentially 2 outcomes: caching or immediate consumption. Since we were unable to determine the proportions of caching jays consuming pecans in the grove and in adjacent oak upland areas, it was not possible to evaluate the importance of pecan mast to the energetics of caching jays.

Food storage behavior by Blue Jays was documented by Hardy (1961:88) and Laskey (1942, 1943). Roberts (1979) provided a review of avian food storing behavior and discussed its evolution. Roberts contended that since storing is energetically costly, adaptations should evolve to increase its benefits. Territoriality should be cost-effective since potential competitors are eliminated from food storage sites. Roberts (1979) suggested that winter territoriality in Blue Jays may have developed to optimize food storage activities. Hardy (1961:45-49) discussed Blue Jay territoriality and indicated that this behavior is shown in breeding birds, but gave no evidence for winter territoriality. In our study, aggressive behavioral activities were very infrequent (Table 4) and comprised a small percentage of the total time budget (Table 3). Furthermore, vocalizations were observed infrequently and in oak upland sites (where caching behavior occurred) jays were secretive, nonvocal, and no evidence of territorial defense was detected. Tacha (in press) found that Blue Jays defended a group territory near an isolated pecan tree in an urban environment against jays of a neighboring flock. In this case, however, a superabundant food resource was not available and territorial behavior was selectively advantageous.

Leppla (1980:37) found that total pecan production in O1 was 43,836.30 kg or 753.20 kg/ha, giving 12.81 kg/tree based on a mean density of 58.8 trees/ha (Batcheller et al. in press). Mean total seed production (N=6 yrs) for 17 pignut hickories (*Carya glabra*) in an Ohio forest was 629.47 seeds/tree (Nixon et al. 1980), giving 1.43 kg/tree based on an average of 440.53 pignut hickory seeds/kg (Nelson 1961). Our study area provided a superabundant food resource when compared to a native forest with similar species composition (both *Carya*). Under these conditions, territorial defense does not appear necessary nor do the cost-benefit relationships foster heavy selection pressures to promote or maintain territoriality.

SUMMARY

Foraging activities and time budget of Blue Jays in Oklahoma pecan orchards were studied in 1978 and 1979. Initiation and completion of foraging activities was directly related to nut availability as influenced by crop maturity, natural nut fall, and

harvest operations. Highest activity levels occurred in early morning. Only arboreal searching activities fluctuated significantly in both years. Jays in pecan orchards occurred singly most often. Many foraged pecans were cached in adjacent oak upland areas. Food storage flights occurred along well defined flight corridors between pecan grove and oak upland habitat types. Although the number of flights varied during the fall, the number of nuts cached per bird per flight was relatively constant. Territorial defense of foraging areas or caching sites was not observed, and we hypothesize that the superabundant food resource (cultivated pecans) reduced the selection pressures fostering this energetically expensive activity.

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TABLE 1. BEHAVIORAL CATEGORIES USED TO DOCUMENT BLUE JAY ACTIVITIES IN OKLAHOMA PECAN ORCHARDS.

Acronym	Behavior	Definition
SFT	searching for food in tree	active and passive searching (ie. movements and scanning), up to procurement of food
CFT	consumption of food in tree	following procurement, includes manipulation of food, hammering, and consumption
NFT	nonforaging activities in tree	preening, loafing, and calling
TNO	time not observed	general location of bird known but specific behavior not identified
SFG	searching for food on ground	same as SFT but on ground
CFG	consumption of food on ground	same as CFT but on ground
NFG	nonforaging activities on ground	same as NFT but on ground
F	flying	inter- and intratree flying activities
AB	aggressive behavior	inter- and intraspecific aggressive activities
CB	caching behavior	activities between arrival and departure at food storage sites

TABLE 2. ACTIVITY LEVELS (JAYS/HA) OF BLUE JAYS IN OKLAHOMA PECAN ORCHARDS, 1978 AND 1979.

	1978	1979
Morning[a]	1.39	1.35
Afternoon	0.39	0.36
Paired *t*-test	$0.005<P<0.01$	$0.01<P<0.02$
Early morning	1.62	1.38
Late morning	0.84	0.59
Paired *t*-test	$0.005<P<0.01$	$0.01<P<0.02$
Early afternoon	0.43	0.57
Late afternoon	0.36	0.14
Paired *t*-test	$0.60<P<0.80$	$0.60<P<0.80$

[a]Morning=½ hr before sunrise-12:30, Afternoon=12:30-½ hr after sunset, Early morning=½ hr before sunrise-09:30, Late morning=09:30-12:30, Early afternoon=12:30-15:30, Late afternoon=15:30-½ hr after sunset.

TABLE 3. TIME BUDGET OF BLUE JAYS IN OKLAHOMA PECAN ORCHARDS, 1978 AND 1979.

	1978				1979			
Interval[a]	1	2	3	OSL[b]	1	2	3	OSL
Behavior[c] N=	39	109	39		20	83	82	
SFT	1.3[b]	28.1[a]	22.7[a]	0.0002	66.6[a]	54.7[a]	15.7[b]	0.0001
CFT	13.5[a]	12.5[a]	6.6[a]	0.4902	5.9[a]	11.1[a]	16.8[a]	0.1980
NFT	58.4[a]	41.6[b]	47.0[a,b]	0.1110	22.6[b]	25.5[b]	45.7[a]	0.0005
TNO	10.6[a]	4.3[a]	5.0[a]	0.2383	0.4[a]	1.7[a]	1.9[a]	0.8182
SFG	1.4[a]	4.0[a]	4.6[a]	0.5975	0	0	7.7[a]	0.0027
CFG	0	0	0		0[a]	0.6[a]	1.3[a]	0.7519
NFG	0	0	0.4[a]	0.1501	0[a]	1.2[a]	1.1[a]	0.7830
F	14.7[a]	9.5[a]	13.2[a]	0.5502	4.5[b]	5.1[b]	9.7[a]	0.0460
AB	0.1[a]	0.1[a]	0.6[a]	0.2712	0[a]	0.1[a]	0.2[a]	0.2320
CB	0	0	0		0	0	0	
Total (%)	100.0	100.1	100.1		100.0	100.0	100.1	

[a]Interval 1=1 Aug-30 Sep, 2=1-30 Oct, 3=1 Nov-30 Dec.

[b]OSL=observed significance level for ANOVA, means with same letter are not significantly different (Duncan's multiple range test, α=0.05).

[c]Behavioral acronyms identified in Table 1.

TABLE 4. BLUE JAY BEHAVIORAL INDICES (NUMBER OF JAYS PERFORMING AN ACTIVITY/TOTAL NUMBER OF JAYS OBSERVED) DURING 3 INTERVALS IN OKLAHOMA PECAN ORCHARDS. 95% CONFIDENCE LIMITS ARE SHOWN. PROPORTIONS DO NOT ADD TO 1.0 SINCE 1 JAY MAY HAVE PERFORMED MORE THAN 1 BEHAVIOR.

	1978			1979		
Interval[a]	1	2	3	1	2	3
Behavior[b]						
SFT	0.05±0.07	0.41±0.09	0.38±0.15	0.85±0.16	0.70±0.09	0.32±0.11
CFT	0.15±0.11	0.18±0.07	0.18±0.12	0.30±0.20	0.26±0.09	0.31±0.10
NFT	0.67±0.15	0.56±0.09	0.82±0.12	0.50±0.22	0.59±0.10	0.76±0.10
TNO	0.18±0.12	0.07±0.05	0.13±0.11	0.05±0.10	0.03±0.04	0.08±0.06
SFG	0.05±0.07	0.07±0.05	0.15±0.11	0	0	0.25±0.10
CFG	0	0	0	0	0.01±0.02	0.03±0.04
NFG	0	0	0.03±0.05	0	0.02±0.03	0.03±0.04
F	0.31±0.15	0.15±0.07	0.62±0.15	0.25±0.19	0.42±0.10	0.53±0.11
AB	0.03±0.05	0.02±0.03	0.05±0.07	0	0.01±0.02	0.08±0.06
CB	0	0	0	0	0	0

[a]Interval 1=1 Aug-30 Sep, 2+1-30 Oct, 3=1 Nov-30 Dec.

[b]Behavioral acronyms identified in Table 1.

TABLE 5. GROUP SIZES OF BLUE JAYS IN OKLAHOMA PECAN ORCHARDS (MIGRATORY FLOCKS EXCLUDED), 1978 AND 1979.

Group size	Frequency	Percent
1	106	71.1
2	23	15.4
3	10	6.7
4	8	5.4
6	1	0.7
8	1	0.7
Total	149	100.0

TABLE 6. NUT SIZE OF CLASS 1 (NONRANDOMLY REMOVED FROM TREES WHERE JAYS WERE OBSERVED FORAGING) AND CLASS 2 NUTS (NUTS COLLECTED FROM THE GROUND THAT THROUGH CIRCUMSTANTIAL EVIDENCE {IE. CRACKED OPEN, NUT MEAT REMOVED} APPEARED DAMAGED BY JAYS) FROM OKLAHOMA PECAN ORCHARDS.

		Class 1		Class 2	
		Length[a]	Width	Length	Width
1978	$\bar{x}$	27.82	15.46		
	SD	3.36	1.38		
	N	31		0	
1979	$\bar{x}$	26.24	14.54	23.94	14.22
	SD	3.43	1.39	2.43	0.84
	N	59		9	

[a]Measurements in millimeters.

CHAPTER IV

BLUE JAY DEPREDATIONS IN OKLAHOMA PECAN ORCHARDS[1]

GORDON R. BATCHELLER[2], JOHN A. BISSONETTE[3],

AND MICHAEL W. SMITH[4]

Abstract. Blue jays are the most important depredator of native Oklahoma pecans. Their populations and behavior was studied to provide a biological basis for effective control. Population levels peaked in early October coinciding with migratory flights and peak nut availability. Although adult males were most abundant, differential control is not feasible due to problems in aging and sexing blue jays in the field. Food storage was a frequent activity but recovery of cached nuts is not practical. Maximum reduction in depredations may result from several direct and indirect control measures applied simultaneously.

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[1]We acknowledge the Oklahoma State University Department of Horticulture and Agricultural Experiment Station for administrative and financial support. Dr. H.G. Vest was instrumental in initiation of the study, and Dr. P.A. Vohs assisted with its design. The Oklahoma Pecan Growers Association fostered cooperation with pecan grove owners. Dr. W.D. Warde provided statistical assistance, and M.H. Batcheller helped in the laboratory and field.

The blue jay (Cyanocitta cristata) is common throughout the year in most parts of Oklahoma (2). Their feeding activities in pecan orchards are of much concern to the state's growers. Leppla (1) showed that jays are the most important depredator of native Oklahoma pecans and may remove as much as 30% of a given crop. Apparently, these high damage levels occur locally, however, nearly all growers report at least some damage by jays.

Efforts to control blue jays are either not effective or economically not feasible. Shooting is probably the most common method of control. Growers that shoot intensively during peak damage periods (October-November) appear to achieve acceptable control levels. However, many growers obtain suboptimal control due to sporadic and nonsystematic shooting programs. Other control measures include sound-scare devices (eg. recorded distress-calls, propane exploders), ground or aerial traps, and avicides. None of these result in satisfactory widespread control of depredating jays.

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[2] Graduate Research Assistant, Oklahoma Cooperative Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, Wildlife Management Institute, and U.S. Fish and Wildlife Service cooperating), Oklahoma State University, Stillwater, OK 74078.

[3] Assistant Leader, Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, Stillwater, OK 74078.

[4] Assistant Professor, Department of Horticulture, Oklahoma State University, Stillwater, OK 74078.

Objectives of this study were to determine blue jay ecology and behavior in Oklahoma pecan orchards to provide a biological basis for management of this pest species. Specific objectives were to document variations in blue jay population levels throughout the fall, to determine which age and sex classes depredated pecans, to document feeding behavior and time budgets (the way an animal partitions its time in various activities), and to determine which pecan trees and groves were most susceptible to depredations.

Field work was conducted during the fall of 1978 and 1979 on 2 native pecan orchards in Lincoln County, central Oklahoma. Orchard 1 was 194 ha in size and contained 58 ha of pecans, and orchard 2 was 97 ha in size and contained 68 ha of pecans. Mean tree density, diameter at breast height (DBH), and height of pecan trees in orchard 1 and 2 were respectively: 61 and 58 trees/ha, 38.7 and 35.0 cm, 14.1 and 14.3 m. Bottomland, oak upland, and pasture habitat types abutted the groves, and cattle were stocked on both areas.

Blue jays were studied through direct observation and by examining collected specimens. Population levels were estimated by counting jays seen or heard in 8 150 m diameter circular plots. Habitat-use was evaluated by measuring pecan trees where blue jay foraging and nonforaging activities occurred.

Blue jays occurred on the study areas throughout the year and nested in bottomland and oak upland areas, but no nests were located. However, immature jays were observed during summer before migration into the area, indicating that breeding activities must have occurred. Despite the presence of breeding birds and young-of-the-year, population levels in spring and summer were relatively low and no significant depredations to marketable pecans were observed.

Population levels in the orchards increased significantly during fall. Peak numbers occurred in early October and reached a level of over 4 jays/ha. These peaks were associated with the occurrence of migratory flocks implying that a large proportion of depredating blue jays were nonresident, migrating birds. Bird band returns obtained from the U.S. Fish and Wildlife Service indicated that blue jays migrating through Oklahoma originated from Arkansas, Iowa, Minnesota, Missouri, Kansas, Nebraska, and North and South Dakota. Following the population peak, numbers declined but stabilized at a level higher than the prepeak density, indicating that some migratory jays wintered in Oklahoma.

We determined age and sex of 218 collected blue jays. The analyses showed that most blue jays in Oklahoma pecan orchards during fall were adult males. Although it may be desirable to selectively control this segment of the population, it would be difficult since blue jays cannot be aged and sexed in the field unless they are first collected.

Depredations increased substantially in late September when pecan shucks (involucre) split longitudinally revealing the palatable nut. During fall, blue jays primarily consume mast; in natural environments this consists mainly of oak and hickory nuts. Pecans represent a preferred food resource for blue jays during fall since they provide an easily exploited, superabundant food resource. Blue jays benefit energetically by exploiting these crops rather than natural forest crops.

Leppla (1) quantified food habits of blue jays collected in Oklahoma pecan orchards during fall 1978 and 1979. Although over 85% of all jays (1978 and 1979) had eaten insects (primarily coleoptera and orthoptera), over 65% consumed plant matter. Of the plant matter, over 40% was mast comprised of approximately equal amounts of pecans and acorns. When comparing 1978 and 1979 data, however, there appeared to be an inverse relationship between percent frequency of occurrence of pecans and acorns.

Jays searched for pecans by visually scanning pecan branches while perched or by actively moving throughout the tree. These activities took relatively little time (<1 min), especially during periods of peak pecan availability (between crop maturity and initiation of harvest operations). Once a nut was procured, 1 of 3 activities occurred: consumption, caching, or discarding of the nut.

Blue jays consumed pecans by holding the nut between their feet while perched on a relatively large branch and hammering at it with their bill. It took approximately 1.5 min for a blue jay to crack open a pecan and about 1 min to consume the nut meat. Oftentimes the meat was incompletely consumed and at least ½ of the nut meat was usually wasted. Following these activities, the nut was discarded at the foraging site. Nuts were discarded even if consumption activities did not take place but the reason for this is not known. However, on 1 occasion a jay was observed cracking open a nut but it was discarded when the jay detected a pecan weevil (Curculio caryae).

Caching or food storage activities were frequently observed. Blue jays are capable of carrying up to 3 pecans at one time: 1 pecan each in throat, mouth, and bill. After obtaining these nuts, they flew along distinct corridors or flight-lines between pecan grove and oak upland habitat types. Typically, flight-lines averaged 50-500 m in length and about 25 m in width. Food storage flights occurred during periods of peak nut availability. Although they took place throughout the day, they appeared to be most intense at midmorning on relatively windless days. Leppla (1) estimated pecan caching loss by blue jays in fall and early winter 1979 at over 400 kg. This represented approximately 1% of total production. After arriving at the oak upland sites the pecans were either consumed or stored. The proportion of pecans stored to those eaten in oak upland sites is unknown, but in either case the nuts are unavailable for harvest and cannot be economically recovered. Food-storing jays probed the forest litter and soil with their bills and deposited one or more nuts in the depression created. It is not known if stored pecans were recovered.

Several habitat-use patterns were identified during this study. Areas where jays foraged were characterized by trees with a large DBH, small perches, and low tree density far from a distinct habitat change. They consumed food on larger perches than were used for other activities and were found in relatively dense areas when nonforaging. Large perches were required to effectively hold and crack open a nut.

Blue jay control attempts will never be 100% effective. Under the most intensive control programs some damage will still occur. However, implementation of several control procedures applied simultaneously should reduce damage to an acceptable level.

Blue jays searched for pecans in the highest nut production areas and did not forage in low nut production areas. Manipulation of pecan grove characteristics to produce areas where blue jays did not forage would conflict with maximum nut production goals. Thus other indirect and direct methods of control are needed.

Shooting appears to be the most effective direct control measure. However, many growers use this technique inconsistently, resulting in minimal effectiveness. Shooting should occur during peak jay activity periods (sunrise-11:00 AM) and should be most intensive during peak population levels; in Oklahoma, early October. Since high population levels coincided with peak nut availability, growers can be confident that they are destroying depredating jays. Blue jays are a migratory bird protected by federal law and kill permits must be obtained from the U.S. Fish and Wildlife Service to legally use this method.

Sound-scare devices such as propane exploders, are most effective when reinforced with periodic shooting or other forms of human disturbance. These devices should be moved around within the groves at least twice a week to prevent habituation of the jays to the sound or its source.

One of the most promising indirect control measures is an early harvest management regime. Darrell Sparks (pers. comm.) reported that early harvest of Georgia pecans was effective in reducing blue jay damage levels. Essentially, removal of the food resource eliminates the target of depredating jays. This method has great promise in Oklahoma pecan orchards but professional horticulturists and growers must work together to make early harvesting feasible considering marketing, equipment, cost, and personnel limitations.

It has been recognized by several Oklahoma growers that pecan damage levels appear lower when acorn production in adjacent oak upland forests is high. Leppla (1) substantiated this observation and suggested another indirect control procedure. Theoretically, by improving oak mast production pecan damage levels should be lower since blue jays seem to prefer acorns over pecans. Acorns are preferred since they are smaller and have thin shells which makes them easier to manipulate and consume. Acorn production could be increased through selective cutting of subdominant oaks and other competing trees. This would release trees in the upper canopy from overcrowding and shading, and facilitate higher mast yields. With increased demands for firewood, cordwood cutting is a promising incentive for achieving desired oak stand conditions.

In conclusion, we would like to reiterate a previous point: maximum reduction of jay depredation levels should result from several direct (shooting, sound-scare devices) and indirect (early harvest, improved oak mast production) control measures applied simultaneously. Although intensive control may be costly, current blue jay damage levels in Oklahoma are severe enough to warrant a major control effort.

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VITA

Gordon Raymond Batcheller

Candidate for the Degree of

Master of Science

Thesis: THE ECOLOGY AND BEHAVIOR OF BLUE JAYS IN OKLAHOMA PECAN ORCHARDS

Major Field: Wildlife Ecology

Biographical:

Personal Data: Born in Riverhead, New York, 25 November 1956, the son of Edward J. and Helen J. Batcheller.

Education: Graduate of Northport High School, Northport, New York, June 1974; attended Maine Maritime Academy, Castine, Maine, 1974-1975; received the Bachelor of Science degree in Wildlife Management, University of Maine at Orono, Orono, Maine, May 1978; completed the requirements for the Master of Science degree in Wildlife Ecology at Oklahoma State University, Stillwater, Oklahoma, December 1980.

Professional Experience: Graduate Research Assistant, Oklahoma Cooperative Wildlife Research Unit, Oklahoma State University, Stillwater, Oklahoma, 1978-1980.

Professional Organizations: The Wildlife Society, Wildlife Management Institute, Wildlife Disease Association, American Ornithologists Union, Wilson Ornithological Society, Northeastern Bird-banding Association.