PRODUCTIVITY AND NEST-SITE SELECTION OF EASTERN BLUEBIRDS IN WISCONSIN

by

Steven M. Kruger

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APPROVED BY THE GRADUATE COMMITTEE OF:

Dr. James W. Hardin
Committee Chairman
Associate Professor of Wildlife

Dr. Raymond Anderson
Professor of Wildlife

Dr. Richard D. Hillier
Associate Professor of Biology

Mr. Kim Mello
Fisheries/Wildlife Specialist
Department of Army
Fort McCoy

PREFACE

This thesis consists of 2 technical papers describing the data that I collected while studying the productivity and nest-site selection of eastern bluebirds (Sialia sialis) in Wisconsin, 1983 and 1984. The paper "Nest-Site Selection of Eastern Bluebirds in Wisconsin" will be submitted to the Journal of Wildlife Management. Data collected but not presented in the papers are provided in the Appendices.

The number of people that contributed to this study is large, and I am indebted to all. Kim and Vicki Mello not only provided the stimulus for the study, but offered assistance, guidance, and support thoughout. Field assistance was provided by Mark Mosey and Jeff Bullen. Drs. R. Roberts and F. Hilpert assisted with statistical analysis of the data. Jeri Thorpe typed the manuscript.

Dr. J. Hardin, committee chairman, reviewed the thesis and provided editorial comments and support. Dr. R. Anderson, Dr. R. Hillier, and Mr. Kim Mello provided additional review of the thesis. My wife Lori, provided support and assistance throughout the study, and shared me unselfishly with the bluebirds for the past 3 years.

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PRODUCTIVITY OF THE EASTERN BLUEBIRD IN WISCONSIN

STEVEN KRUGER, College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, WI 54481

Abstract: Productivity information on eastern bluebirds (Sialia sialis) was collected from 3344 nest boxes in Wisconsin in 1983 and 1984. Bluebirds occupied 24.5% (N=819) of the available nest boxes. The proportion of nest boxes used by bluebirds and Breeding Bird Survey (BBS) results from Wisconsin indicated that bluebird densities were highest in southwestern Wisconsin and lowest in the southeastern portion of the state. Bluebirds produced 4609 eggs ($\bar{x}$=4.23 eggs/nest attempt), 3414 hatchlings ($\bar{x}$=2.74 hatchlings/nest attempt), and 2992 fledglings ($\bar{x}$=2.74 fledglings/nest attempt). Young were successfully fledged from 70.3% of the nests (N=1090). Of 4609 eggs laid, 1195 (26.9%) were lost prior to hatching or failed to hatch. Of 3414 young hatched, 422 (12.4%) were lost prior to fledging. Once hatched, 87.6% of the young fledged. Based on these productivity data and known bluebird mortality rates, the bluebird population in Wisconsin should have increased in 1983 and 1984. Tree swallows (Tachycineta bicolor), house sparrows (Passer domesticus), and house wrens (Troglodytes aedon) occupied 37.2% (N=1244), 8.5% (N=283), and 7.3% (N=243) of the nest boxes, respectively.

Few species have benefited from man's early activities in North America as the eastern bluebird. Clearing of the eastern forests through lumbering operations and farming created near optimal conditions for

bluebirds (Heard 1979). As a species which greatly benefits from fires (Lloyd 1938, Ahlgren and Ahlgren 1960, Stoddard 1963), bluebirds also prospered as a result of the extensive slash-fires which followed logging operations (Pinkowski 1977).

By the early 1960's, bluebirds had suffered a substantial population decline (James 1959, 1961, 1962, 1963; Mahan 1963; Beardslee and Mitchell 1965). James (1962) reported the 1962 Christmas Bird Count population of bluebirds as 80% below the 20-year average of 1938-1958. Zeleny (1976) estimated that bluebirds declined by 90% throughout their range during a 40-year period. Breeding Bird Survey results in Wisconsin from 1966 to 1980 indicated that bluebird populations declined by 76% (Robbins 1982). Bluebirds are currently on the Wisconsin Department of Natural Resources' "Watch" species list (Les 1979).

Numerous studies (Laskey 1939, 1940; Musselman 1935; Thomas 1946; White and Woolfenden 1973; Heard 1979; Hurst 1983) have reported on the use of nest boxes by bluebirds. These studies involved relatively small sample sizes and focused on restricted geographic locations. The objective of this study was to gather productivity information on bluebirds within a portion of Wisconsin to compare productivity among regions of the state, determine the major causes of nest failure, and document the use of nest boxes by other avian species.

STUDY AREA AND METHODS

The study was conducted in 1983 and 1984 in 44 Counties in Wisconsin. The state's flora, physical geography, climate, soil, and plant communities are described by Curtis (1959). Robbins (1977, 1982)

divided Wisconsin into 8 Breeding Bird Survey (BBS) regions based on previous rock, soil, and vegetative studies (Martin 1932, Curtis 1959) (Fig. 1). Locations and ownerships of bluebird nest box trails in each BBS region were obtained through announcements published in popular state environmental, conservation, and natural resource newsletters and magazines. Respondents to the announcements were sent information about the study and asked to complete and return an enclosed questionnaire.

Participants were sent standardized data collection forms with detailed instructions on what to look for and how to record their observations. Nest boxes were inspected every 7 days from 15 April through 31 August. Information collected included: date the nest box was inspected, presence or absence of nesting material, species occupying the nest box, number of eggs and/or young present, and probable causes of mortality or nest failures. Data collection forms were retrieved from the cooperators in early September. Descriptive and chi-square statistics were used to analyze the data.

RESULTS AND DISCUSSION

Productivity data were collected from 1662 and 1682 nest boxes in 1983 and 1984, respectively. Productivity reports were obtained from all BBS regions except Region-1. The average nest box trail had 25.4 nest boxes ($\underline{N}$=131), and had been maintained 5.3 years ($\underline{N}$=73) prior to the 1983 nesting season. All results represent the combined data from 1983 and 1984.

Nest Box Use

Bluebirds occupied (a minimum of 1 egg was laid) 24.5% of the available next boxes (N=3344). The proportion of the nest boxes occupied by bluebirds in BBS Regions-2 through 8 ranged from 7.5 to 35.0% (Table 1), and differed (X^2=108, P<0.005) between regions (Table 2). Region-7, which includes the unglaciated portion of Wisconsin, had the largest proportion of nest boxes used by bluebirds. The vegetation in Region-7 consists of a mixture of xeric forests and prairie grasslands, creating savanna-like conditions (Curtis 1959). Pinkowski (1976) and Thomas (1946) reported that bluebirds preferred to nest in savanna-like areas. The lowest proportion of nest boxes used by bluebirds was in southeastern Wisconsin (Regions-5 and 8). This region is highly urbanized, with the rural areas characterized by the use of intensive agricultural practices. Both conditions provide suitable habitat for house sparrows which compete with bluebirds for nest sites (Kibler 1969, Zeleny 1976).

The 1980 through 1983 BBS results from Wisconsin were compared with nest box use by bluebirds. A significant (r=0.67, P<0.10) correlation existed between the average number of bluebirds observed per BBS transect and the percent of nest boxes occupied by bluebirds in each region. BBS results also indicated that bluebird densities were lowest in southeastern Wisconsin (Regions-3, 5 and 8), and highest in the southwestern portion of the state (Regions-6 and 7) (Table 3).

Tree swallows occupied 1244 (37.2%) nest boxes, and were the most common species using the boxes. Over 50% of the nest boxes in northern Wisconsin (Regions-2 and 4) were occupied by tree swallows. Kibler

(1969) and Kruger (1985) found that tree swallows preferred to nest near water. The relatively large amount of open water in northern Wisconsin is probably responsible for the high proportion of nest boxes used by tree swallows.

House sparrows, house wrens and black-capped chickadees (Parus atricapillus) occupied 283 (8.5%), 243 (7.3%), and 40 (1.2%) nest boxes, respectively. Assuming that nest box use should be equal in all regions of the state, the percent of the nest boxes occupied by tree swallows, house sparrows, and house wrens differed ($P<0.005$) between BBS regions (Table 2). As expected, house sparrow occupancy was highest in Region-8 where they occupied 23.3% ($N=50$) of the boxes.

Tree swallows were major competitors for nest boxes in all regions of the state based on the percent of the boxes that they occupied. House sparrows and house wrens occupied more than 10% of the nest boxes in Regions-4, 7 and 8 (Table 4). Competition for nest sites is often listed as a major cause of the bluebird decline. Zeleny (1976) listed tree swallows, house wrens, house sparrows and European starlings (Sturnus vulgaris) as major competitors for nest sites.

Competition with other avian species did not appear to limit the number of nest boxes used by bluebirds except in Regions-4 and 8. With the exception of Region-5 where the sample size was relatively small ($N=133$), Regions-4 and 8 were the only regions where the number of nest boxes occupied by bluebirds was less than expected (Table 2). House sparrows occupied 12.1% ($N=87$) and 23.3% ($N=50$) of the nest boxes in Regions-4 and 8, respectively. Compared with the rest of the state, house sparrows occupied more nest boxes than expected in both regions

(Table 2). These regions were also the only regions where 2 avian species competing with bluebirds for nest sites occupied more nest boxes than expected (Table 2).

Productivity and Breeding Success

Bluebirds produced 4609 eggs ($\bar{x}$=4.23 eggs/nest attempt), 3414 hatchlings ($\bar{x}$=3.13 hatchlings/nest attempt), and 2992 fledglings ($\bar{x}$=2.74 fledglings/nest attempt) (Table 1). A nest attempt was defined as any nest in which a minimum of 1 egg was laid. Young successfully fledged (a minimum of 1 young fledged) from 70.3% of the nests (N=1090).

The mean clutch size of 4.23 eggs per nest (N=1090) did not differ between regions. Numerous studies (Low 1934, Thomas 1946, Peakall 1970, Pitts 1976) have reported a mean clutch size for bluebirds ranging between 4.0 and 4.5 eggs. Peakall (1970) reported a mean clutch size of 4.51 eggs for bluebirds in Wisconsin (N=112), but did not include nest attempts with abnormally small clutches (<3 eggs) in his calculations. Exclusion of nests where <3 eggs were laid changed the mean estimated clutch size in this study to 4.31 eggs (N=1073).

The productivity of bluebirds in Wisconsin in 1983 and 1984 was above average when compared with 9 other studies (Table 5). The average number of young fledged per nesting attempt was 2.8 in 1983 and 2.7 in 1984. In both years, 70% of the bluebird nesting attempts were successful, and an average of 3.91 young fledged per successful nest. Peakall's (1970) analysis of 8109 bluebird nests revealed that nesting success varied from a low of 52.1% to a high of 78.3%.

Assuming that bluebird mortality rates have remained constant, the bluebird population in Wisconsin should have increased in 1983 and 1984 since productivity of bluebirds exceeded minimum numbers established by Pinkowski (1971). Pinkowski (1971) analyzed band recoveries of bluebirds from Michigan, Wisconsin, Illinois, and Ohio and found that the annual adult mortality rate of bluebirds was 50%; only 33% of the birds that fledged survived to the following breeding season. Using these mortality rates, Pinkowski (1971) theorized that populations in which bluebirds produced more than 2 young per nesting attempt would remain stable, and in populations where each successful nest produced 4 fledglings, only 51% of the nests needed to be successful.

Egg and Hatchling Losses

Of 4609 bluebird eggs laid, 1195 (26.9%) were lost prior to hatching or failed to hatch. Egg losses were classified and placed into 6 categories (Table 6). Failure of the eggs to hatch was the largest factor responsible for egg mortality. Causes of egg loss were difficult to determine; 830 (69.1%) were lost to unidentified causes (Table 7). Major causes of egg loss included: bluebirds rebuilding nests over the eggs (N=98), mammalian depredation (N=77), house wren depredation (N=73), and death of an adult bluebird (N=40).

Of 3414 young hatched, 422 (12.4%) were lost prior to fledging. Hatchling losses were classified and placed into 4 categories (Table 8). Death of the young in the nest accounted for 62.1% (N=252) of the hatchling losses. Causes of hatchling losses were also difficult to determine; 344 (81.5%) were lost to unidentified causes (Table 9).

Review of hatching and fledging success of bluebirds in Wisconsin indicated that the greatest mortality occured during the egg stage; once hatched, 87.6% (N=2992) of the young fledged.

Depredation by raccoons (Procyon lotor), house wrens, house sparrows, and fox snakes (Elaphe vulpina) was responsible for a minimum of 15% (N=178) of the egg losses, and 7% (N=31) of the hatchling losses in this study. Depredation by snakes, mammals, house wrens, and house sparrows was listed as the major cause of mortality of bluebird eggs and young by Thomas (1946), Nice (1957), and Pitts (1976). Over 23% (N=281) of the eggs did not hatch, which is considerably higher than the 6.9% (N=71) reported by Laskey (1940) and 5.9% (N=69) by Pitts (1976). Thomas (1946) found a comparable rate of 24% (N=24) in her study of bluebirds in Arkansas. Despite the large number of eggs that did not hatch, hatching and fledging success of bluebirds in Wisconsin was above average when compared with other studies (Table 5).

Summary

Productivity information on bluebirds was collected from nest boxes throughout Wisconsin in 1983 and 1984. The proportion of the nest boxes used by bluebirds and BBS results from Wisconsin indicated that bluebird densities were highest in southwestern Wisconsin and lowest in the southeastern portion of the state. Contrasting habitat conditions and competition for nest sites in these portions of Wisconsin were used to explain the differences in bluebird densities.

Southwestern Wisconsin undoubtedly has the best habitat for nesting bluebirds in the state. Urban development and intensive

agricultural practices in southeastern Wisconsin have not only reduced the amount and quality of bluebird habitat, but have created habitat conditions that are suitable for house sparrows. House sparrows then compete with bluebirds for a limited number of nest sites.

Productivity of bluebirds in Wisconsin was above average when compared with 9 other bluebird studies. Of 1090 nesting attempts, 70.3% were successful. The average number of young fledged per nesting attempt was 2.8 and 2.7 in 1983 and 1984, respectively. Based on these data and known bluebird mortality rates, the bluebird population in Wisconsin should have increased in 1983 and 1984.

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Table 1. Nest box use and productivity of eastern bluebirds in Wisconsin, 1983 and 1984.

BBS Region	Occupied boxes[a] N	Occupied boxes[a] %	Nest attempts[a] N	Eggs laid N	Young hatched N	Young fledged N
2	157	26.7	210	907	729	691
3	86	20.5	106	459	368	326
4	103	14.3	140	586	437	403
5	10	7.5	10	36	15	15
6	51	27.7	66	269	222	213
7	380	35.0	521	2194	1504	1224
8	32	14.9	37	158	139	120
Total	819	24.5	1090	4609	3414	2992

[a] A minimum of 1 egg was laid.

Table 2. Chi-square analysis[a] on the number of nest boxes occupied by bluebirds, tree swallows, house wrens, and house sparrows in BBS regions 2-8 in Wisconsin, 1983 and 1984.

BBS Region	Number of nest boxes used by			
	Bluebirds	Tree Swallows	House Wrens	House Sparrows
2	E	G**	F**	F**
3	E	E	E	E
4	F**	G**	F*	G**
5	F**	F*	E	E
6	E	E	E	F*
7	G**	F**	G**	E
8	F**	F*	G**	G**

[a] E-number observed equaled expected; F-number observed was less than expected; G-number observed was greater than expected.

* $P<0.05$
** $P<0.005$

Table 3. Breeding bird survey results on the eastern bluebird in Wisconsin; 1980 through 1983 combined[a].

BBS Region	Transects surveyed N	Bluebirds observed N	Bluebirds per transect $\bar{x}$
2	112	95	0.85
3	11	2	0.18
4	31	36	1.16
5	4	0	0.00
6	11	18	1.64
7	55	65	1.18
8	27	7	0.26
Total	251	223	0.89

[a] Unpublished data provided by the USFWS Bird Banding Laboratory.

Table 4. Number of nest boxes occupied[a] by tree swallows, house sparrows, and house wrens in Wisconsin, 1983 and 1984.

BBS Region	Boxes available N	Number of boxes used by: Tree Swallow N	Tree Swallow %	House Sparrow N	House Sparrow %	House Wren N	House Wren %
2	587	322	54.9	20	3.4	20	3.4
3	420	140	33.3	30	7.1	21	5.0
4	720	360	50.0	87	12.1	32	4.4
5	133	33	24.8	7	5.3	9	6.8
6	184	66	35.9	7	3.8	12	6.5
7	1085	263	24.2	82	7.6	115	10.6
8	215	60	27.9	50	23.3	34	15.8
Total	3344	1244	37.2	283	8.5	243	7.3

[a] A minimum of 1 egg was laid.

Table 5. Comparison of productivity in 10 eastern bluebird studies.

Reference	Nest attempts[b] N	Nests successful[c] N	%	Eggs laid N	Hatched N	%	Fledged N	%
Low 1934	86			377	302	80.1	274	72.7[d]
Musselman 1935	301			1290			839	65.0
Walkinshaw 1941	50			203	131	64.5	127	62.5
Laskey 1943[a]	1401			6260	3943	63.0	2786	44.5
Thomas 1946	67	47	70.1	272	213	78.3	172	63.2
Pitts 1976	268	125	46.6	1173	730	62.2	471	40.2
Pinkowski 1979	314	185	58.9	1267			660	52.1
Heard 1979	140	83	59.3	619	389	62.8	340	54.9
Hurst 1983	102	84	82.4	427	351	82.2	328	76.8
Total	2729		58.8	11,888		64.9	5997	50.4
This study	1090	766	70.3	4609	3414	74.1	2992	64.9

[a] Nice 1957.

[b] A minimum of 1 egg was laid.

[c] A minimum of 1 young fledged.

[d] Percent of eggs that became fledged birds.

Table 6. Categories of eastern bluebird egg losses in Wisconsin, 1983 and 1984.

Category of egg loss	N	%
Eggs did not hatch	281	23.5
Eggs were abandoned	274	22.9
Eggs missing from nest	214	17.9
Eggs destroyed	181	15.2
Eggs buried under nest material	124	10.4
Unknown	121	10.1
Total	1195	100.0

Table 7. Causes of eastern bluebird egg losses in Wisconsin, 1983 and 1984.

Causes of egg loss	N	%
Unknown	830	69.5
Bluebird nest over eggs	98	8.2
Mammalian depredation	77	6.4
House wren depredation	73	6.1
Adult bluebird died	40	3.3
Tree swallow nest over eggs	26	2.2
House sparrow depredation	24	2.0
Human disturbance	12	1.0
Storm damage to nest box	11	1.0
Snake depredation	4	0.3
Total	1195	100.0

Table 8. Categories of eastern bluebird hatchling losses in Wisconsin, 1983 and 1984.

Category of hatchling losses	N	%
Young died in nest box	262	62.1
Young missing	67	15.9
Young abandoned	13	3.0
Unknown	80	19.0
Total	422	100.0

Table 9. Causes of eastern bluebird hatchling losses in Wisconsin, 1983 and 1984.

Causes of hatchling losses	N	%
Unknown	344	81.5
Excessive heat[a]	28	6.6
Mammalian depredation	24	5.7
Adult bluebird died	11	2.6
Human disturbance	7	1.7
Snake depredation	4	1.0
House sparrow depredation	2	0.5
House wren depredation	1	0.2
Young physically deformed	1	0.2
Total	422	100.0

[a] Suspected cause.

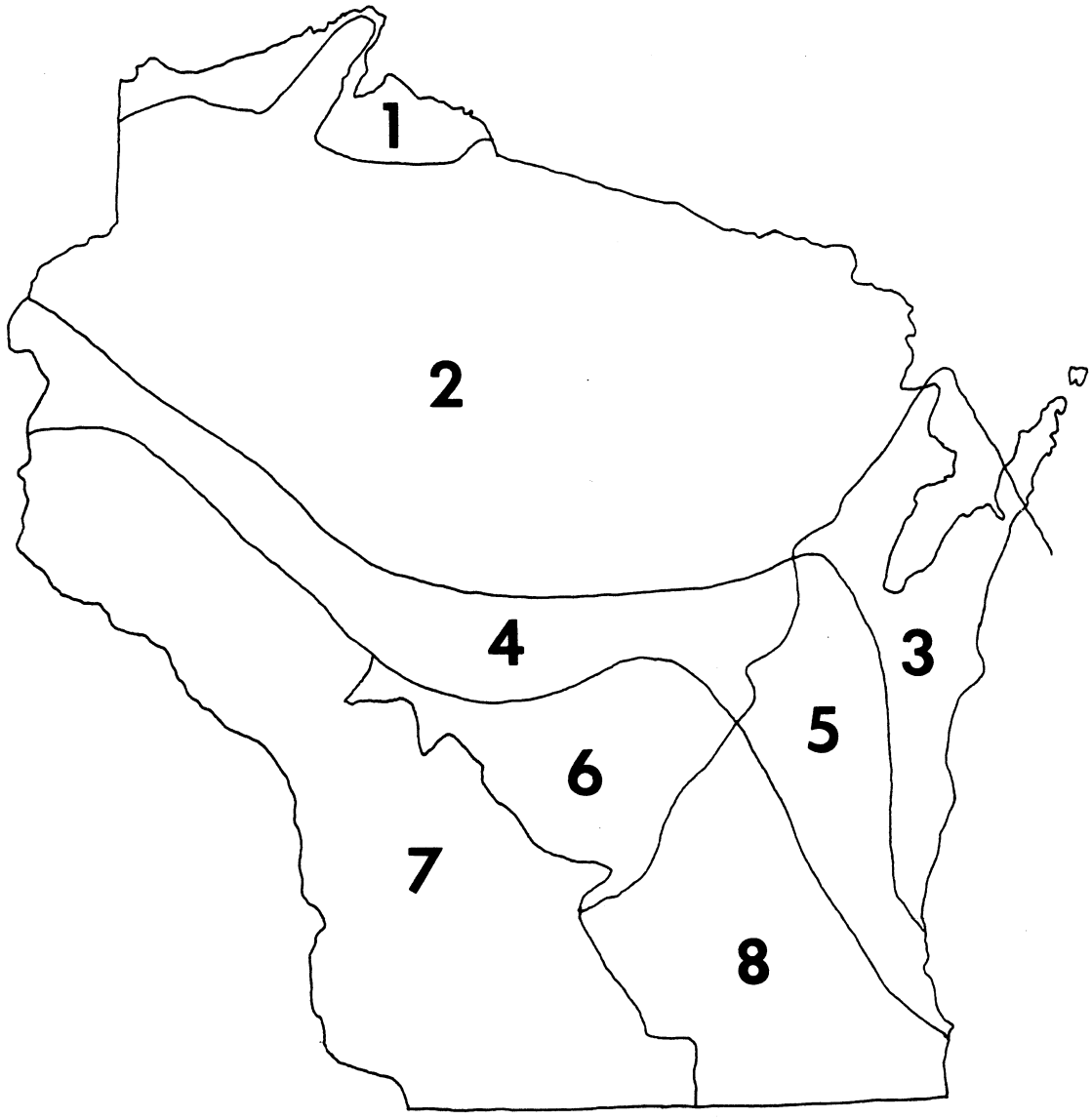

Figure 1. The boundaries of 8 breeding bird survey regions in Wisconsin (Robbins 1982).

NEST-SITE SELECTION OF EASTERN BLUEBIRDS IN WISCONSIN

STEVEN KRUGER, College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, WI 54481

Abstract: Forty-two descriptive variables were used to evaluate 194 nest box sites in southwestern Wisconsin in 1983 and 1984. Eastern bluebirds (Sialia sialis) occupied 118 (60.8%) of the available nest boxes. One-way ANOVA, chi-square, and logistic regression analyses were used to differentiate between occupied and unoccupied nest boxes. Bluebirds tended to select nest sites in open areas, and avoided sites with substantial shrub and canopy cover. Nest boxes most likely to be used by bluebirds had <5% shrub cover within 11.25 m of the nest, <10% canopy cover within 30.0 m of the nest, were >35 m from the nearest forest edge, and >200 m from the nearest permanent water source. A logistic model that will predict the probability (ranging from 0-100%) that a nest box will be occupied by bluebirds is presented. Use of the logistic model should increase the efficiency of nest box trails by ensuring that nest boxes are placed only in locations most likely to attract bluebirds.

Once described as a common species by Audubon (1937), the eastern bluebird has suffered a substantial population decline throughout its range (James 1962, 1963). Wallace (1959) and Zeleny (1976) implicated habitat loss as a major factor in this decline. The lack of information on habitat selection of nesting bluebirds prevents us from assessing the problem of habitat loss. Despite the relatively large amount of information available

on the breeding biology of the bluebird (Thomas 1946; Kibler 1969; Peakall 1970; White and Woolfenden 1973; Pinkowski 1974, 1977a; Pitts 1977), few quantitative studies on habitat selection by nesting bluebirds have been conducted (Heard 1979, Otello 1982, Munro and Rounds 1985). The lack of quantitative information is a major deterrent to nongame bird management (Hooper and Crawford 1969, Smith 1975, DeGraaf 1978). The objective of this study was to determine the nesting habitat selected by eastern bluebirds in Wisconsin.

STUDY AREA

The study was conducted on Fort McCoy, a 24,200-ha military installation in west central Wisconsin. The area lies in a transitional zone between the northern and southern xeric forests of the state (Curtis 1959). Forests cover 72% of the installation, with oaks (*Quercus* spp.), and jack, white and red pine (*Pinus banksiana*, *P. strobus* and *P. resinosa*) being the dominant tree species; grasslands, savannas and open water comprise the remaining 28% of the area (Mello and Hauser 1981). Ten streams and 13 small lakes and ponds are present on the area (Mello and Hauser 1981). This region is part of the unglaciated section of Wisconsin which is characterized by ridges and broad valleys with predominately sandy soils (USDA 1984).

METHODS

Data were collected between 1 June and 31 August in 1983 and 1984. Forty-two descriptive variables were evaluated at each nest site. Circular plots of 11.25 and 30.0-m radii were established with the nest box as the

center (James and Shugart 1970, Otello 1982). Variables measured within the 11.25-m plot included: shrub height; shrub cover (SHRUBCV); presence or absence of perches; box design (BOXTYPE); structure to which the nest box was attached; height of entrance hole above the ground (CAVHT); entrance hole orientation and aspect relative to the nearest forest edge; and presence or absence of tree canopy directly above the box (CANOPY). A visual estimate of the percentage of the 11.25-m plot covered by shrubs was made. The estimate was categorized using an ordinal scale (Daubenmire 1968).

Habitat variables measured within the 30.0-m plot included: presence or absence of perches; percent canopy cover (CPCV) (Otello 1982); percent ground cover (James and Shugart 1970); number of trees >7.6 cm dbh (TOBOLES); average tree height; average tree dbh; tree species present; presence or absence of coniferous and deciduous shrubs; average ground cover height and density; and types of herbaceous cover present. The 30.0-m plot was divided into quarters with a line extending towards the nearest forest edge and a second line running perpendicular to the first. Distance to the nearest tree >7.6 cm dbh (DISTREE 1 to 4) was measured in each quarter. Tree dbh (NBTDBH) and species were recorded for trees on which boxes were attached. Other variables measured included: elevation; aspect; slope; soil texture; presence or absence of natural cavities within 60 m of the box (NC); and distances to the nearest perch, human disturbance, permanent water source, and forest edge (DISEDGE).

Coverage (%) of 9 habitat types was recorded within a 200-m radius of each nest box. Habitat types included: grassland (GRASS), grassland with scattered trees, grassland with shrubs, mixed even-aged hardwood forests,

red pine plantations < 1 m in height, red pine plantations > 3 m in height, water (WATER), buildings or commercially developed areas, and bare soil. Nest boxes were monitored weekly from 20 April through 31 August in both years to determine use by bluebirds. A box was considered to be occupied when 1 or more eggs were laid.

ANOVA analyses were used to identify variables that differed significantly ($P<0.10$) between occupied and unoccupied nest boxes. Variables with a significance level less than 0.10 were used in logistic regression analyses. Variables unsuitable for inclusion in ANOVA and logistic regression analyses were analyzed with chi-square tests.

RESULTS AND DISCUSSION

Vegetative analysis of 194 nest sites was completed; 118 (60.8%) of the sites were occupied by bluebirds. Bluebirds tended to select nest sites in open areas, and avoided sites with substantial shrub and canopy cover. One-way ANOVA (Nie et al. 1975) identified 9 variables that differed significantly between occupied (active) and unoccupied (nonactive) nest sites (Table 1). Cavity height, nest box design, and presence or absence of natural cavities also differed between active and nonactive nest sites (Table 2).

James (1971) and Whitmore (1975) conducted studies on the ordination of avian communities. Both studies concluded that canopy cover, canopy height, and the number of trees per unit area were powerful variables for describing habitat differences. Whitmore (1975) found that percent shrub cover and percent ground cover were also important discriminators describing habitat selection. With the exceptions of percent ground cover

and canopy height, I also found the variables listed by James (1971) and Whitmore (1975) to be important in describing differences between active and nonactive nest sites.

Effects of Shrub and Canopy Cover

Nest sites selected by bluebirds had significantly ($P<0.05$) more grassland (GRASS) than nonactive sites; suitability of a site was reduced as canopy cover increased. Bluebirds occupied nest sites that had less shrub and canopy cover, fewer trees, and were farther from the forest edge than unoccupied nest sites (Table 1). Presence of canopy directly above the nest box was avoided by bluebirds (Table 2). Bluebirds preferred ($P<0.05$) nest boxes placed on smaller trees (<34 cm) over those placed on larger trees. Presumably, larger trees had larger canopies which were avoided.

Bluebirds typically nest in savanna-like areas with abundant open ground (Thomas 1946, Pinkowski 1976). Mature forests with significant amounts of canopy cover are unsuitable for nesting bluebirds (Pinkowski 1976, Heard 1979, Hurst 1983). Pinkowski (1979) found that bluebirds required relatively open areas with scattered perches to forage. Substantial shrub and canopy cover reduces the bluebird's foraging efficiency and the suitability of a site for nesting.

The bluebird's selection against forested and shrubby areas may result from competition it receives for nest sites from house wrens (*Troglodytes aedon*). House wrens prefer to nest along the forest's edge and in shrubby areas (Pinkowski 1977b, Willner et al. 1983, Munro and Rounds 1985). Munro and Rounds (1985) reported that all house wren nests in their study ($N=18$)

were within 30 m of a tree or shrub. The average distance between the nearest forest edge and house wren nests in this study was 28.5 m (N=12). Because of their strong attachment to forested and shrubby areas, house wrens are major competitors with bluebirds for nest sites in those habitats (Zeleny 1976, 1985).

Three factors suggested that bluebirds avoided nesting in woodland and shrubby areas because of house wren competition: (1) The average distance from the nest box to the nearest forest edge was significantly (P<0.10) different between active and nonactive bluebird nest sites. The average distance to the nearest forest edge for nonactive nest sites was 31 m which is near the 30 m distance reported by Munro and Rounds (1985) where house wren nesting occurs. The average active nest site was 38 m from the nearest wood's edge. (2) Bluebirds were less likely to occupy nest boxes placed on the wood's edge (X^2=10.47, P<0.005) than boxes placed off the wood's edge. (3) Shrub cover around active nest sites was significantly (P<0.05) less than shrub cover around nonactive nest sites (Table 1). In each situation, bluebirds avoided habitat conditions favorable to house wrens.

Effects of Water

The percent of the 200-m radius plot covered by water (WATER) differed significantly (P<0.05) between active and nonactive nest sites. Nonactive nest sites averaged 2% of the plot covered by water compared with 0.5% for active nest sites. Tree swallows (*Tachycineta bicolor*) preferred (X^2=7.75, P<0.025) nest sites where water was within the 200-m plot. Nest sites with

water within the plot attracted more tree swallows and fewer bluebirds than nest sites without water (Table 4).

Tree swallows are closely associated with water and frequently use bluebird nest boxes (Kibler 1969). I found that tree swallows occupied 37% (N=3344) of the nest boxes monitored in Wisconsin and were the most common species using the boxes (Kruger 1985). Tree swallows and bluebirds select nest sites in habitats with similar characteristics (Willner et al. 1983, Munro and Rounds 1985). Both species prefer to nest in open areas, but tree swallows frequently nest near water (Bent 1942, Kibler 1969). Unlike bluebirds, tree swallows are not dependent on perches for foraging (Otello 1982). Because of their preference for similar nesting habitat, competition for nest sites exists between tree swallows and bluebirds near water.

Nest Box Design

Three nest box designs were used in this study (Table 2). The box design with an internal floor area of 12.7 x 12.7 cm was preferred by bluebirds (X^2=5.55, P<0.10). Pinkowski (1976) reported that the average internal diameter of natural cavities used by bluebirds was 9.2 cm (N=64), but cavities with internal diameters as small as 5.7 cm were used. Conner and Adkisson (1974) found an average internal diameter of 17.1 cm (N=7) for cavities used by bluebirds. Although the 10.2 x 10.2 cm box had 36% less floor space than the 12.7 x 12.7 cm box, both designs offered adequate floor space for nesting according to Pinkowski (1976). It was not clear why the box design with a 12.7 x 12.7 cm floor was preferred by bluebirds in this study.

There has been considerable experimentation and discussion over which nest box design is best for bluebirds (Kibler 1969, Burtt 1979, Patterson 1979). The objective of most box designs has been to make the box less desirable to species such as house sparrows (Passer domesticus) and tree swallows. Munro and Rounds (1985) found that nest box design was not important for eastern bluebirds.

Logistic Regression

With the exception of NBTDBH, the independent variables listed in Tables 1 and 2 were used in the logistic regression (LR) analysis (Harrell 1980). The resulting logistic model can be used to predict the probability (ranging from 0 to 100%) that bluebirds will occupy a nest site. The stepping computations used were based on the maximum likelihood ratio method (Harrell 1980).

LR analysis selected CAVHT, SHRUBCV, CPCV, and WATER for use in the logistic model. The coefficients indicated that these variables were negatively correlated with the suitability of a nest site for bluebirds (Table 3). As cavity height, shrub and canopy cover, and the amount (%) of water within 200 m of the nest box increased, the suitability of a nest site for bluebirds decreased. Because the coefficients are not in standardized form, we cannot assess the relative importance of the independent variables used in the logistic model (Kachigan 1982).

The logistic model states that the probability that a nest site was occupied by bluebirds equals:

$$\frac{e^{4.15+(-0.02\times CAVHT)+(-0.625\times SHRUBCV)+(-0.04\times CPCV)+(-0.116\times WATER)}}{1+e^{4.15+(-0.02\times CAVHT)+(-0.625\times SHRUBCV)+(-0.04\times CPCV)+(-0.116\times WATER)}}$$

where, the power to which e (the natural antilogarithm) is raised equals the sum of the coefficients multiplied by the values of the independent variables measured at the nest sites. Chi-square results from Brown and Hosmer goodness-of-fit tests were used to check the validity of the logistic model (Harrell 1980). The Brown and Hosmer tests had p-values of 0.758 and 0.954, respectively. Small p-values for either test would have indicated that the logistic model was invalid (Harrell 1980).

The probability that bluebirds would occupy a nest site was calculated for active and nonactive nest sites using the mean values for CAVHT, SHRUBCV, CPCV, and WATER (Table 1). The average active nest site had a 69% probability of attracting a bluebird, compared with 44% for the average nonactive nest site. The ability of the logistic model to correctly predict the probability that a nest site would be occupied by bluebirds was tested. The observed use of nest sites were compared with the predicted probability that nest sites would be occupied by bluebirds. The greatest source of error with the model occurred when the probability indicated that a nest site should be occupied by bluebirds but was not. This error probably resulted from the short length of the study. It is possible that some of the nest sites which were suitable for bluebirds were not occupied during the 2-year study. Territoriality, site tenacity, variation in local bluebird densities, and competition for nest sites with other avian species could have prevented bluebirds from occupying all suitable nest sites.

Management Recommendations

The following recommendations should be considered when planning the location of nest boxes for bluebirds:

1. Nest boxes should be placed a minimum of 35 m from the nearest forest edge to avoid competition with house wrens. Shrub density within a 11.25-m radius of the nest box should be <5%.
2. Nest boxes should be placed a minimum of 200 m from the nearest permanent water source to avoid competition with tree swallows.
3. Nest boxes should be placed in areas lacking natural cavities. Locations with natural cavities within a 60-m radius of the nest box were less likely ($\underline{X}^2=3.86, \underline{P}<0.05$) to attract bluebirds.
4. Nest boxes should not have canopy cover directly above them or be placed on the forest edge. If nest boxes are placed on live trees, dbh of the tree should not exceed 34 cm.
5. Entrance height of the nest box should not exceed 140 cm. Kibler (1969) suggested that lower placement of nest boxes reduced house sparrow competition.
6. Canopy cover within a 30-m radius of the nest box should not exceed 10%. The number of trees >7.6 cm dbh within the 30-m radius should be <20.
7. The area surrounding the nest box should be relatively open; at least 28% of the area within a 200-m radius of the nest box should be grassland with few scattered trees.

Use of the logistic model should increase the efficiency of nest box trails by ensuring that nest boxes are placed only in locations most likely to attract bluebirds. The model will also provide clues as to why a particular site is not likely to attract bluebirds. Use of empirical data in the model will show what habitat changes must occur before a nest site is suitable for bluebirds.

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Table 1. Descriptive statistics and F-ratios for one-way ANOVA of variables with significant differences between nest sites occupied[a] and unoccupied by eastern bluebirds in Wisconsin, 1983 and 1984.

Variable Code[b]	Occupied sites (N=118) $\bar{x}$	SD	Unoccupied sites (N=76) $\bar{x}$	SD	F-Ratio
DISEDGE (m)	37.8	29.0	31.1	26.2	2.61*
DISTREE2 (m)	23.4	16.4	19.2	15.1	3.22*
NBTDBH (cm)	33.8	9.7	39.6	11.4	5.99**
SHRUBCV (%)	0.25	0.6	0.54	0.8	7.43**
TOBOLES (N)	19.4	22.1	25.1	23.3	3.02*
CAVHT (cm)	137.4	22.8	150.3	25.0	13.68***
CPCV (%)	10.1	9.3	15.3	12.9	10.51***
GRASS (%)	28.3	16.8	23.5	16.8	3.69**
WATER (%)	0.5	2.2	2.0	5.5	6.64***

[a] A minimum of 1 egg was laid.

[b] DISEDGE-Distance to nearest forest edge.
DISTREE2-Distance to nearest tree.
NBTDBH- DBH of tree the nest box was attached.
SHRUBCV-Percent shrub cover.
TOBOLES-Number of trees.
CAVHT-Cavity entrance height.
GRASS-Percent grassland habitat.
WATER-Percent water habitat.
CPCV-Percent canopy cover.

* $\underline{P} < 0.10$
** $\underline{P} < 0.05$
*** $\underline{P} < 0.01$

Table 2. Chi-square results for variables with significant differences between nest sites occupied[a] and unoccupied by eastern bluebirds in Wisconsin, 1983 and 1984.

Variable Code[b]	Occupied sites N	Unoccupied sites N	Chi-square values
NC			
available	24 (30)[d]	25 (19)	3.86**
not available	94 (88)	51 (57)	
CANOPY			
present	30 (38)	33 (25)	6.83***
not present	88 (80)	43 (51)	
BOXTYPE[c]			
10.2 cm^2 Open	19 (23)	19 (15)	5.55*
10.2 cm^2 Closed	53 (56)	39 (36)	
12.7 cm^2 Closed	46 (39)	18 (25)	

[a] A minimum of 1 egg was laid.

[b] NC-Presence or absence of natural cavities.
CANOPY-Presence of canopy above the nest box.
BOXTYPE-Nest box design.

[c] Open refers to a screened off hole in the roof of the nest box. Closed refers to nest boxes without the hole. Measurement=floor space.

[d] Numbers in parentheses are expected values; numbers outside parentheses are observed values.

* $P<0.10$
** $P<0.05$
*** $P<0.01$

Table 3. Coefficients for the independent variables used in the logistic model to predict the probability that a nest box would be occupied by bluebirds in Wisconsin.

Variable Code[a]	Coefficients	Improvement chi-square	P-value
CAVHT	-0.020	12.95	0.000
SHRUBCV	-0.625	7.09	0.008
CPCV	-0.040	7.00	0.008
WATER	-0.116	7.62	0.006
Constant	4.15		

[a] CAVHT-Cavity entrance height.
SHRUBCV-Percent shrub cover.
CPCV-Percent canopy cover.
WATER-Percent water habitat.

Table 4. Nest box use by eastern bluebirds and tree swallows at nest sites with and without water within a 200-m radius of the nest box.

Species	Nest box use with water[a] (N=21)		Nest box use without water[b] (N=173)	
	N	%	N	%
Bluebirds	9	43	109	63
Tree Swallows	11	52	54	31

[a] Water present within 200-m radius of nest box.

[b] Water absent within 200-m radius of nest box.

Appendix A. Data form used to record productivity information collected from nest boxes in Wisconsin, 1983 and 1984.

1985

Nest Box #_____

EASTERN BLUEBIRD NEST BOX DATA FORM

Name of owner_____

Address_____City_____State_____ Zip_____

Nearest town/city to nest box_____

County in which the nest box is located_____

DATE	NEST PRESENT? yes/no	BIRD SPECIES	# EGGS	# YOUNG	COMMENTS*

* COMMENT CODES:

01-Adults observed near nest box
02-Nest appears disturbed by predator
03-Young have fledged or left nest
04-Female observed in the nest box
05-Nest deserted
06-Nest taken over by another bird species
07-Blow fly larvae present
08-wasps in nest box

Appendix B. Procedures and information provided to volunteers that collected productivity data from nest boxes in Wisconsin, 1983 and 1984.

Procedures for completing the bluebird data forms:

Bluebirds begin arriving in Wisconsin in early April and continue to nest into August. During this time period, nest boxes should be monitored every 7 days, with 10 days being the longest interval between checks. By checking the boxes this often you will observe things at the nest nest not seen if the boxes are checked less frequently.

It is important that each nest box is assigned a number. If you have 10 boxes, assign numbers 1 to 10 to the boxes. This method ensures that the data collected from each box is recorded on its own data form. Example: Anything observed in box #1 should be recorded on data form # 1, and so on. Carry the data forms into the field with you to make data collection easier.

Record the date and what you observe each time the nest box is checked. Do not disturb the birds needlessly by checking the boxes more than once a week. Several people have expressed concern that they may be disturbing the birds by looking in the boxes. Our records, and the records of others do not indicate that occasional visits to the nest box harm the birds using the boxes. Make your checks quickly, and leave the nest box alone until the next check. The data collected for this study will out-weigh any negative influence that you may cause.

On the data form you will find 6 columns to record the following information: date the nest box was inspected, presence of absence of nest material, the bird species using the nest box, the number of eggs and/or young, and a comment section. The comment section is for you to mention additional things that you observe at the nest sites. You may use the comment codes provided for you at the bottom of the data form or write what you observe.

A sample data form is attached. You will find many variations from this, but all should be easy to record. If you have any questions please contact me.

Appendix B. Continued.

1985

Nest Box # 1

EASTERN BLUEBIRD NEST BOX DATA FORM

Name of owner John Smith

Address Rt. 5 City Nowhere State WI Zip 54480

Nearest town/city to nest box Nowhere

County in which the nest box is located Portage

DATE	NEST PRESENT? yes/no	BIRD SPECIES	# EGGS	# YOUNG	COMMENTS*
5/1	NO	—	—	—	none
5/8	YES	Unknown	0	0	No adults observed.
5/15	YES	Bluebird	5	0	01
5/31	YES	Bluebird	0	5	Young hatched
6/7	YES	Bluebird	0	5	01
6/14	YES	Bluebird	0	0	03
6/21	YES	Tree Swallow	2	0	01, 04
		Continue to collect this			
		information through August.			

* COMMENT CODES:

01-Adults observed near nest box
02-Nest appears disturbed by predator
03-Young have fledged or left nest
04-Female observed in the nest box
05-Nest deserted
06-Nest taken over by another bird species
07-Blow fly larvae present
08-wasps in nest box

Appendix B. Continued.

Basic life history information on 4 bird species commonly found in nesting boxes:

Eastern Bluebird: Found in open areas with scattered trees. Nest is made of fine grasses and weed stems. 3 to 6 blue, sometimes white eggs are laid. Incubation is by female for 13 days. May raise 2 broods per year.

Tree Swallow: Found in open areas, especially common near water. Nest is made of fine grasses, and the cup is lined with many white feathers. 4 to 6 small white eggs. Incubation is by female for 13 to 15 days. Raises only 1 brood per year.

House Wren: Prefers to nest on the forest's edge and in shrubby areas. The nest is made up of small twigs, and is lined with fine grasses and feathers. 5 to 8 reddish-brown eggs are laid. Incubation is by the female for 12 to 15 days. Raises 1 brood per year.

House of English Sparrow: Found in cities and near farms, but its range is expanding into rural areas, Nest is a huge ball of course weeds and grasses. The nest is often lined with feathers. 3 to 7 white to whitish-green eggs which have gray or brown spots. Incubation is by the female for 12 days. Raises 2 broods per year. Note: THe house sparrow is an exotic species which is not protected by law. It should not be allowed to use nest boxes under any circumstances. The nest, eggs and adults should be distroyed whenever possible.

For additional information on these species see:

A Field Guide to Birds' Nests
A Peterson Field Guide Series
by Hal H. Harrison, 1975

Appendix B. Continued.

Identification of nesting failures:

Due to the importance of properly identifying the causes of nesting failures in bluebirds, I am including this information on identification of common causes of nest failure. I cannot over emphasize the importance of not guessing. If you cannot positively identify the cause of a nest failure indicate the cause as unknown. Include notes on any nest failure in the comment section of the data form.

Raccoon: A common predator of bluebirds which will eat the eggs, young, and adults. Raccoons can climb nearly anything, and can reach into the nest cavity to grab eggs or birds out of the nest. Look for a nest which looks disturbed. Claw or scratch marks may be found on the nest box. Raccoons eat their food outside the nest box, so look for coursely broken egg shell fragments or feathers outside the cavity.

House Wren: Another common cause of bluebird nesting failures. Most nest losses attributed to wrens occur in nests with eggs. THe male wren will enter the nest box and puncture the eggs with its beak. The holes may be small, so look closely. If aggressive, the male wren may remove the eggs from the nest and drop them outside of the box or carry them away.

House Sparrows: They destroy eggs, but frequently kill the young and adults by inflicting head wounds. House sparrows will peck at the head of a bluebird until it is dead. Look for bluebirds with with substantial damage to the scalp region. Feathers will be missing, and blood will be found. House sparrows frequently build their nests over the corpse of their victims; therefore, look under all house sparrow nests for dead bluebirds.

Snakes: They will eat the eggs, young and adults. It is very difficult to determine nest failures caused by snakes. They usually leave the nest with no visible clues. Unless you find a snake in the nest box do not tecord any nest failures as snake.

Other: Other causes of nest failure include unfavorable weather, human disturbance, squirrels, and wasps. Take note of anything that can be used to identify why a nest failed.

Appendix C. Nest box use by miscellaneous species in Wisconsin, 1983 and 1984.

Species	1983	1984
Deer mouse (*Peromyscus maniculatus*)	32	54
Flying squirrel (*Glaucomys volans*)	6	4
Red squirrel (*Tamiasciurus hudsonicus*)	0	8
Big brown bat (*Eptesicus fuscus*)	0	1
Gray treefrog (*Hyla versicolor*)	2	3
Great crested flycatcher (*Myiarchus crinitus*)	2	1
White breasted nuthatch (*Sitta carolinensis*)	1	1
European starling (*Sturnus vulgaris*)	1	0