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Nesting Dynamics of the Eastern Bluebird (Sialia sialis) in Southeastern Illinois

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NESTING DYNAMICS OF THE EASTERN BLUEBIRD (SIALIA SIALIS) IN SOUTHEASTERN ILLINOIS

(TITLE)

BY

SUSAN E. NELLE

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

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NESTING DYNAMICS OF THE EASTERN BLUEBIRD (*SIALIA SIALIS*) IN SOUTHEASTERN ILLINOIS

by

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B.S. in Environmental Biology and Zoology,
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ABSTRACT OF A THESIS

Submitted in partial fulfillment of the requirements
for a degree of Master of Science in Environmental Biology
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1989

NESTING DYNAMICS OF THE EASTERN BLUEBIRD (*SIALIA SIALIS*) IN SOUTHEASTERN ILLINOIS

ABSTRACT

Data collected from 1981 through 1988 from an Eastern Bluebird (*Sialia sialis*) nesting box trail, involving 512 nests and 2176 eggs, in Crawford County, Illinois, were analyzed and compared to similar published works. The average nesting season lasted 167.4 days, ran from 17 March through 31 August, and was divided into three breeding peaks (or phases). Most breeding pairs were observed with either one or two clutches per season; however, triple-brooded pairs were also present, the clutches of which coincided well with the three peaks. Most data showed a decrease as the season progressed. For example, mean clutch size was 4.4 eggs (4.8 in phase 1, 4.3 in phase 2, and 3.8 in phase 3); incubation lasted about 14.5 days (15.0 days in phase 1, 14.4 days in phase 2, and 14.3 days in phase 3); the mean number of eggs hatched was 3.2 (3.5 in phase 1, 3.2 in phase 2, and 2.9 in phase 3); the mean number fledged was 2.8 (3.0 in phase 1, 2.8 in phase 2, and 2.4 in phase 3); and about 17 days passed between hatching and fledging (17.4 in phase 1, 17.0 in phase 2, and 17.1 in phase 3). Over 79% of all clutches hatched at least one egg, while 70.8% of all clutches fledged at least one young. Nestling sex ratio was 1:1. Although bluebird eggs are usually blue, 3% of those laid in this study were white. Of all eggs laid, 33.8% failed due to various reasons, of which raccoon predation

(28.6%), house sparrow competition (16.3%), and infertility (14.1%) were the major causes. Plastic bleach jugs were more successful nesting sites than the conventional wooden box, especially when dealing with sparrow competition. Eight percent of all birds banded returned to the area in a following year. More birds banded as adults (21.2%) than those banded as nestlings (5.6%) returned, but no difference was found between the sexes of returning birds. Overall, the bluebird population analyzed in this study was typical of the species.

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INTRODUCTION

The Eastern Bluebird (*Sialia sialis*) was once a common sight throughout the eastern United States, but the species as a whole has declined in numbers this century for various reasons. Concerned individuals have erected bluebird nesting box trails throughout the breeding range of this species in hopes of aiding in a comeback. This thesis was performed to analyze data collected from one such nesting box trail in Crawford County, Illinois, and to compare these findings with those of similar studies on this species.

The nesting box trail used in this project was erected, observed, and maintained by Furl Walden of rural Crawford County, Illinois. What began as a part-time hobby developed into a time-consuming labor of love which included detailed field notes and extensive banding efforts that made this paper possible. The information gathered included various aspects of reproduction as well as data on bluebird returns.

Many authors have published similar research on this species, including but not limited to Graber et al. (1971), Laskey (1939 and 1940), Musselman (1935), Pinkowski (1975a), Thomas (1946), and Zeleny (1976).

The Eastern Bluebird was probably not very common in presettlement days. Colonization efforts of the settlers, such as clearing land and planting orchards, created ideal habitat for this species as well as others that preferred open areas, and the bluebird flourished (Watson in Zeleny,

1976).

During the first part of this century, however, the bluebird declined in numbers due to several factors (Zeleny 1976 and Willner et al. 1983). Although he had no accurate statistics, Zeleny estimated that from the 1930's to the 1970's the bluebird population declined by at least 90 percent. Habitat loss was a prime factor in this decline. Not only was more land being developed for human habitation, but changing farming practices brought about the disappearance of hedge rows, as well as the loss of nesting cavities as hollow limbs were cut from trees in orchards and wooden fences were replaced by those of metal or concrete. Competitors, especially the European Starling (Sturnus vulgaris) and the House Sparrow (Passer domesticus) which were imported into the United States in the 1800's, monopolized many nesting sites favored by bluebirds and consumed much of the available food during the winter. The use of insecticides has also taken its toll on the bluebird, an insectivore. In addition, adverse winter weather conditions, a normal factor from which bluebirds have always been able to recover in the past, have had a lasting effect on bluebird populations this century, indicating that factors other than the weather are taking their toll on this species.

METHODS

The study area was in Crawford County, Illinois, with

nest boxes spread over most of the county in the following township/range coordinates: T5N R11W, T5N R12W, T6N R10W, T6N R11W, T6N R12W, T7N R12W, T7N R13W, T8N R12W, and T8N R13W. The trail was erected in areas with varying amounts of human disturbance, including suburban and rural settings, mostly along roadsides, but also in peoples' yards and on a golf course.

The bluebird box trail in this study was started in 1979 with 15 boxes (Table 1). The trail was maintained and enlarged each year. In 1988, the last year in which data were collected, the trail had grown to include over 200 boxes. In general, only data from the years 1981 through 1987 were included in this analysis; however, data on returns and causes of nesting failures from 1988 were also used.

Two types of boxes were used in this study. Wooden boxes (5 in. x 5 in. x 9 1/4 in.) were constructed of 1 in. boards. In addition, white plastic gallon bleach jugs painted silver to reflect heat and modified with an entrance cut into the side were also set up as nest boxes. The boxes were checked regularly to determine occupancy and monitored for developments in reproduction.

A nest was considered to be active if at least one egg had been laid. Any nest that fledged at least one young was considered to be successful. The lengths of incubation and fledging were determined in the following manner. Since incubation usually begins on the day that the last egg in a

clutch is laid, that day was considered the first day. As for fledging, since nestlings are one day old the day after hatching, that day was considered to be the first day. Any unhatched eggs remaining in the nest were considered to be infertile.

Some adults and most nestlings were banded with metal U.S.F.W.S. bands. Adults were trapped in the box with a round wooden trap door that was triggered by pulling a string when the bird was inside. Nestlings were banded 10 to 12 days after hatching, before they were ready to fledge. When banded, the young were sexed in accordance with the Environmental Management Service (1977) key for this species.

Statistical analysis tests used in this paper were simple standard calculations, including Chi-square tests with a significance level of .95, performed in accordance with Zar (1984).

RESULTS

In this study, a total of 512 nests were built and 2176 eggs were laid from 1980 through 1987 (Table 1). However, partial data for certain nests produced varying totals in some of the tables. For example, no dates were available for two nestings, so they could not be designated to a particular phase of the breeding season. Although 15 boxes were available in 1979, no bluebirds took up occupancy. The number of nests built, eggs laid, and number banded

increased each year (with the exception of the number banded in 1987), not only as the number of boxes increased, but also after the number of boxes leveled off (1982 on) at about 200.

The nesting season began on the first day nest building was observed and ended either with the fledging of the last brood or the destruction of a nest, whichever occurred later. The mean date for the start of the season was 17 March with a range of 26 February to 28 March, while the mean date for the last day of the season was 31 August with a range of 2 August to 13 September (Table 2). The average season length was 167.4 days (range = 132 - 188).

The nesting season was divided into three phases determined by the number of eggs laid on a particular day (Figure 1). The first phase ran from 20 March through 13 May, the second phase from 14 May through 5 July, and the last phase from 6 July through 13 August. These dates also coincided almost exactly with first, second, and third clutches of breeding pairs (see next paragraph for details). The second phase or peak was the largest, since most of the eggs were laid during this time. The first peak was smaller than the second, the third peak being the smallest.

The Eastern Bluebird is considered to be double-brooded throughout most of its range but tends to be triple-brooded near the center of its range (Peakall 1970). The nesting box trail used in this study is located just north of what Peakall considered to be the center of this species' range.

Most of the breeding pairs in this study (54.0%) were observed to have only one clutch (Table 3). This table can be misleading, since it only attributes multiple broods to those banded pairs that were positively identified with several different broods in one season. It is quite possible that those pairs documented as having only a single brood could have had other broods unobserved elsewhere. A little over 30% of the pairs made two attempts at nesting per season, while almost 15% attempted three nestings in one season. Of the 46 total pairs attempting three clutches in a season, 43.5% successfully fledged all three clutches. One pair attempted four clutches, of which only the last one was successful, while all attempts failed for the pair that attempted five nestings.

The overall season clutch size was divided almost evenly between 4 and 5 eggs (Table 4). However, when the season was divided into phases, a distinct trend was evident. The clutch size dropped as the season progressed. More that 70% of clutches contained 5 eggs in phase 1, but during phase 2 almost 50% of clutches contained 4 eggs and a little over 40% had 5 eggs. By the third phase, almost 68% of the clutches had only 4 eggs. Over 20% of clutches in phase 3 were comprised of only 3 eggs.

The mean clutch size for all years was 4.4 eggs (range = 1 - 8) (Table 5). When divided into the three phases, clutches laid in the first phase were largest (mean = 4.8 eggs, range = 2 - 7), followed by the second phase

(mean = 4.3 eggs, range = 1 - 8), and finally the third phase (mean = 3.8, range = 1 - 5). The means for the phases of each separate year also follow this trend. However, there is no significant difference between the means for the phases.

Bluebirds normally lay blue eggs; however, white eggs are occasionally laid. The percent of white eggs at the Crawford County study site ranged between 0% and 4.6% yearly with 3.0% for all years combined. All of the eggs in a single clutch were always the same color, whether blue or white. Of the 497 clutches laid, 2.8% were white. Egg color seems to be determined by the female. For example, one female laid all white clutches three years in a row with three different mates. However, two males whose mates laid white eggs in 1986 returned in 1987 with different mates that laid blue eggs. Finally, there was no evidence that birds that hatched from white eggs would in turn lay white eggs. Two females that hatched from white eggs returned to lay blue eggs, while two other females from blue eggs returned to lay white eggs. An interesting sideline to this subject developed when an albino nestling, hatched from a blue egg, was born to normally pigmented parents; the mother was also hatched from a blue egg.

The estimated mean incubation time for all years was 14.5 days (range = 11 - 21, S.D. = 0.953). When divided into phases, those clutches laid in the first phase took the longest to hatch (mean = 15.0 days, range = 13 - 21, S.D. =

1.091); phase 2 followed with a mean of 14.4 days (range = 11 - 18, S.D. = 0.826), while clutches laid during the third phase had the shortest incubation period (mean = 14.3 days, range = 13 - 18, S.D. = 0.737). All years except 1986 followed this trend. However, the means of the phases were not found to differ significantly from each other.

Over 79% of a total of 497 clutches hatched successfully (Table 5), with percents for individual years ranging from 69.9% in 1987 to 100% in 1982. When divided into the three phases, phase 3 had the highest overall percent of successful hatching (82.1%), followed by the first phase (79.1%), and finally the second phase (78.5%).

The mean number of eggs hatched per nest was 3.2 eggs (range = 0 - 7) (Table 5). The means for the three phases decreased as the season progressed (phase 1: mean = 3.5, range = 0 - 6; phase 2: mean = 3.2, range = 0 - 7; phase 3: mean = 2.9, range = 0 - 5). No significant difference was found between the means of the phases.

The male to female sex ratios for nestlings gradually changed from slightly more males than females in 1982 (1.7 males for every female) to slightly more females than males in 1987 (1 male for every 1.2 females) with an overall ratio of 1 male for every 1.0 females. The Chi-square value for 1982 with a sample size of 83 birds was the only one that exceeded the critical value ($X^2_{.05,1}=5.313$); all others, as well as the overall value ($X^2_{.05,1}=0.349$), were well under the critical value. However, the difference in 1982 could

be due to the small sample size or inexperience in sexing during the first year.

The estimated mean number of days between hatching and fledging overall was 17.1 days (range = 12 - 22, S.D. = 1.668). When divided into the separate phases, the first phase had the longest fledging time (mean = 17.4, range = 12 - 22, S.D. = 1.806), followed by the last phase (mean = 17.1, range = 13 - 22, S.D. = 1.725), and finally phase 2 (mean = 17.0, range = 12 - 20, S.D. = 1.185), but these differences are not statistically significant.

The overall percent of clutches laid that fledged at least one young was 70.8%, while the overall percent of clutches hatched that fledged was 89.6% (Table 5). When divided into phases, the second phase had the highest percent of clutches laid that fledged (72.5%), followed by the last phase (71.6%), and finally the first phase (68.6%). The fledging success rate of clutches that hatched at least one young followed a similar trend (phase 2: 92.3%, phase 3: 87.2%, and phase 1: 86.8%).

Out of a total of 2176 eggs laid, 1383 produced fledglings (Table 5). The mean number of fledglings per nest was 2.8 (range = 0 - 7). The overall mean number of young fledged per nest decreased as the season progressed with a mean of 3.0 (range = 0 - 6) for the first phase, 2.8 (range = 0 - 7) for the second phase, and 2.4 (range = 0 - 7) for the third phase. However, only the first two years and the last two years followed this trend. No significant

difference was found between the means of the phases.

For the years 1981 through 1987, about 34% of all eggs laid failed to fledge (Table 6). In 1988 alone, a year of severe drought, over 53% of all eggs failed. Losses were greatest earlier in the season, and decreased slightly as the season progressed. Egg failures can be attributed to a number of causes. In this study, the raccoon (Procyon lotor) was the major cause of egg loss, being responsible for 28.6% of losses from 1981 through 1987. Over half of the losses in 1988 were due to raccoon predation. The second major cause of losses was the House Sparrow (Passer domesticus), which competes for nest sites and not only destroys eggs and young, but also may kill the parents. Infertility was another major cause of egg failures. Both raccoon predation and infertility losses for 1988 were almost double of the losses for the average of the preceding seven years. Other causes of failures ranged from snakes to humans to weather conditions, and various other minor reasons.

Although fewer plastic jugs than wooden boxes were used in this study, the nesting attempts made in plastic jugs were more successful than those in the wooden boxes (Table 7). This success was apparent not only in the overall total, but also in each individual year, but the difference was not significant ($X^2_{.05,1}=1.927$). It was also discovered that sparrows did not nest in plastic jugs as often as wooden boxes, aiding in the overall success of plastic jugs.

Of 1543 birds banded, 8.0% (123 birds) were recaptured sometime during the next years (Table 8). The Chi-square values for males and females did not exceed the critical value ($X^2_{.05,1}=0.203$), meaning there was no significant difference between the two sexes in the number of returns. However, there was a significant difference between recaptures of birds banded as adults and those banded as nestlings ($X^2_{.05,1}=4.301$). Over 21% of birds banded as adults were recaptured, while only 5.6% of birds banded as nestlings were recaptured. One male banded in 1980 returned for three consecutive years to the same box. Two separate pairs returned for two consecutive years with the same mates. A male banded in 1982 was not seen again the following year but was recaptured the next five years (1984 through 1988). Twenty-two birds were recaptured in two separate years after being banded, while three others were recaptured three times and two more returned four different years. Five dead bluebirds were recovered from boxes on the study site where they were roosting during the winter. Seven others were found dead of other reasons -- 4 from sparrow attacks, 1 probably hit by a car, and two lost to unknown causes. Also, one bluebird banded in the study area was found dead in winter in a roost box near Jackson, Mississippi.

DISCUSSION AND CONCLUSIONS

Von Haartman (1957) suggested that the number of breeding pairs of a cavity-nesting species in any given area was limited by the number of acceptable holes available. Very few bluebirds were observed in the Crawford County study area before the nest box trail was set up in 1979, probably due to the lack of available nest sites (Munro and Rounds 1985). However, the year after boxes were erected, bluebirds began to take advantage of the situation, and were soon abundant in the study area (Table 1).

The nesting season in the present study was considered to extend from the time nest building was first observed until the last clutch of the season either fledged or was destroyed, whichever occurred later. The mean season length was 167.4 days (Table 2). This method varied from that of Peakall (1970), who calculated the season length by determining 90% of the days between the dates the first clutch and the last clutch were completed. Peakall (1970) found that the breeding season was longest at the center of the bluebird's breeding range (Kentucky, Tennessee, West Virginia, Missouri, Arkansas, Oklahoma, and Nebraska) and decreased outward to the periphery. If the same method was used in the present study (Figure 1), the nesting season at the Crawford County study site lasted 104 days, which is close to Peakall's calculation for Illinois and Indiana (94 days) and nearby Kentucky and Tennessee (102 days). Data of early researchers were used by Peakall, and calculations by

later individuals (Pinkowski, 1975a; White and Woolfenden, 1973) corroborated Peakall's compilation.

Zeleny (1976) reported that nest building for the first brood in the south occurred in mid-March, in the middle latitudes in early April, and in the northern United States and Canada in late April or early May. He further stated that nesting is essentially over by early September. Egg laying in the present study ran from 20 March through 13 August (Figure 1). This corresponded with other observers' findings. Peakall (1970) stated that the breeding season for Illinois and Indiana ran from 21 March through 27 August. Graber et al. (1971) reported that the nesting season in Illinois began in mid-March and ended in mid-August, although they stated that laying was primarily over by the end of June. Musselman (1934) reported an early nest with eggs on 20 March in western Illinois.

Various researchers divided the bluebird breeding season into peaks and/or phases. These two terms appear to be quite similar but in fact refer to two distinctly different ways of analyzing the data. In the literature, "peaks" are determined by the number of eggs laid, as in Figure 1, while "phase" usually refers to the time of the season during which the clutch is laid or the number of the clutch (i.e. the first, second or third brood of the same nesting pair in the same season). A phase need not include a peak (Pinkowski 1975a). In the present study the terms are synonymous, since first, second, and third broods

occurred during the corresponding phases, provided they were not prematurely terminated. The Crawford County bluebird trail had three phases that corresponded with the three peaks in egg laying (Figure 1). In Illinois, Graber et al. (1971) reported three peaks, the first being in April, the second in May, and the third in June, while Musselman (1935) reported two peaks for Illinois. Pinkowski (1975a) and Laskey (1940) reported three phases in Michigan and Tennessee respectively. However, while Laskey had three peaks to correspond with the three phases, Pinkowski had only two, because his second phase consisted of only a few pairs that were late nesters and would not make another attempt that season. The first two phases are similar to Pinkowski's (1975a) findings, but differ from Graber et al. (1971) in that the first peak was the largest in Graber's study, while the second phase was the largest in the present study. This difference could be due to the fact that bluebird populations have increased since the Graber et al. (1971) study, and the increase in numbers meant that more and more birds would be first year nesters, which may have arrived in the area later than older birds, thus causing the second peak in the present study to be the largest. Also, while the peaks from Graber et al. (1971) were in April, May, and June, the peaks in the present study ran from mid-March through mid-May, mid-May through early July, and early July through mid-August (Figure 1).

Different authors stated varying statistics on the

number of broods per breeding pair per season, depending on the geographic location of their study site. Zeleny (1976) and Bent (1949) reported that the bluebird was generally double-brooded, but may occasionally produce three broods in one season. Kibler (1969) generalized that bluebirds usually nested three times in the south, but rarely as many times in the north. Peakall (1970) found that the bluebird usually had a single brood in the northern-most periphery of its range, three broods in the central part of its range, and two broods elsewhere. Pinkowski (1975a) supported this statement, finding two broods the norm in southern Michigan, but only a single brood in northern Michigan probably relating to the shortened breeding season. Similarly, Hamilton (1943) reported that bluebirds were double-brooded in New York. Nearly 15% of the breeding pairs in the present study were observed making three attempts at nesting in a single season (Table 3). Over 40% of these were successful in all three attempts, but two pairs that made four and five attempts had only one and no successful clutches respectively. This information was gathered from observations of banded pairs in the study area. In Illinois, Holcombe (1930) reported multiple broods, while Musselman (1935) more specifically stated that the species was only double-brooded. Graber et al. (1971) supported the latter, saying that reports of triple broods in the state had not been substantiated. Thomas (1946) reported that the species was usually triple-brooded in Arkansas, but would

occasionally nest four times; 2.6 attempts was the average. White and Woolfenden (1973) also found that this species was triple-brooded in Florida.

The number of pairs in the present study making only one nesting attempt was extremely large; this is due to several factors. First, only birds that could be positively identified were attributed with multiple broods. Second, bluebirds have been known to switch nesting sites between broods (Graber et al. 1971), so bluebirds observed in this study could very likely have raised other broods outside the study area or in natural cavities.

Lack (1947, 1948) reported that in Old World passerines the clutch size increased with increasing latitude. However, Peakall (1970) stated that clutch size is largest at the center of the bluebird's range and decreases outward, both north and south. The mean clutch size in the present study was 4.4 eggs per clutch (Table 5), which was in between Crowell and Rothstein's (1981) mean clutch size of 4.31 eggs for Illinois and Peakall's (1970) clutch size of 4.52 for Illinois and Indiana. Bent (1949) found that 5 eggs was the norm nationwide, with a range of 3 to 7. Hamilton (1943) reported that clutches in New York were usually 4 to 6 eggs. Also, clutch size was reported to be largest in the spring, decreasing as the season progressed (Peakall 1970, Musselman 1946, Laskey 1940, and Pinkowski 1975a and 1977, Graber et al. 1971, Hamilton 1943). This trend was quite visible in the present study (Tables 4 and

5). Pinkowski (1975a) suggested that this seasonal variation was controlled proximately by the amount of energy the female had already invested into previous broods, with the ultimate control being the number of young that could be fed. Another factor he thought could bring about smaller clutches later in the season was the proximity of the molt. Several large clutches (consisting of seven or eight eggs each) were observed in the present study, raising the question as to whether they may not be from a single pair, but rather eggs of several different parents. This is a possibility, especially when one considers all of the observations of multiple parentage, adoption, and egg dumping in this species (Musselman 1946, Gowaty 1983a and 1983b, Pinkowski 1978, Plissner and Gowaty 1988, Laskey 1947, Hamilton 1943). Gowaty and Karlin (1984) reported that bluebirds are polygamous and that 25% of the complete bluebird families they analyzed using electrophoretic techniques showed evidence of multiple parentage. However, Walden reported to me no evidence indicating that these large clutches were the result of more than the one pair that was seen raising them.

Bluebird eggs are usually pale blue, but occasionally white eggs are laid. Usually all the eggs in a clutch are the same color, although rarely one or more eggs in an otherwise normally pigmented clutch will be white (Laskey 1943, Graber et al. 1971, and Pinkowski 1975a). Three percent of all eggs laid in the Crawford County study site

were white, while 2.8% of all clutches were white. According to Pinkowski (1975a), the percent of white eggs laid in a population decreases as one goes out from the center of the bluebird's range, varying from 0% to 2.8% with increasing latitude. Gross (1968) summarized the following list percents: 10% in Kentucky, 3% in Arkansas, 2.5% in New Jersey, 2% in Michigan, 1.75% in Ohio, 1% in both in both Iowa and Pennsylvania, and 0.5% in Indiana. Laskey (1940) reported 4.2% for Tennessee, while Musselman (1946) listed 5 to 6% for Illinois. In a manuscript cited in Bent (1949), Laskey reported findings similar to the present study; however, a high of 9.1% for one year was reported.

Lack (1958) noted that albinism is probably an adaptation enabling the parents to see the eggs in the low light levels of the nesting cavities. According to Pinkowski (1975a) the polymorphism in egg color is probably due to differences in light levels of various cavities used by bluebirds. Shallow, better lit cavities would favor blue eggs, while deeper darker cavities would be more favorable for white eggs.

In the present study, the average incubation time was 14.5 days, decreasing as the season progressed. Graber et al. (1971) stated that incubation lasted 13 to 15 days, usually 14, in Illinois, which corresponded with Holcombe's (1930) findings for the northern part of the state. Bent (1949) reported an average of 12 days nationwide. Incubation time showed two trends, one clinal and the other

seasonal, with both influenced by average daily temperatures. First, incubation took longer in the more northern regions, where incubations in excess of 15 days or more were common, probably due to cooler temperatures, especially in the spring (Pinkowski 1974 and 1975a, Hamilton 1943, and Smith 1937). Incubation periods in the southern areas of the range typically lasted 13 or 14 days (Laskey 1940, Thomas 1946, and White and Woolfenden 1973). The second trend, which was seasonal, seemed to be a more northern phenomenon, with the length of the incubation period decreasing as the season progressed and the seasonal temperature increased. This was also apparent in Pinkowski's (1975a) study in Michigan as well as the present study, but was not apparent in extreme southern parts of the breeding range (White and Woolfenden 1973), where seasonal temperature changes are not as drastic.

Over 79% of the clutches at the present study site hatched successfully, ranging from 69.9% to 100% for individual years (Table 5). No comparable data were available for Illinois, but percents for other parts of the nation were similar. Kendeigh (1942) found a success rate of 84% in Ohio, while White and Woolfenden (1973) reported that 81% of the eggs in their Florida study hatched. Laskey (1940) found that less than 50% of the eggs in her study hatched successfully. Nice (1957) reported success rates of 63%, 64.5%, 78.3%, and 80% for various observers. Later clutches were only slightly more successful (Table 5). The

number of eggs hatched per clutch decreased, but clutch size also decreased, thus causing the percent to increase. This trend was the opposite of that observed by other researchers (Musselman 1935 and 1946, Laskey 1946, and White and Woolfenden 1973), which they attributed to the hotter, dryer conditions of summer. These conditions would tend to increase infertility, but entire clutches were rarely lost to this factor.

The sex ratio among nestlings was almost exactly 1:1 in the present study. Lombardo (1982) found that the sex ratio of the Eastern Bluebird displayed binomial distribution, supporting the hypothesis that it is solely the result of Mendelian sex determination. Pinkowski (1974) reported that summer broods had slightly more females than males, although the numbers were not significantly different from the expected ratio. He also reported a 5% error in sexing, which was comparable to that found in the present study.

In general, fledging takes two to three weeks from the time of hatching until the young leave the nest, provided there is no disturbance that would cause premature fledging. It took approximately 17 days after hatching for the young to fledge in the present study. Bent (1949) reported 14 to 16 days nationwide. Graber et al. (1971) reported 15 to 17 days (usually 16) for Illinois, and Holcombe's (1930) study supported this. While there was a geographic trend with the length of the incubation, there seemed to be no similar trend here. Laskey (1940) and Hamilton (1943) both reported

fledging times of 14 to 16 days, while 17 or 18 days were observed by White and Woolfenden (1973) and Thomas (1946). Pinkowski (1975a and 1975b) reported means of 19.24 and 18.8 days respectively; however, no birds left the nest before 16 days. The nestling period was longest during the spring (Table 5) which corresponded with Pinkowski's findings (1975b).

Almost 71% of clutches laid fledged young, while 89.6% of those hatched were successful (Table 5). Most researchers reported only the percents of eggs laid that fledged. Graber et al. (1971) reported only 24% success for the spring, but 54% success for summer nestings for Illinois, while Musselman (1934) had a success rate of 68%. Nice (1957) published the following success rates for various regions: 44.5%, 62.5%, 63.2%, 65%, and 72.7%. Other reported success rates were 57.9% from an accumulation of data of ten researchers (Pinkowski 1975a), 63% (Thomas 1946), 57% (Kendeigh 1942), 50.3% and 57.6% for two consecutive years (Laskey 1943), and 55 to 69% (White and Woolfenden 1973). In the present study, the second phase was most successful, although all phases were very close (Table 5); this disagrees with findings of Graber et al. (1971) and Laskey (1940), who found drastic differences between phases. This could be because different factors causing failures had their major effect during different parts of the season, thus balancing each other out.

About 34% of all eggs laid from 1981 through 1987

failed to fledge (Table 6). This number is slightly different from what would be expected from a comparison with the percents in Table 5. Table 5 deals with success of entire clutches, while Table 6 deals with individual eggs. Since only a part of a clutch may be lost to various factors, percents vary between the two tables. For the year 1988 alone, over 53% of all eggs failed. In 1988, a year of severe drought, the increase in failures was due not only to infertility but also to increased predation, mainly by raccoons, that may have resulted from reduced food sources during this dry spell. Failures decreased as the season progressed, a trend also observed by Graber et al. (1971). Predators caused the greatest losses, resulting in 41.1% and 61.5% of the total losses for the 1981-1987 period and 1988 alone, respectively. Laskey (1939) reported that losses to predators were 25%, Kibler (1969) found 33%, and Thomas (1946) gave a figure of 42%. The raccoon was the single major cause of failure in the present study, resulting in 28.6% of the losses (1981-1987) and over half of the losses in 1988. There is no mention of raccoon predation in Illinois literature, but Pinkowski (1975a, 1975b, and 1977) also indicated that the raccoon was the major predator of this species. Snakes were another major predator in the present study, as well as in other studies (Musselman 1935 and 1946, Laskey 1940 and 1946, Kendeigh 1942, Bent 1949, Kibler 1969, and Hensley and Smith 1986). Members of the genus Elaphe were cited as the main reptilian predator, but

identification of snakes was not carried out in the present study. Cats were a minor predator at the Crawford County study site, which was also reported by Laskey (1940 and 1943) and Bent (1949).

In the present study, failures due to competitors accounted for 25.2% of the losses for 1981-1987, but only 9.2% for 1988. House sparrows were the major culprit, also a problem for other observers (Bent 1949, Kibler 1969, and Graber et al. 1971). Sparrows were not as apt to use plastic jugs for nest sites as they were to use the wooden boxes. Zeleny (1976) knew of no published reports on the success of plastic jugs, but it is my opinion that use of plastic jugs in areas where sparrows are common could aid in increasing bluebirds, since competition for these nest sites would not be as intense.

Minor competitors at the Crawford County study site were house wrens (Troglodytes aedon), mice, flying squirrels (Glaucomys volans), woodpeckers, and various arthropods. Graber et al. (1971) reported that wrens were not a problem in southern Illinois; however, Bent (1949), Pinkowski (1976), and Musselman (1935) found them to cause considerable trouble in various areas. Mice were reported by Bent (1949) and Pinkowski (1976); these two researchers as well as Kibler (1969) reported flying squirrels taking over bluebird nest boxes. Woodpeckers were reported in southern Illinois (Graber et al. 1971). It is interesting to note the incidence of various arthropods causing

failures. Ants, a large unidentified insect, and spiders were observed in nest boxes in the present study. These and various other arthropods were reported by Laskey (1940), Hamilton (1943), Thomas (1946), Bent (1949), Kibler (1969), and Pinkowski (1975a).

Weather is a major factor influencing losses of eggs, young, and adults according to many researchers. In the present study, only a small percent of failures were directly caused by inclement weather. Musselman (1940), Bent (1949), Nice (1957), Kibler (1969), Graber et al. (1971), and Pinkowski (1975a) reported that freezing weather in the spring was a major cause of nesting failures. Cold weather also caused losses of adults. Musselman (1941) mentioned an early spring storm that killed half of the breeding population in western Illinois. Graber and Graber (1979) reported that during the severe 1976-1977 winter, the bluebird population in southern Illinois dropped 84-90% from that of previous years.

Infertility was another cause of failures related to weather. Infertility usually increases as the season progresses, due to heat and drought (Musselman 1935, Graber et al. 1971, and Pinkowski 1975a). In the present study, infertility in the last two phases increased slightly over that of the spring. Overall, the infertility rate for 1981-1987 was 14.1%, but increased dramatically in 1988 (24.1%), probably due to the severe heat and drought. The following infertility rates were published by various observers: 9%

(Graber et al. 1971), 7% (Peakall 1970), 13% (Thomas 1946), 8% (Laskey 1939), and 8.6% (Musselman 1935). The infertility rate for the present study was higher than that of other researchers, which could be a result of incorrect interpretation of unhatched eggs. It is possible that some eggs calculated as infertile were actually casualties of cold weather. This would also explain the low percent of failures accredited to weather.

Generally, the percent of banded birds that returned to an area to nest is fairly small. Only 8% of all birds banded in the Crawford County study area were recaptured in one or more of the proceeding years (Table 8). Although slightly more banded males that females returned to the area, no significant difference in the sex of returning birds was found. Over 21% of adults banded returned, but only 5.6% of those birds banded as nestlings were recaptured, which is significantly different. Of the birds found dead, those found in the winter were equally distributed between the two sexes. The bird found in a winter roosting box in Mississippi is very interesting, since little is known about bluebird migrations, and bluebirds banded in one area are rarely found elsewhere. Concerning the ones killed by other means, mostly by sparrow attacks, the majority were male, leading to the assumption that the males are more involved in the "combat" with this competitor. In Illinois, Graber et al. (1971), Holcombe (1930), and Musselman (1934) all reported that bluebirds

sometimes returned to the vicinity of their birth to re-nest, although Musselman did comment that birds banded as adult were more likely to return than those banded as nestlings. Laskey (1940) reported a return rate of 2.2%, while Thomas (1946) stated that 6 of 10 banded males and 8 of 13 banded females re-nested in the same area for two consecutive years; one male and one female were seen three years in a row. Laskey (1940) reported that faithfulness to a certain area was more common in females that males; however, Pinkowski (1975a) found that this characteristic was strongest in adult males (with 33.3% returns), followed by adult females (with 9.7%), while birds banded as nestlings had a return rage of only 5.3%. The results of the present study compare favorably with those of other observers. It appeared that nestlings did seem to scatter more, as reported by Musselman (1935), while adults tended to return to areas where they had previously nested. Another possible explanation is that a higher mortality rate was experienced in the first year of life, thus decreasing the number of birds banded as nestlings that was available to return. Pinkowski (1977) found that all returning adults in his study area had nested successfully the previous year. While the success rate in the present study was not that dramatic, this trend was also apparent. Perhaps the favorable conditions and reproductive success experienced in one year would imprint the area more strongly on the birds, thus making their return the nest more likely.

Overall, the breeding bluebird population in Crawford, County, Illinois, was very typical of other populations found throughout their breeding range. The number of bluebirds seemed to be increasing, which Zeleny (1976) attributed not only to in increase in public awareness about the plight of the bluebird, but also to the nesting box trails set up throughout their breeding range. However, he pointed out that this recovery could be reversed by a single severe winter. I think that the bluebird is out of danger of extinction, to which end some people thought it was headed (Zeleny 1976), and as more nest boxes are provided and more research is done to develop better boxes or other methods of predator control, the bluebird will continue to flourish.

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Table 1. Yearly development of a bluebird box trail in Crawford County, Illinois.

Year	No. boxes	No. nests	No. eggs laid	No. banded
1979	15	0	0	0
1980	50	4	19	5
1981	104	21	95	24
1982	209	26	116	110
1983	187	51	223	166
1984	200+	53	241	210
1985	200+	67	297	212
1986	200+	126	549	421
1987	200+	153	653	400
Total	200+	512	2176	1548

Table 2. Length of the bluebird nesting season for each year and mean for all years combined in Crawford County, Illinois.

Year	First nest begun	Last nest begun	Last nest ended	Total no. of days
1981	24 March	17 July	2 August	132
1982	22 March	27 July	30 August	162
1983	15 March	3 August	6 September	176
1984	28 March	3 August	7 September	163
1985	25 March	2 August	5 September	164
1986	10 March	10 August	13 September	188
1987	26 February	31 July	1 September	187
Mean	17 March	31 July	31 August	167.4

Table 3. Number of nesting attempts per breeding pair per year, total for all years, and percent of total number of pairs making a certain number of attempts as determined by observations of banded pairs in Crawford County, Illinois.

	No. of pairs making a certain no. of attempts				
Year	1	2	3	4	5
1981	11 (63.6)*	2 (0)	2 (50.0)	0	0
1982	17 (70.6)	4 (100)	1 (100)	0	0
1983	29 (72.4)	12 (75.0)	0	0	0
1984	15 (66.7)	10 (60.0)	6 (50.0)	0	0
1985	26 (69.2)	10 (50.0)	7 (57.0)	0	0
1986	22 (63.6)	31 (71.0)	13 (38.5)	1 (0)	0
1987	47 (53.2)	25 (52.0)	17 (35.3)	0	1 (0)
Total	167 (64.1)	94 (62.8)	46 (43.5)	1 (0)	1 (0)
%	54.0	30.4	14.9	0.3	0.3

* Numbers in parentheses indicate percents of pairs that successfully raised all attempted broods.

Table 4. Percent of nests by clutch size for complete season and three phases, 1981-1987, in Crawford County, Illinois.

	Clutch size							
	1	2	3	4	5	6	7	8
Season total (497 nests)*	0.6	1.4	7.8	43.7	43.5	2.6	0.2	0.2
Phase 1 (153 nests)	-	0.7	3.3	18.3	70.6	6.5	0.7	-
Phase 2 (247 nests)	0.8	1.6	5.7	48.8	41.1	1.6	-	0.4
Phase 3 (95 nests)	1.0	2.1	20.8	67.7	8.3	-	-	-

* Two nests included for which phase data were unavailable.

Table 5. Clutch size, hatching success, and fledging success per nest, 1981-1987, in Crawford County, Illinois.

	Season total (497 nests)[1] (2176 eggs)[1]		Phase 1 (153 nests) (736 eggs)		Phase 2 (247 nests) (1069 eggs)		Phase 3 (95 nests) (363 eggs)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Clutch size	4.4	0.802	4.8	0.656	4.3	0.797	3.8	0.635
Eggs hatched								
Number	3.2	1.856	3.5	1.987	3.2	1.851	2.9	1.537
Percent	(79.1)		(79.1)		(78.5)		(82.1)	
Young fledged								
Number	2.8	1.996	3.0	2.208	2.8	1.944	2.4	1.705
Percent[2]	(70.8)		(68.6)		(72.5)		(71.6)	
Percent[3]	(89.6)		(86.8)		(92.3)		(87.2)	

1/ Two nests included for which phase data were unavailable.
2/ Percent of clutches laid that fledged successfully.
3/ Percent of clutches hatched that fledged successfully.

Table 6. Causes for egg failures in percents for the entire season and the three phases, 1981-1987 and 1988, in Crawford County, Illinois.

	Entire season		Phase 1	Phase 2	Phase 3
No. eggs laid	2176	(713)[1]	736	1069	363
No. eggs failed	735	(382)	261	360	114
% eggs failed	33.8	(53.6)	35.5	33.7	31.4
Predators	**41.1**	**(61.5)**	**11.4**	**22.6**	**7.1**
Raccoon	28.6	(50.8)	8.8	13.2	4.5
Snake	11.8	(10.7)	1.9	7.3	2.6
Cat	0.7	-	0.7	-	-
Competitors	**25.2**	**(9.2)**	**13.4**	**10.8**	**1.0**
House sparrow	16.3	(7.9)	9.5	6.3	0.5
House wren	3.5	(1.3)	1.8	1.8	-
Arthropods[2]	2.3	-	-	1.8	0.5
Mouse	1.4	-	1.4	-	-
Flying squirrel	1.0	-	-	1.0	-
Woodpecker	0.7	-	0.7	-	-
Other	**19.5**	**(5.2)**	**6.5**	**8.0**	**5.0**
Abandoned	5.0	-	1.6	1.8	1.6
Human	4.2	(1.0)	0.8	2.6	0.8
Weather	2.0	(2.6)	1.4	0.7	-
Unknown	8.3	(1.6)	2.7	3.0	2.6
Infertile eggs	**14.1**	**(24.1)**	**4.2**	**7.6**	**2.3**
Total	99.9	(100)	35.5	49.1	15.4

[1]/ Numbers in parentheses are for 1988 only for which no phase data were available.

[2]/ Arthropods included ants, a large unidentified insect, and spiders.

Table 7. Yearly comparison of nesting success in wooden nesting boxes and plastic jugs in Crawford County, Illinois.

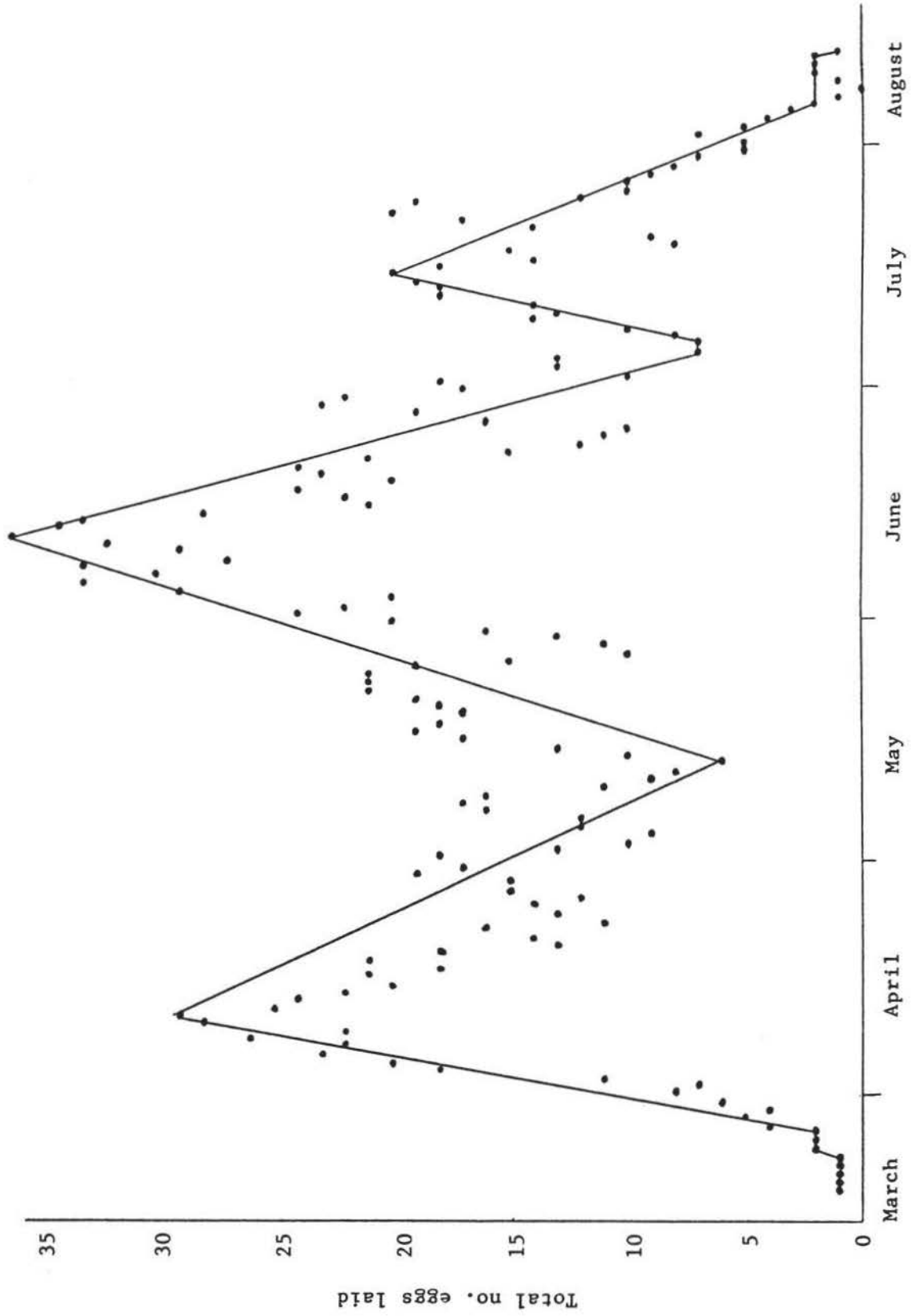
	Wooden boxes		Plastic jugs	
Year	No. of nests	% success	No. of nests	% success
1981	21	61.9	0	-
1982	26	88.5	0	-
1983	41	75.6	10	80.0
1984	29	65.5	24	91.7
1985	37	73.0	30	80.0
1986	85	67.1	41	85.4
1987	105	56.2	48	75.0
Total	344	68.6	153	81.7

Table 8. Number of bluebirds banded as adults and juveniles according to sex, and returns of banded birds in Crawford County, Illinois.

	No. banded	No. returns	Percent returns
No. birds banded as:			
Adults	236	50	21.2
Males	104	26	25.0
Females	132	24	18.2
Juveniles	1312	73	5.6
Males	624	38*	6.1
Females	645	35	5.4
Unknown	43	*	*

* Two juveniles banded as unknown returned and were identified as males, thus being added to the male data.

Figure 1. Number of bluebird eggs laid per day for the years 1981 through 1987 in Crawford County, Illinois.


Total no. eggs laid
35
30
25
20
15
10
5
0
March
April
May
June
July
August