broods had reduced exposed surface area through which they could dissipate heat, which may have increased the need for shading.

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**Nesting ecology of the Loggerhead Shrike in central Missouri.**—Loggerhead Shrike (*Lanius ludovicianus*) populations have declined in North America (Bystrak, Stud. Avian Biol. 6:34–41, 1981; Morrison, Am. Birds 35:754–757, 1981) especially in the midwest (Geissler and Noon, Stud. Avian Biol. 6:42–51, 1981) including Missouri (Kridelbaugh, Missouri Acad. Sci. Trans., 15:111–119, 1981). Lowered reproductive success may be responsible for this decline (Anderson and Duzan, Wilson Bull. 90:215–220, 1978). Studies on the nesting ecology of this widespread species are limited to the older works of Miller (Univ. Calif. Publ. Zool. 38:11–242, 1931) and Bent (U.S. Natl. Mus. Bull. 197, 1950), and the more recent papers by Graber et al. (Ill. Nat. Hist. Surv. Biol. Notes 83, 1973) and Porter et al. (Southwestern Nat. 19:429–436, 1975). Except for the work of Graber et al. in Illinois (which relied heavily on museum records for nesting data), there have been no studies of shrike nesting ecology conducted in the midwest. The present study was initated to aid in understanding the breeding biology of the Loggerhead Shrike in the region, and to compare it with previous studies done in other states to determine whether reduced reproductive success was responsible for the decline of shrikes in Missouri.

*Study area and methods.*—This study was conducted during the 1980 and 1981 breeding seasons (March–July) within a 24-km radius of Columbia, Boone Co., central Missouri. The 1980 nesting season (April–June) was hot and dry with a total of 15.6 cm (6.13 in) of precipitation, 17.7 cm (6.97 in) below normal (U.S. Dept. Commerce, Climatological Data 84 [4, 5, 6], 1980). The 1981 breeding season was cold and wet with a total of 53.8 cm (21.2 in) of precipitation, 20 cm (8.1 in) above normal (U.S. Dept. Commerce, Climatological Data 85 [4, 5, 6], 1981).

Most breeding pairs were located south and east of Columbia in rolling agricultural areas consisting of a mixture of rowcrops (primarily soybeans), wheat, hayfields, pasturelands, woodlots, and hedgerows. Breeding birds were trapped, using a modified wire-mesh chickadee trap baited with a mouse (Kridelbaugh, N. Am. Bird Bander, 7:50–51, 1982), and banded with a U.S. Fish and Wildlife Service aluminum band on one leg and one or two colored plastic bands on the other. Sixty adults and 120 fledglings were marked during this study. Nests of all breeding pairs were located, and were visited once every 4 days to record data on the nest-site, nesting behavior, nesting habitat, and success. In this paper three terms are used as measures of reproductive success: (1) hatching success—percentage of eggs laid that hatched; (2) fledging success—percent of young hatched that fledged; and (3) nest success—percent of nests from which one or more young fledged.

*Arrival and abundance.*—Twenty-eight breeding pairs were located in 1980 and 23 in 1981. The average relative abundance of nesting shrikes observed along a 15.5-km route was 0.42 pairs/km. The breeding population in central Missouri is relatively large when compared with other parts of the state (Kridelbaugh 1981). Male Loggerhead Shrikes began arriving in mid-February and established breeding territories. All nine of the wintering birds on the

study area were color-banded and none remained to breed. Likewise, none of the breeding birds or young were known to remain on the study area during winter.

*Site fidelity.*—Several authors have commented on the high degree of philopatry exhibited by Loggerhead Shrikes (Miller 1931, Bent 1950, Porter et al. 1975). In 1981 54% (15 of 28) of the areas used by nesting birds in 1980 were again occupied. There was a disparity in the fidelity between sexes. Of 15 males banded in 1980, seven (47%) returned in 1981 and set up territories in the same area used the previous year. None of 15 females banded in 1980 returned the following year. In 1980, 90 fledgling were banded on the area. One fledgling (a male) returned and nested 3.75 km from where it fledged. This sexual bias in philopatry was significant ($\chi^2 = 9.1$, df = 1, $P < 0.05$) which indicates that in this year males were more faithful to territories of the previous years than were females.

*Nest initiation and site selection.*—Completed nests were found from 23 March–12 June. Peak nest initiation occurred during late April, with a second peak in late May when color-banded birds renested (Fig. 1). In Illinois shrike nesting peaked in late April (Graber et al. 1973), at higher latitudes in Colorado the nesting peak was in late May (Porter et al. 1975), while in Alabama the peak was reached in early April (Siegel, M.Sc. thesis, Univ. Alabama, Birmingham, Alabama, 1980). In each of these studies, shrikes were one of the earliest nesting passerines in the area.

I observed the construction of nests by three pairs and the time required to construct a nest was 10, 11, and 12 days, respectively. Graber et al. (1973) reported a nest-building period of 5–7 days for two nests which were partially completed when found. The nests were bulky structures made of sticks, with some grass and herbaceous stems, and a lining of cattle hair with some feathers (similar to those described by Bent [1950]). Experienced adult males were first to arrive and establish territories and later led females to potential nest-sites.

Shrikes nested in a variety of trees and bushes. Eastern redcedar (*Juniperus virginianus*) (58%), multiflora rose (*Rosa multiflora*) (12%), honey locust (*Gleditsia triacanthos*) (8%), and osage orange (*Maclura pomifera*) (7%) were used most frequently. Other vegetation nested in included slippery elm (*Ulmus rubra*), hawthorn (*Crataegus* spp.), black cherry (*Prunus serotina*), scotch pine (*Pinus sylvestris*), and lombardy poplar (*Populus nigra*). Sixty-two percent of all nests were along fence lines or hedgerows. Pastureland surrounded 67% of 60 nests, and the remaining nests were located in oldfields (20%), urban areas (6%), hayfields (5%), and a wheat field (2%). Graber et al. (1973) also found redcedar, multiflora rose, and osage orange were commonly used by nesting shrikes, but gave no data on the percentage of these nests located in hedgerows. Siegel (1980) reported that Alabama shrikes nested principally in redcedar, and 65% of their nests were in hedgerows associated with pastures. In Colorado, Porter et al. (1975) listed elms (*Ulmus* sp.), willows (*Salix* sp.), cottonwoods (*Populus* sp.), and Russian olive (*Elaeagnus angustifolia*) as support for 70% of all nests. They also found shrikes using grasslands more than cultivated fields. These studies indicate the importance of a dense nesting site (i.e., cedars and thorny vegetation), in open grasslands (i.e., pastures) for breeding Loggerhead Shrikes.

The average height of nests was 3.2 m. Height was significantly affected by the vegetation in which the nest was placed, and was greatest in deciduous trees and lowest in multiflora rose (Kruskal-Wallis test; $\chi^2 = 14.79$, df = 2, $P < 0.05$; Table 1). First nests were positioned significantly lower than second nests (Mann-Whitney $U$; $\chi^2 = 9.21$, df = 1, $P < 0.05$; Table 1). Nesting success was not affected by nest height ($\chi^2 = 2.63$, df = 1, NS). The average height of nests in Alabama was 3.0 m (Siegel 1980), and in Colorado it was 2.2 m (Porter et al. 1975).

*Egg-laying and incubation.*—Female shrikes layed one egg a day and the clutch-size ranged from 3–7 with most clutches having 5 or 6 eggs (Table 2). The average clutch-size of

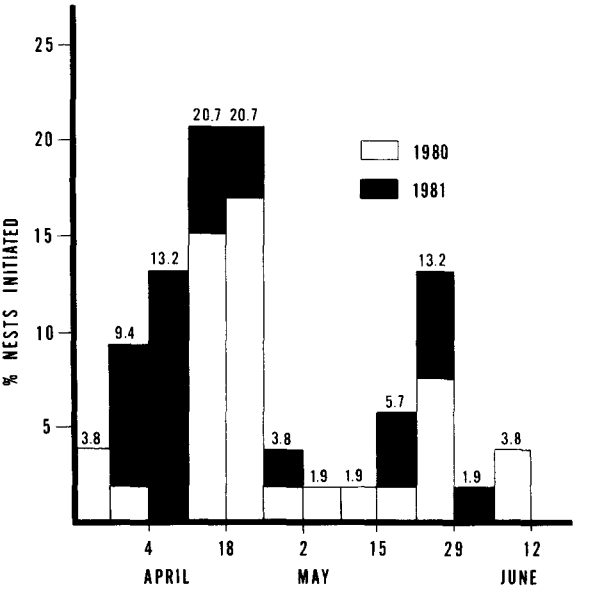


FIG. 1. Date of clutch initiation in 60 Loggerhead Shrike nests in central Missouri, 1980 and 1981.

shrikes in Florida was 4.38 (N = 16) (Lohrer, M.Sc. thesis, Univ. S. Florida, Tampa, Florida, 1974), in Alabama 5.0 (N = 32) (Seigel 1980), in Illinois 5.68 (N = 134) (Graber et al. 1973), and in northcentral Colorado 6.39 (N = 65) (Porter et al. 1975). Loggerhead Shrikes exhibit a latitudinal cline in clutch-size as do many other species (Spearman correlation, $r_S = 1$, N = 5, $P < 0.05$; Cody, Evolution 20:174–184, 1966). There was no correlation between clutch-size and date of nest initiation, nor was there a significant difference in the clutch-size in first and second nests (Mann-Whitney $U$; $\chi^2 = 0.15$, df = 1, NS).

I never saw males participating in incubation. This is contrary to what Bent (1950) reported, but agrees with comments made by Siegel (1980). Males fed incubating females on the nest. Shrikes are penultimate incubators (begin incubation with next to last egg), or even antepenultimate in some cases. This results in asynchronous hatching (usually 2 days between oldest and youngest). This difference in age leads to brood reduction during the first week of incubation when environmental conditions are adverse (cold or wet). In 10 nests where one or two young disappeared, the youngest nestlings were gone while the older, larger siblings survived. During the 1980 nesting season (dry and warm) brood reduction occurred at only one nest, while in 1980 (wet and cold) it occurred at nine nests (difference significant, $\chi^2 = 6.41$, df = 1, $P < 0.05$). At one nest the youngest nestling was found dead in the nest bowl and its stomach was empty suggesting that it starved. At other nests the adults probably removed young before I found them. Adults may remove dead nestlings as if they were foreign material or they may eat them or feed them to surviving young. On three occasions I observed adults canabilizing their own young that had been blown out of the nest and died.

The average incubation period for 13 nests was 17 ± 0.96 days (range = 16–20 days). Miller (1931) reported 16-day incubation period (N = 14), Porter et al. (1975) reported an

## TABLE 1

HEIGHT OF NESTS OF LOGGERHEAD SHRIKES IN CENTRAL MISSOURI

| | N | Height (m) |
|---|---|---|
| Average (all nests) | 60 | 3.2 ± 2.0 |
| Eastern redcedar | 36 | 3.4 ± 2.0 [a] |
| Multiflora rose | 7 | 1.1 ± 0.2 [a] |
| Deciduous trees | 17 | 3.7 ± 2.0 [a] |
| Nest in hedge | 37 | 2.9 ± 1.8 |
| Isolated nest | 23 | 3.7 ± 2.3 |
| 1st nest | 50 | 2.8 ± 1.8 [a] |
| 2nd nest | 10 | 5.2 ± 2.3 [a] |

[a] Paired difference significant (Mann-Whitney *U*-test, $P < 0.05$).

average of 16 days (N = ?), and Lohrer (1974) found incubation averaged 16.9 days (N = 16).

The average number of eggs hatching per nest was 4.9 with an average hatching success of 85.3% (Table 2). Of 36 eggs that failed to hatch, nine were infertile, three had dead embryos, three were lost to adverse weather (blown out of nest), 12 were destroyed by predators (primarily snakes), six were abandoned, and for three the cause of failure was unknown. Hatching success did not differ significantly between years (Mann-Whitney *U*, NS). In Alabama hatching success was 84.7% (Siegel 1980), and in Colorado (Porter et al. 1975) it was 79.5%. Porter et al. (1975) also found no yearly difference in hatching success.

*Nesting and fledging period.*—In my study males did not brood the nestlings, but both birds fed the young. The male made more feeding trips to the nest than the brooding female. Both adults participated in nest sanitation by removing fecal sacs and regurgitated pellets. Mean fledging period in 14 nests was 19.1 ± 1.4 days (range = 17–21 days); Miller (1931) reported 20 days, Siegel (1980) 17.6 days, and Porter et al. (1975) 17 days. Lohrer (1974)

## TABLE 2

COMPARISON OF NEST SUCCESS AND PRODUCTIVITY OF LOGGERHEAD SHRIKES IN CENTRAL MISSOURI, 1980 AND 1981

| | $\bar{x}$ ± SD | N | 1980 | N | 1981 | N | *P* |
|---|---|---|---|---|---|---|---|
| Clutch-size | 5.71 ± 0.66 | 45 | 5.52 ± 0.67 | 23 | 5.91 ± 0.61 | 22 | NS[a] |
| No. hatching per nest | 4.86 ± 1.72 | 43 | 4.61 ± 1.90 | 23 | 5.15 ± 1.50 | 20 | NS[a] |
| Hatching success | 85.3% | 43 | 83.5% | 23 | 87.3% | 20 | NS[a] |
| No. fledging per nest | 3.04 ± 2.35 | 53 | 4.08 ± 2.04 | 26 | 2.04 ± 2.23 | 27 | <0.05[a] |
| Fledging success | 59.4% | 43 | 77.1% | 22 | 41.9% | 21 | <0.05[b] |
| Nest success | 69.1% | 55 | 82.1% | 28 | 55.5% | 27 | <0.05[b] |

[a] Mann-Whitney *U*-test.
[b] $\chi^2$ test.

TABLE 3
REPRODUCTIVE SUCCESS OF LOGGERHEAD SHRIKES IN NORTH AMERICA

| State success, Authority | Nests | | Eggs | | Fledging | |
|---|---|---|---|---|---|---|
| | No. | % success | Hatched[a] | % success | No.[a] | % success |
| Alabama, Siegel (1980) | 37 | 43.2 | — | 84.7 | — | 50.0 |
| Colorado, Porter et al. (1975) | 65 | 62.2 | 5.1 | 79.5 | 3.6 | 55.9 |
| Illinois, Graber et al. (1973) | 20 | 80.0 | — | — | 4.6 | — |
| Illinois, Anderson and Duzan (1978) | 13 | 72.0 | — | 83.0 | 3.9 | 88.0 |
| Missouri, this study | 60 | 69.1 | 4.9 | 85.3 | 3.0 | 59.4 |

[a] Average per nest.

found that young at nests which were disturbed daily fledged at about 17 days, but not until 19 days from undisturbed nests.

Fledging success in 1981 was significantly lower than in 1980 (Mann-Whitney $U$, $P < 0.05$; Table 2). In 1981, frequent storms with torrential rains and cold temperatures occurred just before the young would have fledged resulting in loss of entire broods at eight nests. In 1980 only one nest was lost to severe weather. This difference in nest survival was significant ($\chi^2 = 5.58$, df = 1, $P < 0.05$). The dead nestlings had food in their stomachs and probably died from hypothermia. Porter et al. (1975) also found significant yearly variation in the average number fledged (2.2–4.7) and in fledging success (35.8–71.0%). The average number fledged per nest (3.0) and the fledging success (59.4%) found in this study are similar to the results of other studies (Table 3).

I found that after fledging the young remained in the nest tree for 2 or 3 days before flying to other perches and remained dependent on adults for 3 or 4 weeks post-fledging; they then began to forage successfully on their own. This is similar to the findings of Miller (1931). Also, I found that during the period of dependency the male is abandoned by the female, and thus he must meet the food demands of the fledglings. I observed males "training" their young during this period to recognize potential prey items by drawing them into close proximity with prey, permitting them to make the capture. By 30 June all breeding birds and their young had left the study area except for those that were renesting, and even they had left by 31 July in both years.

*Nesting success and renesting.*—The average nesting success was 69.1% but it differed significantly between years ($\chi^2 = 4.59$, df = 1, $P < 0.05$; Table 2). In 1980 predation was the major cause of nesting failure, but the high winds with heavy rains accounted for 8 of 11 nest failures during the 1981 nesting season. In Colorado, Porter et al. (1975) found significant yearly differences in nesting success (47.8–82.4%). They found that predation accounted for 52% of nest failures, but during the year with lowest success, weather accounted for 67% of the nest failures. Siegel (1980) reported that predation caused 71.4% of nest failures and that the rest were due to abandonment. All studies (Table 3) show that nesting success of Loggerhead Shrikes exhibits great variability from year-to-year, but is relatively high for an open-nesting altricial species in the North Temperate Zone (Nice, Auk 74:305–321, 1957). Therefore, reduced nesting success does not appear to be responsible for the decline of the Loggerhead Shrike in Missouri.

The vegetation in which the nest was placed affected fledging and nest success (Table 4). Nests in multiflora rose had the poorest success, perhaps because they were very low and

TABLE 4

EFFECTS OF VEGETATION ON NEST PRODUCTIVITY AND SUCCESS OF LOGGERHEAD SHRIKES IN CENTRAL MISSOURI (1980–81)

| Vegetation | % success | | |
|---|---|---|---|
| | Hatching | Fledging | Nest |
| Multiflora rose | 78.6 (6)* | 32.4 (6)[a] | 42.9 (7)[c] |
| Deciduous trees | 92.1 (11) | 75.4 (11)[b] | 93.8 (16)[d] |
| Eastern redcedar | 85.5 (26) | 52.7 (23) | 62.5 (32)[e] |

* Numbers in parentheses are sample sizes.
[ab] Paired difference significant ($\chi^2 = 4.82$, df = 1, $P < 0.05$).
[cd] Paired difference significant ($\chi^2 = 7.59$, df = 1, $P < 0.05$).
[de] Paired difference significant ($\chi^2 = 5.18$, df = 1, $P < 0.05$).

provided poorer support (easily tilted by winds). Nest success was highest in deciduous trees, probably due to their thorny nature (Table 1). Siegel (1980) also found success lowest in multiflora rose, and highest in osage orange. There was no significant difference ($\chi^2 = 0.04$, df = 1, NS) in nesting success between nests in isolated trees and nests in hedges.

Loggerhead Shrikes were considered multibrooded by Miller (1931) and Bent (1950), but Lohrer (1974) found them regularly double-brooded in Florida. No evidence of double broodedness was observed in Colorado, although renesting was common (Porter et al. 1975). In Alabama, Siegel (1980) reported that 3 of 20 successful pairs nested again. He also noted that 4 of 11 pairs renested after an initial nesting failure. In the present study 7 of 38 successful pairs (18.4%) attempted a second nest, and 5 of 17 pairs (29.4%) with an initial nesting failure renested. All second nests were built within the original territory. Perhaps some pairs left the study area before renesting. In areas where weather conditions are favorable, and the nesting season is long, shrikes appear to be double brooded (i.e., Florida [Lohrer 1974], California [Miller 1931]). At higher latitudes the number of birds raising a second brood, after a successful initial nesting attempt, declines (Porter et al. 1975).

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**Adaptive response of nesting Clapper Rails to unusually high water.**—On 13 April 1980, I observed Clapper Rails (*Rallus longirostris*) respond to high water by building their nest higher. The nest was in *Spartina alterniflora* in a saltwater marsh in Ocean Springs, Jackson Co., Mississippi. Within 24 h more than 20 cm of rain fell in the area. When the rails were first observed at 09:30 it had just stopped raining. One rail was on the nest, a second, judged to be the male by its brighter orange bill and more distinctive flank and head