

**Status and Breeding Ecology
of the Loggerhead Shrike in Virginia**

by

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(ABSTRACT)

Although loggerhead shrikes (*Lanius ludovicianus*) are still relatively widespread, Breeding Bird Survey results indicate that breeding population have declined substantially in Virginia and other parts of the species' range. Loggerhead shrikes should be considered for federal threatened status. I studied breeding chronology, productivity, and habitat use of 20 loggerhead shrike pairs in 1985 and 36 pairs in 1986. Yearly productivity in this Ridge and Valley population was 2.44 young raised to independence per breeding pair. Shrikes selected eastern red cedars (*Juniperus virginiana*) and hawthorns (*Crataegus spp.*) as nest support more than expected based on availability. Shrikes selected more, produced more young in, and were more likely to reoccupy active pastures compared to other habitat types. Herbaceous vegetation structure can limit shrike prey availability and may be responsible for the differential productivity and reoccupancy in active versus idle pastures. These results led to the development of hypotheses to explain the shrike decline. Shrikes are very sensitive to changes in successional stages of grassland foraging areas. Changed land-use practices such as smaller areas of farmland and pasture, and larger fields and area of rowcrops, may partially explain the decline in Virginia. Changes in the intensity, phenology, or placement of cattle grazing can result in lowered shrike productivity and may have also contributed to the decline. Further studies of shrike reproductive success, mortality, and habitat use should be conducted in stable and declining populations.

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I thank [redacted] for always being my friend and for his willingness to visit me no matter how far afield I stray. [redacted] taught me how to live comfortably earning a graduate stipend (with some help from Pizza Inn and Milwaukee's Best). My parents [redacted] and the rest of my family are a constant source of support and encouragement.

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INTRODUCTION

The loggerhead shrike (*Lanius ludovicianus*) once was relatively common throughout much of the United States, southern Canada, and Mexico (Miller 1931, Bent 1950, Morrison 1981). Recently, however, United States and Canadian populations have declined (Fraser and Luukkonen 1986). Breeding bird surveys and Christmas bird counts have provided the best quantitative evidence of these declines (Bystrak 1981, Morrison 1981); the opinions of local experts, summarized annually in *The Blue List* (Arbib 1979), support the results of these surveys.

The causes of shrike declines are not understood completely. Kridelbaugh (1982) attributed the decline in Missouri to conversion of pastures and hayfields to rowcrops. Hedgerow removal also may reduce the quantity or quality of shrike habitat (Graber et al. 1973). Cely and Corontzes (1986) suggested that increased farm size and succession of abandoned fields to woods impacted South Carolina's shrike populations. While habitat loss may be partially responsible for shrike declines in some areas, some suitable shrike habitat appears to be vacant (Fraser and Luukkonen 1986). Furthermore, quantitative information about habitat requirements and recent changes in habitat availability are lacking. Graber et al. (1973) attributed a slow decline in Illinois between 1900 and 1957 to habitat loss and a very rapid decline after 1957 to unknown causes.

Pesticide contamination has also been suggested as an explanation for the decline. Anderson and Duzan (1978) analyzed shrike carcasses and eggs from southern Illinois. They found DDE (a

metabolite of DDT) in subcutaneous fat and eggs, as well as significant reductions in eggshell thickness. Morrison (1979) did not find decreases in eggshell thickness in California and Florida where populations seem to be declining slowly. Despite these results, excessive reproductive failures associated with DDT contamination have not been reported in U.S. shrike populations (Anderson and Duzan 1978, Kridelbaugh 1983). While recent studies indicate that reproductive success is relatively high, no historic data on reproduction are available for comparison. Cadman (1985) cites unpublished studies suggesting that environmental contaminants may have lowered reproductive rates in Canadian populations. Anderson and Duzan (1978) speculated that the decline in Illinois was associated with excessive fledgling, juvenile, or adult mortality rather than reproductive failures.

Another chemical that has affected bird populations is dieldrin. This chemical can result in toxicosis and death and at sublethal levels can interfere with the normal development of hunting behavior in shrikes (Busbee 1977). Both DDT and dieldrin were banned from most applications in the early 1970's, and several species appear to be recovering from their effects. There is no evidence that shrike populations are recovering, suggesting that that these contaminants may not be responsible for recent shrike declines. It is possible that chemicals that have replaced DDT and dieldrin are impacting shrike populations.

Legrand (1986) speculated that a disease may be responsible for the decline. Competition for food between shrikes and American kestrels (*Falco sparverius*) or Starlings (*Sturnus vulgaris*) has also been proposed as an explanation (Cadman 1985). Cadman (1985) also cites fledgling mortality caused by vehicle collisions as another possibility. Climatic changes have been suggested as the cause of the decline of red-backed shrikes in Britain (Bibby 1973). While many hypotheses have been proposed, few data are available to test their validity.

Understanding shrike declines will require a more thorough knowledge of life histories, population parameters, and habitat requirements in declining and stable populations. Similarly, Milburn (1981) stated that: "Support should be given to future research on the cause of the decline of the loggerhead shrike. So little is known about the behavior, ecology, and habitat requirements of the bird in the east that a conservation effort designed to reverse its decline would have little chance of success." After summarizing the status of the shrike in the Northeastern United States,

Milburn (1981) reported that Virginia is the last Northeastern state that supports a large enough shrike population that could be studied practically. Thus, Virginia made an ideal area to study this species. Objectives of the study were to:

1. Determine the status of breeding shrikes in Virginia
2. Locate a breeding population in Virginia that could be studied
3. Quantitatively describe shrike nesting habitat
4. Estimate yearly reproductive rates of shrike pairs in Virginia

This report will be organized into two main sections. The first section will deal with objectives 1 and 2. The second will address objectives 3 and 4.

DISTRIBUTION AND STATUS

METHODS

I used several sources to locate recent and historic shrike sightings in Virginia. Notices were published in popular Virginia ornithological newsletters requesting reports of shrike sightings. I used banding records, Breeding Bird Survey records, Christmas bird count records, museum records, and other literature to supplement the survey. The U.S. Fish and Wildlife Service (FWS) provided banding records and Breeding Bird Survey records. Christmas bird count records were taken from Milburn (1981) and the Virginia Society of Ornithology's journal, *The Raven*. I requested information about shrike study skins and egg collections from museums suggested by Kiff (1979).

Many sources provided only general descriptions of the locality of sightings. Therefore, I summarized distribution information by county or independent city. When records did not specifically report county information, the record was assigned to the most probable county. For example, the breeding bird survey records contain the starting point for a route and not the coordinates where birds were sighted. Some routes cross county boundaries and there is some un-

certainty in assigning records to counties. I assigned these sightings to the county where the route originated.

Breeding records were considered confirmed records when nests or young were observed and potential records when single birds or pairs were sighted from April-August. Shrike sightings before 1980 were designated "historic" sightings and sightings from the 1980 through 1986 were designated "recent." Historic and recent winter shrike distributions were mapped similarly using shrike sightings from November through February. Sightings during March, September, and October could include many birds on migration and were not used to map distributions.

During the 1985 field season, the study team searched for shrikes from April through August. These searches were conducted at sightings reported during the field season and at sightings from previous breeding seasons. I asked the person reporting the sighting to lead field personnel to the location. When this was impossible, the person was interviewed and asked to specify the location. Shrike searches were conducted within circles with 500 meter radii centered on the location of the sighted bird. Shrike breeding territories have radii much smaller than 500 meters (Porter et al. 1975); therefore, search circles of this size would include the nests of shrikes sighted on territory. The study team searched unforested habitats within the circle with the aid of binoculars and spotting scopes. When a bird was observed, the area was searched for nests. Searches lasted approximately 1-2 hours or until a shrike nest was located. When a search was unsuccessful, I repeated the procedure several times throughout the breeding season. I felt confident that my searching technique would locate nesting shrikes in the immediate area (200-300 meters from the search center). During the 1986 field season, effort was concentrated in Rockingham and Augusta counties. Breeding sites found during 1985 were searched a minimum of three times in 1986. The study team searched additional locations where shrikes were reported in 1986.

Shrike population trends were determined using Breeding Bird Survey data. Breeding Bird Survey data were provided by the FWS. The FWS also provided results of their own analyses of these data. I analyzed the Virginia Breeding Bird Survey data using a simple linear regression of shrikes per Breeding Bird Survey route on year. Because many routes had not been established prior to 1968, I only analyzed data collected after 1967. I tested the null hypothesis of no trend

by testing the significance of the regression slope. Because all routes were not surveyed each year, and because the number of routes within an ecological stratum within the state is not proportional to the area of that stratum, there is some potential for bias in the resulting equation (Sauer pers. comm. 1986). The FWS analysis accounts for these potential biases and was used as a check on my analysis and to compare Virginia's trend to other state's trends.

The FWS provided population trends for U.S. and Canadian political regions. I used these data to compare Virginia's shrike abundance and population trend with other states and Canadian provinces. U.S. states and Canadian provinces were considered in this comparison only if data were available for more than ten routes per state or province (Drogy pers. comm. 1986). Data analyses were performed using the SAS (1985) statistical package.

RESULTS

DISTRIBUTION

I obtained 111 confirmed breeding records (38 historic and 73 recent) in 26 of Virginia's 95 counties and 7 of Virginia's 38 independent cities. An additional 28 counties and 5 independent cities contained potential breeding records only (Appendices I-VI, Fig. 1). I obtained 148 historic potential breeding records and 54 recent potential breeding records. Twenty-one of 46 (45.6%) counties and 8 of 11 (72.7%) independent cities with one or more historic breeding records had no recent breeding records; however, the locations of recent records were widely distributed (Fig. 2). Eight counties and one independent city without historic breeding records contained recent records.

I located winter records from 50 counties and 5 independent cities (Appendices III and VI, Fig 3). Twenty-four of 45 (53.3%) counties and 4 of 5 (80%) independent cities with historic re-

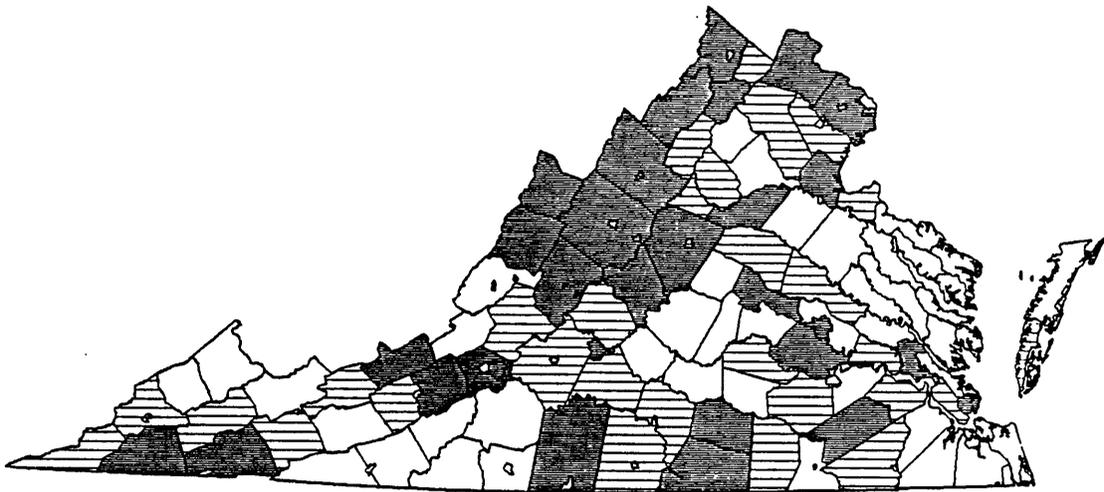


Figure 1. Loggerhead shrike breeding range in Virginia. Solid shading represents counties and independent cities with confirmed breeding records. Areas with horizontal ruling contain potential breeding records only.



Figure 2. Historic and recent breeding range in Virginia. The upper map represents data for pre-1980 breeding seasons and the lower map represents data for the 1980-86 breeding seasons. Shaded areas represent counties with confirmed or potential breeding records.

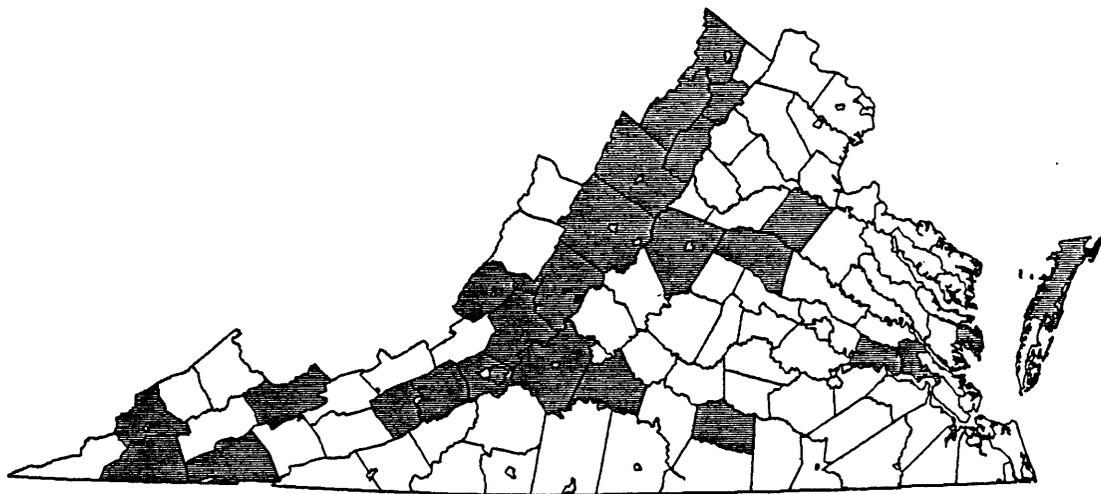
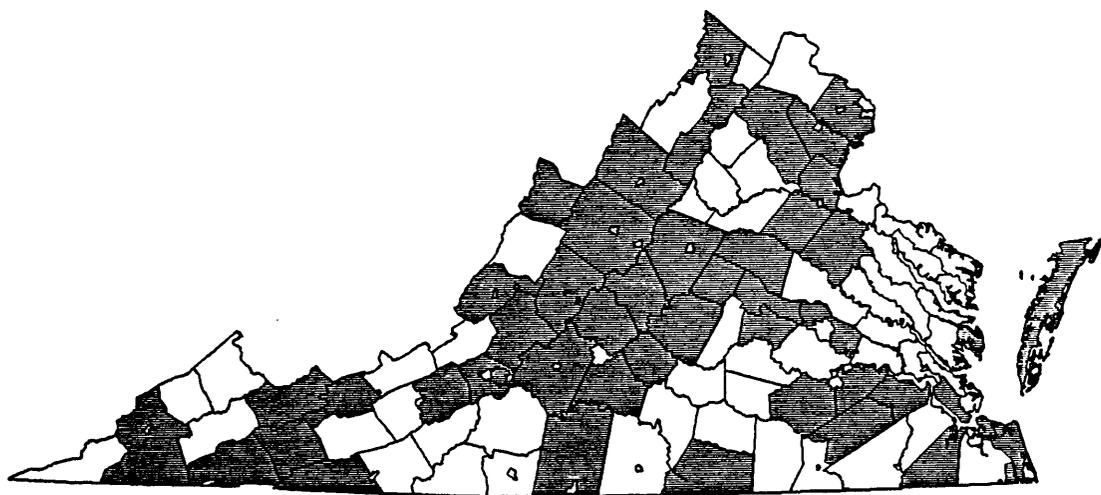


Figure 3. Historic and recent winter range in Virginia. The upper map represents data for winters prior to 1980 and the lower map represents data for the winters 1980-81 through 1985-86. Shaded areas represent counties where shrikes were observed.

cords did not have recent records (Fig 3). Five counties with recent winter records did not contain historic records.

FIELD SEARCHES

Between 1 April 1985 and 13 July 1985 the study team searched 32 locations. I considered searches successful if one or more shrikes were observed. Overall searching success was 59.4%; however, search success differed between areas where shrikes were reported during the field season (success = 76.2%, N = 21) versus reports from previous years (success = 27.3%, N = 11; $\chi^2 = 7.16$; $df = 1$; $p = 0.007$). Sixty-eight percent of 22 sites occupied in 1985 were reoccupied in 1986 (Appendix VII). The reoccupancy rate I observed did not differ significantly from the rate of 54% (N = 28) reported by Kridelbaugh (1982) for a Missouri population ($\chi^2 = 1.096$; $df = 1$; $p = 0.295$).

The majority of recent sightings came from Augusta and Rockingham counties and intensive field work was concentrated there in 1986. Volunteers from the Rockingham and Augusta bird clubs contributed a great deal of time searching during 1985 and 1986, which may account for the greater numbers of recent sightings there. I observed 49 breeding areas distributed over Augusta, Bath, Highland, Lunenburg, Montgomery, Rockingham, Shenandoah, and Warren counties (appendix VII). Most (81.6%) were in Augusta, Rockingham, and Shenandoah counties.

The population in the Shenandoah Valley was at a high enough density to permit detailed observations at nest sites. One field worker could visit the breeding locations I observed in Augusta, Rockingham, and Shenandoah counties in 3 days or less.

POPULATION TRENDS

The number of shrikes counted per Virginia Breeding Bird Survey route declined significantly between 1968 and 1983 (Fig. 4). The least-squares linear equation fit to these data indicate a 94% reduction in the number of shrikes counted per Breeding Bird Survey route between 1968 and 1983 ($y = 4.57 - 0.054x$; $p < 0.01$; $r^2 = 0.53$). The FWS fit a logarithmic equation to Breeding Bird Survey data between 1966 and 1985 and found a significant decline in Virginia ($p < 0.01$). They estimated that shrikes have declined at a rate of 10.0% per year.

Twenty-nine of the 32 U.S. and Canadian political regions that I considered in the comparison showed declining population trends (Fig. 5). All regions with significant ($p < 0.01$) trends showed declines and the overall continental trend showed a significant 3.7% yearly decline ($p < 0.01$). Compared to other U.S. states and Canadian provinces, Virginia supports a relatively low density breeding population that is declining rapidly (Fig. 5). Many of the Northeastern and Midwestern states had too few shrikes to be accurately censused by the Breeding Bird Survey. The trend in North Carolina was similar to that in Virginia and the rate of decline in the Southeast coastal states appears to be most severe at northern latitudes (Fig. 6).

DISCUSSION

The loggerhead shrike is a widespread but rare bird in Virginia. Populations have declined substantially and no recent records were found for some counties that historically supported shrikes. However, distribution changes could not be assessed accurately because records are based upon opportunistic rather than controlled searching effort. The results of the Virginia Commission of Game and Inland Fisheries, Breeding Bird Atlas project may provide a more complete and recent data base to compare to the historic shrike distribution.

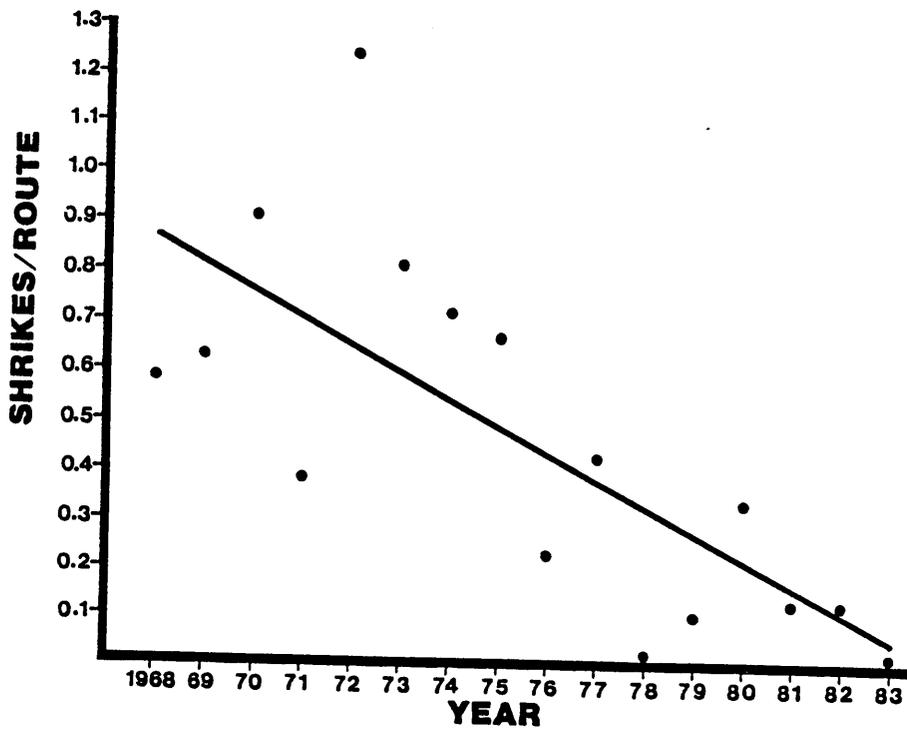


Figure 4. Loggerhead shrike population trend in Virginia. The line represents the least-squares equation fit to yearly Breeding Bird Survey count averages.

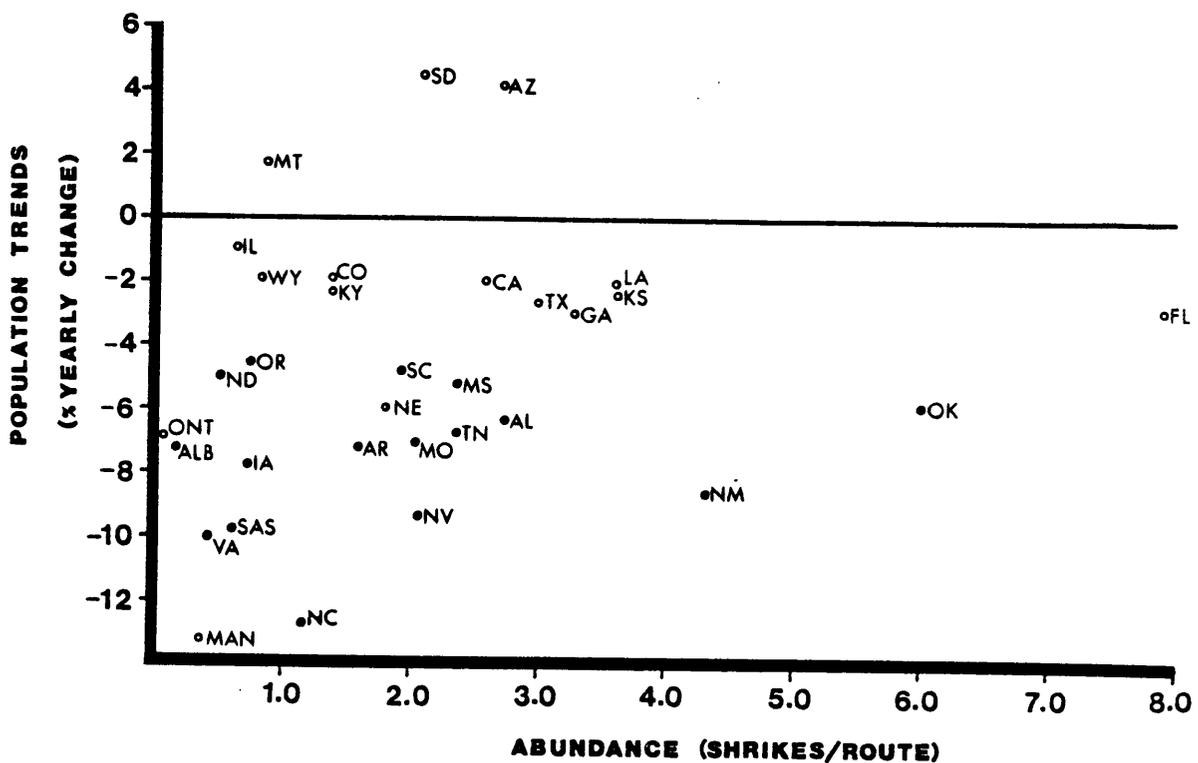


Figure 5. Regional shrike abundance and population trends. Data are from U.S. and Canadian Breeding Bird Surveys between 1966 and 1985. Open circles represent nonsignificant trends and closed circles represent significant trends ($p < 0.01$). Two letter abbreviations are U.S. states and three letter abbreviations are Canadian provinces.

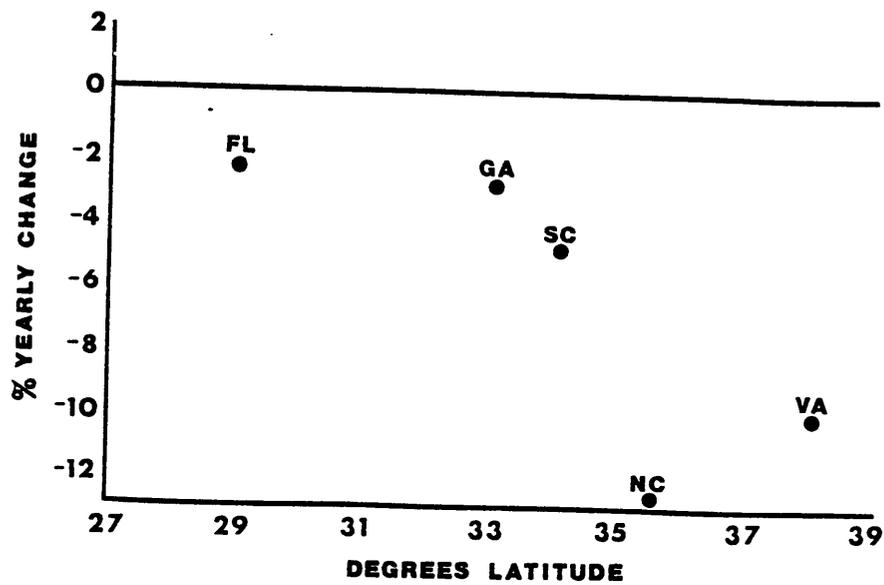


Figure 6. Population trends in Southeast coastal states. Abbreviations indicate state.

The differential searching success at recent and historic sightings and the inactivity of 31.8% of the 1985 breeding sites in 1986 suggests that breeding territories have become vacant. The loss of breeding territories may indicate mortality or abandonment and movement to new breeding territories.

Based on Miller's (1931) range criteria, the Ridge and Valley province of Virginia lies in a region of overlap between the migrating (*L. l. migrans*) and non-migrating (*L. l. ludovicianus*) subspecies. Both subspecies and intermediate forms may breed in the region; only *L. l. ludovicianus* breeds in the Piedmont and Coastal Plain regions. Both subspecies may also be winter residents in Virginia. One hatch-year shrike banded in Quebec during August 1945 was recovered in Virginia during February 1946 (Burnside 1977). One shrike banded near Blacksburg spent the winters of 1984-85 and 1985-86 near the breeding site. Shrikes were also observed during the winters of 1985-86 and 1986-87 near breeding sites located in the Shenandoah Valley region (Finnegan pers. comm. 1986). Thus, the shrike is an uncommon year-round resident of Virginia, but some of the breeding individuals may be migratory and some winter birds are migrants from northern breeding areas.

Breeding populations have declined substantially and current trends suggest that the shrike soon may be extirpated in Virginia. Given the widespread decline of this species and the uncertainty over the reasons for decline, both *L. l. ludovicianus* and *L. l. migrans* should be considered threatened or endangered in Virginia.

Breeding Bird Survey data indicate that the shrike decline is occurring over a large portion of its range. Most of the Northeastern states support too few shrikes to make intensive research feasible (Milburn 1981, Novak pers. comm. 1986) and the Canadian provinces support sparse populations that are declining rapidly. The low numbers in the Northeast and Midwest and the pattern of decline along the Southeast coast suggest that the decline has proceeded from north to south in the east. The FWS considers the more northern migrant subspecies (*L. l. migrans*) to be most threatened (Dodd et al. 1985). While this subspecies should receive top priority, other subspecies have declined rapidly and should also be considered for threatened status.

HABITAT AND PRODUCTIVITY

METHODS

STUDY AREA

The habitat and productivity studies were conducted in Augusta, Bath, Highland, Montgomery, Shenandoah, and Rockingham counties, Virginia. These counties lie in the Ridge and Valley physiographic region. Ridges were dominated by the oak-hickory (*Quercus spp.-Carya spp.*) forest type. Valleys were primarily pasture with lesser amounts of hay, rowcrop, and old fields. Small woodlots were interspersed throughout the valleys.

Fieldwork was restricted to unforested valleys that were bounded by contiguous upland forests. The study area consisted of valleys where shrikes were known breeding residents. Valley-forest boundaries were determined from 7 1/2 minute U.S.G.S topographic maps. The primary study valley was the Shenandoah Valley east of the forested Shenandoah Mountain and West of the forested Blue Ridge and Massanutten mountains. The northern and southern boundaries of this study

valley were between 38° 50' and 38° 00'. Smaller study valleys were distributed throughout the area (Fig 7).

LOCATING NESTS

Shrikes are relatively rare breeding birds in Virginia and I anticipated difficulty locating enough breeding pairs to make research feasible. Two years prior to beginning field work notices were published in state ornithological newsletters and journals requesting readers to report shrike sightings. Experienced volunteers from the Augusta and Rockingham bird clubs volunteered searching time during the 1985 and 1986 field seasons. Volunteers were familiar with the study area and searched primarily from vehicles. The study area has many roads and provided thorough coverage of open habitats. When shrikes were reported, the study team conducted field searches as described in the previous methods section.

HABITAT MEASUREMENTS

I tested the overall hypothesis that habitat used as nest sites was randomly chosen from available habitats. Habitat measurements were designed to examine selection at two scales. The smaller scale (microhabitat) included the nest tree and the habitat within 11.3 m of the tree. Measurements at this scale were taken in August, after young had left the nest area. A randomly chosen tree within 200 m of the nest tree was paired with each nest tree for comparison. I chose random trees by establishing a random point within 200 m of the nest tree. The tree nearest the random point that was large enough to support and conceal a shrike nest was measured. I discarded other random points that fell in cover types different than the nest tree was located.

At each nest tree and paired random tree, several variables were measured. I recorded species, height, and presence or absence of vines for each tree. Heights were measured with a clinometer or tape measure. I counted the number of trees and shrubs greater than 1 meter tall in each of two

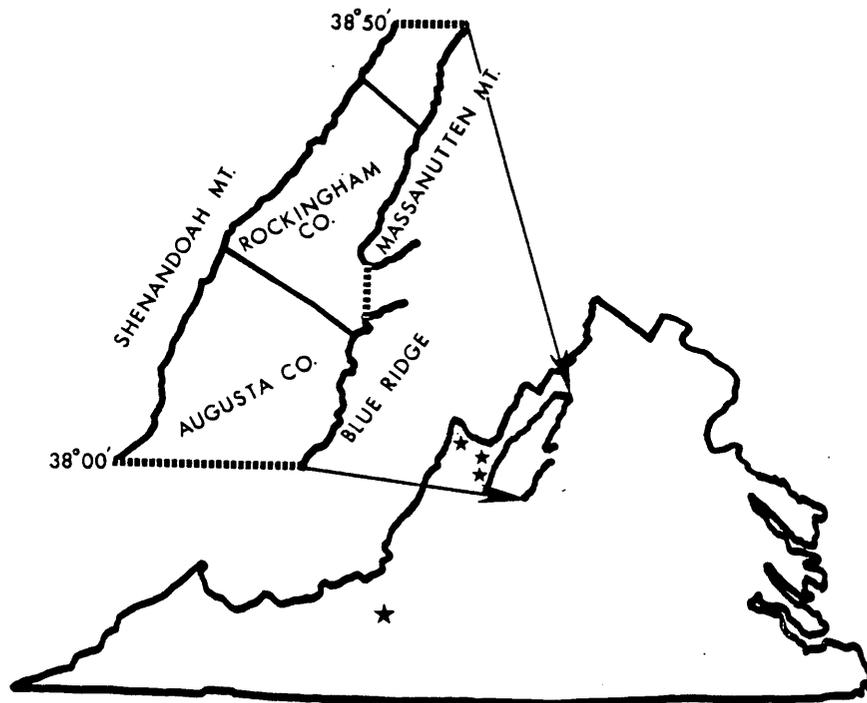


Figure 7. Study areas in the Ridge and Valley province of Virginia. Stars show the locations of small study valleys and the enlarged map shows the Shenandoah Valley study area.

height classes (≥ 1 m but ≤ 2 m, and > 2 m). Distances to nearest barbed-wire fences and roads also were measured. Nest height, concealment, and herbaceous plant measurements were taken at nest trees only. Nest concealment was quantified using scores of 1 to 5 (1 = poorly concealed, 5 = completely concealed) taken as close to hatching date as possible. I scored each nest viewed from the top, side and bottom and the three scores were averaged to produce one value for each nest.

Ground vegetation characteristics near nest trees were measured in 1985 only. Four 10 m transects were used to quantify herbaceous vegetation. The first was positioned at a random direction starting at the edge of the tree canopy. The three others were positioned at 90, 180, and 270 degrees relative to the first. Transects that fell outside of the cover type or in a crop field were repositioned so that all transects measured characteristics of pastures, hayfields, old fields, or lawns adjacent to the nest tree. I used a tape measure to delineate each transect. I estimated ground cover by recording the length of bare ground intersecting one edge of the tape. Herbaceous plant heights were measured at the beginning, middle and end of each transect. At each sample point a meter stick was held perpendicular to the ground and the height of the tallest plant touching the stick was recorded.

The second scale of selection (macrohabitat) included habitat characteristics within 200 meters of the nest tree. I chose this scale to approximate the size of a shrike breeding territory (Kridelbaugh 1982). Measurements were taken from aerial photographs at a scale of 1:3960. I centered the 200 meter radius plots on the nest tree and on random points. When there were multiple nestings at a breeding site, a visual estimate of the arithmetic center of the nest trees was used as the center. If nests were positioned more than 100 meters apart, I measured separate plots and averaged them to characterize the breeding site. I centered random plots on the tree closest to the random point. I chose random points by picking random latitudes and longitudes within each valley known to contain shrike nests. Random points were not used if they fell in forest or within city limits as designated on 7 1/2 minute U.S.G.S. topographic maps. Seventy-nine points were measured. The proportion of random points in each valley approximated the proportion of the total sample of nest sites within each valley.

I ground-truthed aerial photographs for nest sites and random points from May through August 1986. Photographs ground-truthed early (May and June) were checked again later in the summer to ensure that land-use practices had not changed. I searched random points during ground-truthing and recorded the presence or absence of suitable nest support plants within the circle. Searches were performed as described earlier, except that I limited searches to approximately 300 meters from circle centers and only 1/2-1 hour was spent at each point. Cover types and other habitat features were recorded directly on the photograph. The positions of fences, hedgerows, and utility wires were recorded. I used the following land-use classifications: forest, active pasture, idle pasture, hay, rowcrop, old field, and lawn. Active pastures differed from idle pastures in the intensity of grazing during the spring and summer. Active pastures were grazed intensively and were characterized by short grass length. Idle pastures received little or no grazing pressure and were commonly maintained by mowing. Hayfields were maintained by mowing and were characterized by the lack of fences and commonly had a mix of broad-leaved herbaceous plants and grasses. The major rowcrop on the study area was corn. Old fields were identified by the presence of perennial weeds and invading woody plants and were not grazed or mowed.

I measured the lengths of fences, hedgerows, and utility wires and areas of different cover types using an electronic planimeter (Tektronix, model 4956). Utility lines with multiple strands of wire were measured as one length. Availability of large perches was quantified using four transects radiating from the center of the sample plot on photographs. The number of transect-perch intersections in each of four quadrants was recorded. Large trees, fences, utility wires, and other potential perches discernible on the photograph were included. I counted perches only if they were within one of the unforested cover types. Fences or utility lines counted as one perch intersection, regardless of the number of strands of wire. When a transect went through a forested area, the forest-field boundary was counted as one perch and trees within the forest boundary were not counted. The average of the four transects was used to characterize the sample plot.

The sample of breeding sites located by the study team was closer to roads than expected at random. Because some habitat variables were related to the distance to roads, I chose a subset of random points that approximated the frequency distribution of distances to roads in the breeding

site sample. This eliminated road effects at the macrohabitat scale when comparing random points to breeding sites.

REPRODUCTIVE RATES

When possible, I visited nests approximately twice weekly. Some isolated nests were visited only once a week. Nest contents were observed with a mirror attached to a telescoping pole. I climbed trees or used ladders to observe higher nests. The number of eggs or young was recorded at each visit. When nests failed I examined the vicinity of the nest for eggshells, or remains of young and examined the condition of the nest. Adults were watched for signs of renesting after failure and second nesting throughout the season. Barbed wire, thorns and other likely objects were searched for impaled prey. I removed nestlings and banded them with FWS aluminum bands and color bands (A.C. Hughes Co.) and weighed them at approximately 10 days after hatching. When nestlings reached approximately 17-18 days, I avoided placing the mirror near the nest to prevent premature fledging. I continued monitoring nest sites after young fledged to estimate fledgling survival. Young remain dependent on the parents for 3-4 weeks after fledging (Kridelbaugh 1983). Young vocalize during this period when adults deliver prey and these vocalizations aided in locating young. When possible, the color bands of young were determined to avoid double counting individuals. Visits made after fledging lasted 1/2-2 hours.

DATA ANALYSIS

Many of the habitat variables were not normally distributed. Therefore, I used nonparametric procedures (Conover 1971) to test for differences in numerical variables. Chi-square tests and log-linear models were used to examine the relationships among categorical variables. Habitat similarity between random points and sites where shrikes produced young were calculated using Euclidean distances from the mean habitat vector for successful sites and the vectors for each ran-

dom point or successful site. Data for successful sites and random points were combined and standardized so that all the variables in the combined data set had means equal to zero and standard deviations of one. All macrohabitat variables except the distance to road were used to calculate Euclidean distances. I calculated relative Euclidean distances between the mean vector of successful sites and individual records (breeding sites or random points) by dividing all distances by the maximum. This produced similarity scores between 0 (most similar to habitat at successful sites) to 1 (least similar). Data analyses were performed with SAS (1985) and BMDP (Dixon 1985) statistical software packages.

I used Mayfield's (1961) method of calculating nest success. Nests were considered successful if one or more young fledged. I split the nesting cycle into egg laying through hatching and nestling through fledging periods and calculated probabilities of survival for each period separately. Overall nest success was calculated by multiplying the two probabilities. Standard errors of survival probabilities for each period were estimated according to (Johnson 1979) and the standard errors of the products of the two survival probabilities (the overall probability of survival) were calculated according to Topping (1957:82). Complete data were not available for all pairs, so for comparing first nest attempts to others I assumed that nests initiated after 29 April represented second or third nestings. I also calculated productivity assuming that I had located all nesting attempts for a subset of pairs followed throughout the breeding season. These calculations also assumed that shrikes were seasonally monogamous. Rates of increase were calculated from demographic data using formulae in Krebs (1985:174) and a computer program similar to that reported by (Grier 1979).

I determined clutch initiation dates for shrike nests by interpolating laying dates between visits or backdating from known hatching or fledging dates. I back-calculated laying dates using 17 days for incubation and 19 days from hatching to fledging (Kridelbaugh 1983).

RESULTS

I located 28 nests initiated by 20 breeding pairs in 1985 and 56 nests initiated by 36 breeding pairs in 1986. Complete data were not available from all pairs because some were found late and others were too isolated to check on a regular basis. The study team found shrikes at only one of 79 random points searched in 1986. Two breeding sites were occupied by single birds in 1985 and 1986; two additional breeding sites with single birds were discovered in 1986. These birds sang from exposed perches and in one instance I observed a single bird defend the area against a conspecific. I took habitat measurements at two breeding sites occupied in the early 1980's (Finnegan pers. comm. 1985) that were unoccupied in 1985 and 1986.

BREEDING BIOLOGY

I banded 5 adults and 56 young during the 1985 breeding season and one adult during the winter of 1984-85. Two of the adults (both male) returned and bred in the same locations in 1986. Two female young were relocated in 1986. One young had taken her mother's place as a breeding adult in its natal territory. Her mother was seen in the same territory at the end of the 1986 breeding season. The other young was found as part of a breeding pair approximately 23.5 km from its natal territory. I did not know the sexes of three adults banded in 1985. I banded 6 adults, 99 nestlings, and 1 fledgling in 1986. Two adult banded pairs remained together and banded individuals remained near nest sites throughout the nesting season.

Shrikes laid one egg per day ($N = 4$ nests). I observed females incubating before the entire clutch was laid and assumed that shrikes began incubation on the second to the last egg (Kridelbaugh 1983). Nestlings hatched asynchronously, but I did not visit nests often enough to determine differences in hatching times. For one nest checked on consecutive days, the minimum time between the first and last egg hatching was 24 hours. Kridelbaugh (1983) reported 2 days

between first and last hatching. Shrikes averaged 17 days of incubation before hatched eggs were found (N=5 nests, range 16-18). Nestlings left the nest (fledged) an average of 18.4 days after hatching (N=7 nests, range 17-20). At one nest, fledging occurred at 15 days after hatching, but I excluded the nest from analysis because I disturbed it and may have caused premature fledging.

The distribution of clutch initiation dates was bimodal (Fig. 8); the first peak occurred in April and the second peak occurred in late May to early June and was a result of renesting after failures and second nests. Four of 12 (33.3%) pairs in 1985 and 14 of 19 (73.7%) pairs in 1986 with successful first nests initiated a second nests. Two pairs in 1986 attempted third nests after their second nests failed; only one of the three nests was successful for both pairs. The rate of second-nesting after successful first nests differed between the two years ($\chi^2=4.92$, $df=1$, $p=0.027$). Four of six (66.7%) unsuccessful pairs renested in 1985 and 4 of 9 (44.4%) unsuccessful pairs renested in 1986.

NEST SPACING

Shrikes placed second and third nests close to the previous nest site ($\bar{X}=90.6$ m, $SE=15.8$ m, range=7.7-342.0 m, N=26). Second nest attempts after initial successful nests were placed similar distances from the original site as were renestings after initial failures (Wilcoxon rank sum test, $p=0.515$, $\bar{X}=76.7$ and 121.9 m, N=16 and 9 for nestings after successful and unsuccessful nests respectively). Some birds may have left the territory before attempting alternate nests; however, most birds remained in the vicinity of the territory until late July or early August. Twelve pairs in 1986 that nested within territories occupied in 1985 placed first nests an average of 85.6 m (range=0-244.0 m, $SE=26.6$ m) from first nests in 1985. Four of these pairs placed nests in approximately the same place within the same tree in 1986 as in 1985. We found 5 cases where occupied shrike territories were adjacent to one another. The average distance between the 5 nests of these pairs was 545.7 m (range=395.2-819.4 m, $SE=79.4$ m).

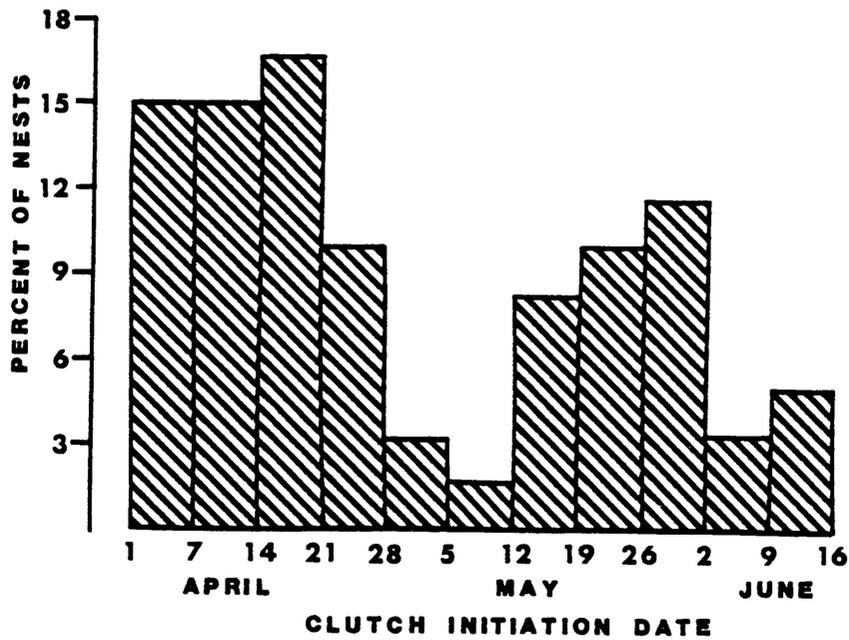


Figure 8. Weekly distribution of clutch initiations. Data are for 60 nesting attempts from 1985 and 1986 combined.

REPRODUCTIVE RATES

Shrike had 4, 5, and 6 egg clutches only. Mean clutch size tended to be lower in second nests (Table 1). The distribution of 4, 5, and 6 egg clutches differed between first and second nests ($\chi^2 = 12.67$, $df = 2$, $p = 0.002$), due primarily to the increase in 4 egg clutches and the decrease in 5 egg clutches for second nests (Table 2). Clutch size was negatively correlated with clutch initiation date ($r = -0.295$, $p = 0.044$, $N = 47$).

Eighteen of 25 (72.0%) nests with known outcomes fledged at least one young (were successful) in 1985 and the outcomes of 3 nests were unknown. Thirty-six of 55 (65.5%) nests with known outcomes were successful in 1986 and the outcome of one nest was unknown. Nesting success was lower when calculated using the Mayfield (1961) method (Table 1). Nest success was similar between years and between first and second nestings (Table 1).

Nests had similar survival rates from laying to hatching and for nestling periods. Seven (26.9%) nests failed during incubation, 7 failed during the nestling stage, 3 (11.5%) failed prior to laying, 3 failed during laying, 2 (7.7%) were abandoned close to hatching, and for 4 (15.4%) failures the stage was unknown. The daily survival rate of nests from laying through hatching was 0.9849 ($SE = 0.0048$) and the daily survival rate of nests with young was 0.9919 ($SE = 0.0033$).

Of 201 eggs surviving until just prior to hatching, 173 (86.1%) hatched; similarly, hatching success was 90.6% (173 hatched of 191 eggs) when two nests failing near hatching were eliminated. The second value (90.6%) better represents hatchability (Koenig 1982) since the eggs in the two nests not considered were probably abandoned just prior to hatching. Hatchability refers to the probability that eggs will hatch given that they are not destroyed or abandoned before the time required for normal development.

An average of 4.59 eggs hatched per successful nest ($N = 34$, $SE = 0.23$ eggs) and 156 hatched eggs produced 138 fledglings from 34 successful nests. Thus, 11.5% of the eggs that hatched did not produce fledglings in successful nests. This statistic provides a measure of individual nestling loss when some members of the brood eventually fledge. Since nest predators normally take an

Table 1. Reproductive characteristics of loggerhead shrike nests in the Ridge and Valley province of Virginia.

Variable and year	First nests ¹		Second and third nests		All nests combined	
	N	\bar{X} or %	N	\bar{X} or %	N	\bar{X} or %
Clutch size						
1985	10	5.30 (0.15) ²	7	4.86 (0.34)	17	5.12 (0.17)
1986	24	5.21 (0.10)	12	5.00 (0.25)	36	5.14 (0.11)
Years combined	34	5.24 (0.09)	19	4.95 (0.19)	53	5.13 (0.09)
Nest success (% fledging at least one young)³						
1985	11	56.7 (17.2)	8	57.9 (21.7)	19	57.0 (13.4)
1986	24	66.4 (10.2)	14	58.5 (14.1)	38	63.9 (8.4)
Years combined	35	64.0 (8.8)	22	57.9 (11.8)	57	62.1 (7.1)
Young fledged per successful nest						
1985	10	4.40 (0.45)	6	3.50 (0.56)	16	4.06 (0.36)
1986	18	3.94 (0.36)	12	3.83 (0.27)	30	3.90 (0.24)
Years combined	28	4.11 (0.28)	18	3.72 (0.25)	46	3.96 (0.20)
Young surviving to independence per successful nest⁴						
1985	9	1.78 (0.43)	5	2.80 (0.49)	14	2.14 (0.35)
1986	16	3.31 (0.34)	12	2.17 (0.41)	28	2.82 (0.28)
Years combined	25	2.76 (0.30)	17	2.35 (0.32)	42	2.60 (0.22)

¹If we did not know the complete history of the pair, nests initiated prior to 29 April were considered first nests and later nests were considered second and third nests.

²Standard errors in parentheses

³Calculated using Mayfield's (1961) technique.

⁴"Independent" young refer to individuals 40 days or older. Many young remained with adults and begged from parents after this age but hunted and were successful at capturing prey.

Table 2. Frequencies of 4, 5, and 6 egg clutches by nesting attempt.

Clutch size	N first nests	N second and third nests
4	1 (5.1) ¹	7 (2.9)
5	24 (19.2)	6 (10.8)
6	9 (9.6)	6 (5.4)

¹Numbers in parenthesis are expected values under the null hypothesis of independence.

entire brood, it reflects the degree of brood reduction within nests. Eight of 34 (23.5%) successful nests with complete hatching and fledging information lost one or more young.

The numbers of young fledged in successful nests followed a pattern similar to clutch size; i.e. there was a tendency for more young to be fledged from successful first nests (Table 1), however, this difference was not significant (Wilcoxon rank sum test, $p = 0.274$).

Young remained with adults longer than 3 weeks after fledging, but could hunt for themselves and were often difficult to follow after that time. Therefore, I limited the analysis to data gathered up to three weeks after fledging (40 days after hatching). "Independent" young refers to young 40 days or older. I presume that most young that disappeared prior to 3 weeks after fledging died; however, some may have dispersed earlier than others.

Two of 14 (14.3%) broods in 1985 and 3 of 28 (10.7%) broods in 1986 disappeared after fledging. The low number of young surviving to independence in first nests for 1985 may have been partially caused by my inexperience in finding all surviving fledglings from broods (Table 1). Overall, successful nests produced 2.6 independent young (Table 1).

Shrike pairs raised an average of 2.44 young per year (Table 3). The number of young raised per pair was similar in 1985 and 1986 (Wilcoxon rank sum test, $p = 0.122$). Shrikes in Virginia had reproductive rates similar to those of other populations (Table 4), however, fledgling mortality was not estimated by those authors. An average of 20% (range = 14.3-25.5%) of the eggs laid did not produce fledglings in successful nests (Table 4: $1 - (\text{young fledged per successful nest} / \text{average clutch size})$).

FACTORS REDUCING REPRODUCTIVE OUTPUT

I attributed most nest failures to predators (Table 5); many of these nests were not damaged and often no egg or young remains were found. Suspected nest predators included black rat snakes (*Elaphe obsoleta obsoleta*), and blue jays (*Cyanocitta cristata*). Suspected predators on fledglings include sharp-shinned hawks (*Accipiter striatus*) and feral cats. Two nests were abandoned near the

Table 3. Productivity of loggerhead shrike breeding pairs in the Ridge and Valley province of Virginia.

Variable ¹	1985		1986		Years combined	
	N	\bar{X} SE	N	\bar{X} SE	N	\bar{X} SE
Nesting attempts	18	1.44 0.12	28	1.71 0.11	46	1.61 0.09
Successful nests	17	1.00 0.12	27	1.07 0.15	44	1.05 0.10
Young fledged	15	3.87 0.62	24	4.04 0.72	39	3.97 0.50
Young surviving to independence	15	1.73 0.34	24	2.88 0.49	39	2.44 0.34

¹All variables express productivity on a per pair basis.

Table 4. Productivity of loggerhead shrike breeding pairs in the United States.

STUDY AREA	SOURCE	N ¹	AVERAGE CLUTCH SIZE	NESTS PER PAIR	NEST SUCCESS	YOUNG FLEDGED PER SUCCESSFUL NEST	YOUNG FLEDGED PER PAIR
VIRGINIA	This study	57(2)	5.13	1.61	62.1	3.96	3.97
MISSOURI	Kridelbaugh (1982)	55(2)	5.71	1.22 ²	69.1	4.40 ³	3.71 ⁴
COLORADO	Porter et al. (1975)	77(4)	6.39	-	66.2	5.40	3.57 ⁵
ALABAMA	Siegel (1980)	37(1)	5.00	1.16 ²	43.2	3.96	1.98 ⁴
ILLINOIS	Graber et al. (1973)	20(1)	5.7	-	80.0	4.6	3.7 ⁵
ILLINOIS	Graber et al. (1973)	25(?)	5.6	-	71.0	4.8	3.4 ⁵
ILLINOIS	Anderson and Duzan (1978)	13(1)	5.2 ⁶	-	71.9	3.9	2.8 ⁵
SOUTH CAROLINA	Cely and Corontzes (1986)	50(1)	-	1.42 ²	68.0	4.47	4.32 ⁴
MINNESOTA	Temple and Brooks (1986)	34(1)	5.81	1.17 ²	73.5	4.33	3.72 ⁴

¹Number of nests used to calculate nest success (number of years of study in parentheses).

²Calculated based on reported renesting rates of successful and unsuccessful pairs.

³Calculated as: young fledged per nest / nest success.

⁴Calculated as: nests per pair x nest success x young fledged per successful nest.

⁵Represents a minimum value because nests per pair could not be determined.

⁶Calculated from eggs collected / number of complete clutches.

Table 5. Causes of loggerhead shrike nesting failures in the Ridge and Valley province of Virginia. Data include failures from laying to fledging.

Cause of failure	1985		1986		Years combined	
	N	%	N	%	N	%
<i>PREDATION</i>	4	57.1	9	47.4	13	50.0
<i>ABANDONMENT</i>	1	14.3	4	21.0	5	19.2
<i>FAILURE TO HATCH¹</i>	0	0.0	2	10.5	2	7.7
<i>INADEQUATE SUPPORT</i>	1	14.3	1	5.3	2	7.7
<i>STARVATION</i>	0	0.0	1	5.3	1	3.9
<i>UNKNOWN</i>	1	14.3	2	10.5	3	11.5
<i>TOTAL</i>	7	100.0	19	100.0	26	100.0

¹May have been abandoned near hatching.

time when eggs were scheduled to hatch and 3 nests were abandoned apparently before eggs were laid. Some nests that appeared to have been abandoned during the laying period may have actually been preyed upon prior to abandonment.

I was able to speculate on the causes of death for 17 young shrikes near or after fledging. I found the remains of nine (53.0%) cannibalized juveniles impaled or in the vicinity of impaling areas used by adults. I found remains of an additional three juveniles (17.6%) near nests, but not near impaling areas; these young were probably killed by other predators. The remains of three juveniles were found dead on the sides of roads and were probably killed by collisions with vehicles. Two (11.8%) juveniles were thin and weighed less than normal and showed other signs of malnourishment prior to disappearing. This sample of juvenile deaths is biased towards carcasses found easily and may not be representative of the population.

Nestling development within a brood varied considerably at about 10 days after hatching. The mean difference between heaviest and lightest individuals in broods of two or more was 5.1 grams ($N = 34$, $SE = 0.57$ g). The magnitude of difference was correlated with the number of young in a brood ($r = 0.418$, $p = 0.014$). I used the deviations of individual nestling weights from the brood's mean weight (nestling weight - mean nestling weight) as a measure of a nestlings condition relative to the other members in the brood. The deviations from mean nestling weight within a clutch differed between young known to survive and those suspected dead prior to becoming independent (signed rank test, $p = 0.057$; $\bar{X} = 0.55$ g, $N = 40$, and $\bar{X} = -0.57$ g, $N = 39$ for known survivors and suspected mortalities, respectively). Relative deviations (deviations from mean weight / mean weight) exhibited a similar relationship (signed rank test, $p = 0.051$).

MICROHABITAT SELECTION

Shrikes selected eastern red cedars and hawthorns as nest support much more than expected and used black locusts and other species less than expected based on availability (Table 6). Two nests were placed in honeysuckle (*Lonicera sp.*) supported by a fence and were not included in

Table 6. Species distribution of 75 plants used by loggerhead shrikes for nest support compared to the distribution of 75 randomly selected plants within 200 m of nest sites.

Species	% Use	% Available
Eastern red cedar (<i>Juniperus virginiana</i>)	46.7*	17.3
Hawthorn (<i>Crataegus spp.</i>)	25.3*	6.7
Osage orange (<i>Machura pomifera</i>)	6.7	9.3
Multiflora rose (<i>Rosa multiflora</i>)	5.3	10.7
Black walnut (<i>Juglans nigra</i>)	5.3	8.0
Black locust (<i>Robinia pseudoacacia</i>)	2.7*	13.3
Rusty blackhaw (<i>Viburnum rufidulum</i>)	2.7	2.7
Other species	5.3* ¹	32.0 ²

*Significant difference between use and availability based on the simultaneous confidence interval approach with overall $\alpha = 0.20$ (Marcum and Loftsgaarden 1980).

¹Other used species include: Elm (*Ulmus spp.*) N = 1, Sassafras (*Sassafras albidum*) N = 2, and Sycamore (*Platanus occidentalis*) N = 1.

²Twelve available species were not used.

Table 6. One pair nested in a pile of osage orange brush. Shrikes selected trees that had vines or other tree species providing additional cover more than expected at random ($\chi^2 = 14.52$, $df = 1$, $p < 0.001$; Table 7). Nests were commonly placed where vines and the support plant grew together. Together, nests in cedars and hawthorns had higher concealment scores compared to other species ($\bar{X} = 3.42$, $SE = 0.13$, $N = 53$; and $\bar{X} = 2.87$, $SE = 0.20$, $N = 21$ for cedars and hawthorns, and others respectively; Wilcoxon rank sum, $p = 0.024$).

First nests were lower than second and third nestings ($\bar{X} = 2.6$ m, $SE = 0.2$ m, $N = 45$, and $\bar{X} = 5.5$ m, $SE = 0.6$ m, $N = 29$ for first, and second and third respectively; Wilcoxon rank sum, $p < 0.001$). First nests were also lower with nest height expressed as a percent of tree height (nest height / tree height; $\bar{X} = 0.51$, $SE = 0.02$, $N = 45$, and $\bar{X} = 0.64$, $SE = 0.03$, $N = 29$ for first, and second and third nests respectively; Wilcoxon rank sum, $p = 0.002$).

I fitted a log-linear model (Fienberg 1985:71) to test for interactions between tree use (nest tree or random tree), date (first nests versus others), presence or absence of vines or other cover species and tree type (evergreen or deciduous). I rejected a model testing for independence between tree use and the three-way interaction of the remaining variables ($G^2 = 37.15$, $df = 7$, $p < 0.0001$). Terms were added to the model in steps until I found the most parsimonious model that explained the data. The final model indicated that shrikes selected cedar trees and trees with additional cover more than expected at random; but these characteristics were selected independently of date and each other (i.e. trees with additional cover were selected independently of tree type). When I began with a saturated model (interaction of all variables) and deleted terms, the same model was chosen.

When compared with local availability, nest trees were closer to roads than expected at random (Table 8). Thirty-two percent of the 75 nest trees were located in hedgerows; the same percentage of randomly selected trees fell within hedgerows. Impaling structures (thorny vegetation or barbed wire) were present within 11.3 m of nest sites and random sites at similar frequencies ($\chi^2 = 0.667$, $df = 1$, $p = 0.414$).

Table 7. Species providing additional cover or support at 75 nest trees and 75 randomly chosen trees within 200 m of nest trees.

Species	% Use	% Available
Honeysuckle (<i>Lonicera</i> spp.)	24.0	6.7
Multiflora rose (<i>Rosa multiflora</i>)	8.0	1.3
Virginia creeper (<i>Parthenocissus quinquefolia</i>)	4.0	1.3
Other species	12.0	9.3
None present	52.0	81.3

Table 8. Microhabitat characteristics measured at loggerhead shrike nest trees and randomly selected trees within 200 m of nest trees.

Variable	Significance ¹	Nest Trees (N = 75) \bar{X}	Random Trees (N = 75) \bar{X}
Distance to Barbed-Wire Fence (m)	0.277	28.5 (4.1) ²	35.5 (4.8)
Distance to Road (m)	0.030	104 (12)	121 (11)
Tree Height (m)	0.645	6.8 (0.5)	7.1 (0.5)
Short Woody Plant Density (plants/ha) ³	0.514	161 (57)	130 (29)
Tall Woody Plant Density (plants/ha) ⁴	0.322	196 (29)	185 (31)
Total Woody Plant Density (plants/ha) ⁵	0.500	358 (77)	315 (54)

¹Signed rank test.

²Standard errors in parentheses.

³Woody trees and shrubs ≥ 1 m and ≤ 2 m in height.

⁴Woody trees and shrubs greater than 2 m in height.

⁵Sum of short and tall woody plants.

MACROHABITAT SELECTION

Occupied breeding sites had over twice the area of active pasture than was expected at random (Table 9). Shrikes also selected areas close to water, but avoided sites with larger areas of rowcrop. Vacant sites had less active pasture than occupied sites and tended to have more idle pasture and rowcrop than active sites (Table 9). Generally, vacant sites were more like random sites than occupied sites, but vacant sites had more area in idle pastures than random points.

Ground vegetation was higher and much more variable at the end of the 1985 breeding season at sites that were not reoccupied in 1986 versus those that were reoccupied (Table 10). Ground cover was very similar at occupied and vacant sites.

While the mean characteristics at occupied sites and random points differed for several variables, many random points were very similar to productive shrike breeding sites (Fig. 9). Eighteen of 75 (24.0%) random points that had suitable nesting support within the sampling circle were also very close (similar) to the mean habitat vector for successful sites (Fig 9); only 4 of the 79 (5.1%) random points lacked suitable nesting support.

RELATIONSHIPS BETWEEN HABITAT AND PRODUCTIVITY

I used three species groups (cedar, hawthorn, and others) to test the hypothesis that species and nest success (probability of fledging one or more young) were independent. Nest success was independent of species group ($\chi^2 = 2.30$, $df = 2$, $p = 0.316$). Similarly, neither concealment nor the presence of vines was associated with nesting success ($\chi^2 = 1.10$, $df = 2$, $p = 0.578$; and $\chi^2 = 0.575$, $df = 1$, $p = 0.448$ for concealment and presence of vines respectively). Early, lower nests tended to be more productive than late and high nests (Table 11). There was also a tendency for failing nests to be surrounded by more woody plants (Table 11).

Yearly productivity of shrike pairs was related to several habitat variables (Table 12). Shrikes were most productive when breeding areas were dominated by active pastures and in areas with

Table 9. Macrohabitat characteristics measured at random points and loggerhead shrike breeding sites. Measurements were taken from aerial photographs within 12.57 ha. circular plots.

Variable	Significance ³	Random Points (N = 30) ¹ \bar{X}	Occupied Sites ² (N = 35) \bar{X}	Vacant Sites (N = 9) \bar{X}
Area of Active Pasture (ha)	< 0.001	3.69 A ⁴ (0.67) ⁵	7.94 B (0.58)	4.20 A (1.31)
Area of Idle Pasture (ha)	0.024	1.04 A (0.33)	1.89 AB (0.47)	3.30 B (1.06)
Area of Hay (ha)	0.340	1.79 (0.54)	0.56 (0.21)	0.57 (0.27)
Area of Lawn (ha)	0.226	0.82 (0.25)	0.50 (0.23)	0.67 (0.34)
Area of Oldfield (ha)	0.229	0.64 (0.25)	0.40 (0.20)	0.67 (0.39)
Area of Rowcrop (ha)	0.011	2.03 A (0.53)	0.33 B (0.14)	1.92 A (0.83)
Area Forested (ha)	0.643	1.67 (0.46)	0.44 (0.11)	0.79 (0.44)
Perch Availability	0.428	2.76 (0.26)	3.22 (0.25)	3.17 (0.50)
Length of Fence (m)	0.140	1004 (85)	1209 (63)	1164 (112)
Length of Utility Wire (m)	0.741	463 (64)	435 (45)	512 (85)
Length of Hedgerow (m)	0.251	524 (56)	651 (55)	764 (139)
Distance to Water (m)	0.050	271 A (36)	160 B (21)	378 AB (137)
Distance to Road (m)	0.639	140 (31)	100 (18)	118 (30)

¹Forty-nine random points were not considered to eliminate road effects (see text for discussion).

²Territories were considered occupied if one or more adults were observed between 1 April and 31 August.

³Kruskal-Wallis test (Conover 1971) of the null hypothesis that all three row means are equal.

⁴Row means with different letters are significantly different (Wilcoxon rank sum test, maximum experimentwise error rate for each variable controlled at 0.05 by setting the comparisonwise error rate at $\alpha = 0.0167$ (SAS 1985:472)).

⁵Numbers in parentheses are standard errors.

Table 10. Structural characteristics of herbaceous ground vegetation within 10 meters of nest sites. Data were collected in August for 1985 nests only. Only grassland habitats near nests were measured.

Variable	Significance ²	Occupied Sites ¹ (N = 13)		Vacant Sites (N = 9)	
		\bar{X}	SE	\bar{X}	SE
Average Plant Height (cm)	0.082	15.1	3.2	25.4	5.3
Variance of Plant Height	0.016	121.2	49.8	763.4	296.4
Ground Cover (%)	0.920	94.1	1.6	93.6	2.4

¹Territories were considered occupied if one or more adults were observed between 1 April 1986 and 31 August 1986.

²Wilcoxon rank sum test.

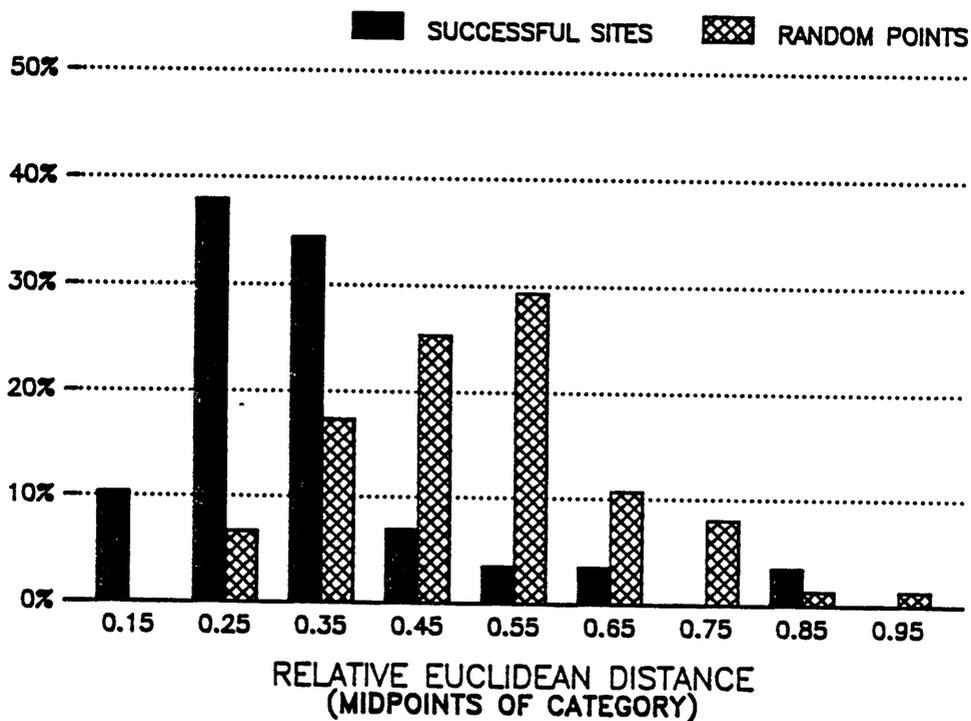


Figure 9. Habitat similarity of random points and successful sites. Prior to calculating distances, data were standardized so that all habitat variables had means of zero and standard deviations of one. Absolute Euclidean distances were divided by the maximum distance to produce relative scores. Small scores indicate high similarity of random points or successful sites to the average habitat at successful sites.

Table 11. Relationships between microhabitat variables and productivity of shrike nests. Habitat measurements were taken within 11.3 m radius circular plots.

Variable	Significance ⁴	Successful Nests ¹ (N = 49) ³ \bar{X}	Unsuccessful Nests (N = 23) ³ \bar{X}	Correlation Coefficient ² (N = 65) ³ r
Nest Initiation Date ⁵	0.006	118 (3.4) ⁶	139 (6.3) ⁶	-0.370 (0.006) ⁷
Nest Height (m)	0.065	3.5 (0.4)	4.4 (0.6)	-0.173 (0.169)
Concealment	0.799	3.3 (0.2)	3.2 (0.2)	0.175 (0.164)
Distance to Barbed-Wire Fence (m)	0.680	31.1 (5.6)	23.5 (6.0)	0.209 (0.095)
Distance to Road (m)	0.244	111 (14)	93 (22)	0.054 (0.667)
Tree Height (m)	0.672	6.8 (0.6)	6.8 (0.7)	-0.034 (0.788)
Short Woody Plant Density ⁸	0.199	83 (18)	337 (179)	-0.191 (0.128)
Tall Woody Plant Density ⁸	0.206	168 (18)	264 (179)	-0.207 (0.098)
Total Woody Plant Density ⁸	0.191	251 (43)	601 (230)	-0.215 (0.085)

¹Nests were successful if one or more young fledged.

²Pearson product moment correlation of number of young fledged and each variable.

³Sample sizes for nest initiation dates are n = 42, n = 12, and n = 54 for successful, unsuccessful, and correlation respectively.

⁴Wilcoxon rank sum test comparing successful and unsuccessful nests.

⁵Date is expressed in Julian day.

⁶Standard errors in parentheses for successful and unsuccessful.

⁷Probability value testing the hypothesis r = 0.

⁸Plants per hectare.

Table 12. Relationships between macrohabitat variables and productivity of shrike pairs. Habitat measurements were taken from aerial photographs within 12.57 ha circular plots.

Variable	Significance ³	Successful Sites ¹ (N = 29) \bar{X}	Unsuccessful Sites (N = 10) \bar{X}	Correlation Coefficient ² (N = 34) r
Area of Active Pasture (ha)	0.046	7.96	5.14	0.378 (0.027) ⁴
Area of Idle Pasture (ha)	0.202	1.57	4.39	-0.357 (0.038)
Area of Hay (ha)	0.659	0.59	0.55	-0.006 (0.971)
Area of Lawn (ha)	0.932	0.36	0.96	-0.179 (0.312)
Area of Oldfield (ha)	0.425	0.45	0.33	0.020 (0.910)
Area of Rowcrop (ha)	0.376	0.56	0.16	-0.102 (0.565)
Area Forested (ha)	0.264	0.63	0.28	0.070 (0.694)
Perch Availability	0.071	3.50	2.55	0.384 (0.025)
Length of Fence (m)	0.712	1214	1142	0.008 (0.964)
Length of Utility Wire (m)	0.198	492	336	0.026 (0.886)
Length of Hedgerow (m)	0.111	634	831	-0.267 (0.127)
Distance to Water (m)	0.910	189	156	0.125 (0.482)
Distance to Road (m)	0.489	107	103	-0.008 (0.962)

¹Sites were considered successful if one or more young survived to three weeks post-fledging in 1985 or 1986.

²Pearson product moment correlation of the number of young raised to independence within a territory and each habitat variable. If data were available for both years, the average of the two years was used (includes unsuccessful sites).

³Wilcoxon rank sum test comparing successful and unsuccessful sites.

⁴Probability value for testing the null hypothesis $r = 0$.

many perches, and were less productive in areas dominated by idle pastures (Table 12). Nest success, young fledged per nest, and overall yearly productivity were significantly higher at sites dominated by active pastures compared to other habitats (Table 13).

I modeled the potential influence of lowered productivity in poor quality habitats on population growth rates by holding adult mortality rates constant and varying first-year mortality and reproductive rates. When assuming that yearly adult mortality is 50% (a range of 40-60% was reported by Ricklefs (1973) for passerines in temperate regions), a mortality rate of 66.6% for young between independence and breeding produced a stable population in active pastures (i.e. with 3.02 independent young produced/pair/year). With the same mortality rates, the average reproductive rate (2.44 young/pair/year) produced a 6.9% yearly decline (finite rate of increase = 0.9315). An average reproductive rate of 1.45 young/pair/year (the case if all pairs had bred in habitats other than active pastures), produced a 20.6% yearly decline.

DISCUSSION

BREEDING BIOLOGY AND REPRODUCTIVE SUCCESS

My limited banding information indicates that shrikes are seasonally monogamous and some individuals breed in the same territory in consecutive years. Kridelbaugh (1983) found that pairs in Missouri remained together throughout the season and that 47% of the males and no females returned to the same breeding areas in consecutive years. Other authors have commented on the high degree of site fidelity in loggerhead shrikes, but in unmarked populations (Miller 1931, Bent 1950). Loggerhead shrikes breed in their first year (Kridelbaugh 1983, this study) and hatch-year birds have the ability to disperse long distances (Kridelbaugh 1983, Burnside 1987, this study).

Table 13. Reproductive rates at sites dominated by active pastures compared to sites dominated by other habitats. Data from 1985 and 1986 combined.

Variable	Significance ²	Active Pastures ¹		Other Habitats	
		N	\bar{X}	N	\bar{X}
Clutch Size	0.202	39	5.18	12	4.92
Nest Success ³	0.033	53	75.5	27	51.9
Young Fledged / Nest	0.051	48	2.92	23	1.83
Young Fledged / Successful Nest	0.673	35	4.00	11	3.82
Independent Young / Successful Nest	0.814	33	2.55	10	2.50
Independent Young / Pair / Year	0.032	21	3.02	10	1.45

¹Includes sites where half or more of a 12.57 ha circular plot was composed of active pasture.

²Tests the null hypothesis that reproductive parameters are equal in active pastures and other habitats. A chi-square test was used to compare nest success and Wilcoxon rank sum tests were used for other parameters.

³Percentage of nests fledging one or more young.

There can be high variability in reproductive success between years within shrike populations (Porter et al. 1975, Kridelbaugh 1983). In Virginia, the 1985 and 1986 breeding seasons were unusually warm and dry (NOAA 1985,1986). Kridelbaugh (1983) reported lowered reproductive rates and a higher incidence of brood reduction during a cold, wet spring. Thus, my data may show higher productivity than would be expected during an average spring and several years of productivity data within the same population would make comparisons between populations more meaningful.

In general, the incubation and nestling periods I observed agreed with other studies (summarized by Kridelbaugh 1983). Kridelbaugh (1983) found a bimodal distribution of clutch initiation dates, similar to that found in this study. Porter et al. (1975) found a unimodal distribution in Colorado suggesting that renesting after successful breeding was uncommon. Shrikes nest early, but those at high elevations or more northern latitudes tend to have later and shorter breeding seasons (e.g. compare Graber et al. 1973, Porter et al. 1975, Siegel 1980, Kridelbaugh 1983, and this study 1987). Shrikes tend to be multibrooded at southern latitudes where weather is favorable and nesting seasons are long (Kridelbaugh 1983).

Clutch size in shrikes, as in many bird species, is positively correlated with latitude (Kridelbaugh 1983). Hesse et al. (1937) proposed that shorter day length at southern latitudes limits time available for food searching and ultimately, the number of young that can be fed. Thus, the relationship between clutch size and latitude is thought to reflect an adaptation that matches clutch size to food available for young. Shrikes at southern latitudes have smaller clutch sizes, but can take advantage of longer breeding seasons to produce approximately the same number of young as shrikes in the north.

Factors other than latitude may also be important determinants of clutch size in loggerhead shrikes. The hypothesized cause of the relationship of clutch size and latitude does not explain the relatively large year to year clutch size fluctuations reported by Porter et al. (1975) and, to a lesser degree, by Kridelbaugh (1983). Also, my study area was similar in latitude to Kridelbaugh's (1983), but I found a smaller clutch size. Thus, while shrike clutch sizes show a trend across latitudes, there is considerable variation even at similar latitudes.

I found that clutch size decreased later in the season, but Kridelbaugh (1982) found no relationship between clutch size and initiation date. Many hypotheses have been proposed to explain the seasonal decline in clutch sizes of birds (Murphy 1986). Since breeding chronology and latitude were very similar in Virginia and Missouri, declining day lengths later in the breeding season would not completely explain the relationship between date and clutch size in Virginia. Despite this, many bird species have smaller clutch sizes in later breeding attempts (Murphy 1986) and this trend probably does not represent aberrant reproduction in Virginia shrikes.

Egg hatchability generally declines in birds poisoned with organochlorine insecticides such as DDT (Jefferies 1975:188). Koenig (1982) reported an average hatchability of 90.6% for 155 bird populations of various species. Hatchability for 95 passerine populations averaged 91.2%, very similar to the hatching rate (90.6%) I observed for shrikes. Anderson and Duzan (1978) reported 83% survival of eggs during hatching. Porter et al. (1975) reported clutch and brood sizes that indicated that approximately 89.0% (average clutch size / eggs hatched per successful nest) of the eggs in successful nests hatched. Siegel (1980) reported 84.7% hatching of the eggs observed from laying until hatching. Approximately 93.3% of the eggs not destroyed by predators, abandoned, or blown out of nests hatched in Missouri (Kridelbaugh 1983). Thus, hatchability has been normal, except perhaps in Illinois (Anderson and Duzan 1978) and Alabama (Siegel 1980). These results support the idea that DDT is not currently causing excessive hatching failures.

When compared on a per nest basis, shrike reproductive rates are relatively high. Nesting success was similar in most studies and the numbers of young fledged per successful nest fell within a small range when expressed as a percentage of clutch size. These statistics show rather consistent rates of reproductive failure. Shrike nesting success is high compared to other open-nesting altricial species (Kridelbaugh 1983). Alone, however, nesting success and numbers fledged can be misleading measures of productivity. The number of young produced annually per pair is the best measure of reproductive output, especially since pairs in some populations commonly have multiple nestings in one year.

Most of the nesting studies (i.e. Graber et al. (1973), Anderson and Duzan (1978), Kridelbaugh (1983), and this study) were apparently conducted in declining populations and there

are no pre-decline productivity data to compare to recent data. The Colorado study (Porter et al. 1975) was conducted over several years in a relatively stable population and provides the best standard for comparisons. Productivity may have been below normal in Alabama (Siegel 1980) and Illinois (Anderson and Duzan 1978), however, both of these studies were conducted during only one breeding season. If mortality rates were similar in Colorado and other parts of the shrike's range, reproductive rates should have been high enough to maintain stable populations--provided mortality between fledging and independence is similar among populations. Future studies should estimate young produced per pair, including survival after fledging. These statistics will provide a better basis to make comparisons among populations.

FACTORS REDUCING REPRODUCTIVE OUTPUT

Predation, abandonment, and weather were the most commonly cited causes of nesting failures in other studies (Kridelbaugh 1983, Porter et al. 1975, Siegel 1980). My study was similar, except that weather did not appear to be an important factor. Predation is a commonly cited cause of nest failures in passerines (Ricklefs 1969) and excessive nest predation does not seem to be a problem in shrike populations. Also, the importance of predation may be overestimated in all studies because other factors such as abandonment and inadequate food supplies may increase the probability of predation.

Shrikes were rather tolerant of disturbance on my study area. Two nest trees used in 1985 were destroyed after the breeding season and pairs nested at both sites in 1986, using alternate nest trees nearby. The upper quarter of one nest tree was trimmed off in 1986 during incubation. While the nest was ultimately unsuccessful, the female returned after the disturbance and continued to incubate. Adults made aggressive displays and vocalized loudly when I went close to nests. Often, the adults made "clacking" sounds and came within inches of my mirror as I looked into nests. These visits created a temporary disturbance, but when I was out of sight the adults would quickly

(less than 10 minutes) return to nests and incubate eggs or feed young. I was cautious during the late nestling stage because banding nestlings at that time caused premature fledging in one 1985 nest.

Repeated disturbance at frequent intervals could cause nesting failures. I visited nests about twice weekly and these visits lasted only a few minutes each. Disturbance at more frequent intervals, such as when overly enthusiastic bird watchers come to observe rare birds, could cause problems. At one nest in 1986 I suspected that an overzealous photographer caused some structural damage to a nest and may have contributed to the losses of some eggs. Where shrikes are rare, records detailing the locations of breeding sites should be kept confidential.

Some shrikes nested very close to roads (less than 3 m for 3 nests), but passing cars and trucks did not flush incubating females. Nest success or other reproductive parameters were not related to distances to road, but some fledglings were killed by collisions with vehicles. These results suggest that shrikes are relatively tolerant of human activities and that human disturbances were not a major problem on my study area.

There is evidence that shrike productivity was limited by food during my study. A cicada (family Cicadidae) hatch occurred at one territory in 1986, providing a surplus of available food. This pair used this food source extensively. I found one cicada impaled and numerous remains (wings mainly) in the nest area on several visits. This pair raised seven young to independence from two successful nests--the record number for both years of the study. We also observed several nests with young that were severely malnourished. Their weights were low and feathers were underdeveloped for their age.

Other evidence indicating food limitation included partial losses of broods from some nests. Asynchronous hatching led to high ranges in nestling weights. Porter et al. (1975) and Kridelbaugh (1983) reported similar findings. The degree of developmental variability within a brood was probably most dependent on energy delivery by adults. When food is limited, larger broods would suffer most from malnourishment. Lack (1966:34-36) reported that mean nestling weight was inversely related to brood size in the great tit (*Parus major*) and that young in larger broods received less food per individual than in smaller broods. The positive correlation I found between the range of shrike nestling weights and brood size supports the contention that food limitation increased the

magnitude of weight differences among siblings. Mead and Morton (1985) reported similar findings after experimentally manipulated brood sizes and feeding rates of asynchronous hatching mountain white-crowned sparrows (*Zonotrichia leucophrys oriantha*). In loggerhead shrikes, I found that the smallest and presumably the youngest individuals sometimes became malnourished and adults sometimes resorted to cannibalizing all or a part of the brood. Adults may have eaten nestlings after they died from malnourishment. Kridelbaugh (1983) also observed asynchronous hatching, brood reduction, and cannibalism of young; he also found a higher rate of brood reduction in the second year of his study, which he attributed to wet and cold weather.

The fact that juveniles surviving to independence tended to be heavier when banded compared to their siblings that disappeared supports the idea that the heavier and presumably older nestlings in a brood have a better chance of surviving to independence. Mead and Morton (1985) reported that the smallest white-crowned sparrow chicks received fewer feeding offers and when broods were reduced, the youngest chick died most often. Lack (1966:40) reported a positive relationship between weight on the 15th day after hatching and percent recovery, suggesting that heavier nestling great tits had higher survival rates.

Brood reduction may allow shrikes to produce some young when food becomes limited. Several hypotheses have been suggested to explain the adaptive significance of hatching asynchrony and brood reductions (reviewed by Mead and Morton 1985). Mead and Morton (1985) proposed that hatching asynchrony may provide some of the advantages predicted by earlier hypotheses, but that its evolution was simply an incidental outcome of the hormonal mechanisms involved with egg-laying. Without brood reductions, some of the successful nests I observed may have failed. In either case, the fact that nestlings or fledglings were lost from successful nests supports the contention that more young hatched than could be fed.

HABITAT SELECTION

Shrikes on my study area preferred eastern red cedars and hawthorns for nest support--especially those with vines growing through the crowns. Many other species were relatively common but were used much less frequently. Other shrike studies conducted within the range of the eastern red cedar (Harlow et al. 1979) showed that shrikes most commonly selected this species as nest support (Graber et al. 1973, Siegel 1980, Kridelbaugh 1983, Cely and Corotzes 1986, Temple and Brooks 1986, this study). However, a variety of species are used. Porter et al. (1975) reported that nest site selection was based on the degree of cover a plant provided rather than on the particular species. I found that nests in cedars and hawthorns were more concealed than nests in other species; thus, while cover is an important nest tree characteristic, some species provide better cover and are selected more frequently.

Shrikes nest early throughout their range (Kridelbaugh 1983) and on my study area built nests before most deciduous plants had leafed out. Honeysuckle and multiflora rose developed leaves earlier than most woody plants and when these plants grow within the crown of nest trees, they offer additional concealment (especially in early nests) and support. Similarly, evergreen trees such as cedars provide a continuous cover source throughout the season and have many branches to support nests.

Dense, thorny plants such as hawthorns provide good support and thorns may discourage some predators. I found it very difficult to remove nestlings from nests in hawthorns. Less dense thorny plants, such as black locust are not as attractive to shrikes and provide less support and concealment; however, second nests were placed higher and tall species such as black locust and walnut may be more attractive later in the season because they provide a means of placing nests higher. I also noticed that later nests tended to be in trees with more open canopies than early nests (including cedars).

While shrikes were selective in choosing nest trees, the characteristics of nest trees were not significantly correlated with nest outcomes. Kridelbaugh (1983) found that loggerhead shrikes in Missouri were most successful in deciduous trees and least successful in multiflora rose. I would

expect differential success only if a substantial number of individuals chose marginal sites. My study area had an abundance of apparently high quality nest trees; thus, the probability of a nest being destroyed by predators was not influenced by species, concealment categories, or the presence or absence of vines. Concealment would be more variable early in the season and may have been more important in determining nest success if I had been able to measure it prior to many species developing leaves.

Selection at the scale that approximates the territory (macrohabitat) is best understood in the context of shrike foraging ecology. Loggerhead shrikes hunt from perches, taking prey primarily from the ground by detecting prey movement (Miller 1931:210). Mills (1979) presented theoretical and empirical evidence that suggested that prey detection and net energy gains of foraging shrikes are dependent on perch height, ground vegetation height, and the resulting concealment of prey. Carlson (1985) showed that red-backed shrikes detected prey more easily when prey was close to perches and when ground vegetation was absent. Similarly, Lewartowski (1982) felt that sparse ground vegetation provided quality foraging habitat for the woodchat shrike (*Lanius senator*). These species hunt from perches and have foraging habits similar to loggerhead shrikes. Similarly, other studies have reported that short, sparse ground vegetation provides quality foraging habitat for a variety of predatory bird species (Craighead and Craighead 1969, Bechard 1982, Toland 1987). Toland (1987) found that kestrels had better hunting success in short grass habitats than in longer grass habitats. Prey can become more concealed and less available to predators in long grass habitats. Thus, ground vegetation height and density can limit shrike prey availability.

My opportunistic observations of foraging shrikes agreed with other studies. Shrikes hunted almost exclusively from perches. However, on two occasions I observed shrikes walking along the ground catching insects. Rock outcrops were a common feature of pastures on my study area and I commonly saw shrikes catching prey and hunting near them as opposed to the surrounding grass areas. In one territory, grass grew long after cattle were removed from a pasture and a cemetery 85 m from the nest provided the only short grass area nearby. The adults hunted from the fence surrounding the cemetery and fledglings moved to the area to be fed.

I found that shrikes selected, were more productive in, and were more likely to reoccupy breeding areas dominated by active pastures. Active pastures were grazed throughout the breeding season and provided a consistently short structure that may make prey relatively easy to detect. Also, cattle dung provides habitat for some species of scarab beetles (Family Scarabaeidae) that were frequently found impaled near nest sites. Similarly, shrikes nested in areas close to open water, but active pastures are characterized by having a constant water source for cattle. Water is essential for cattle, but the relationship between open water and shrikes is much less certain. Watering areas do concentrate cattle use, causing loss of ground vegetation, and prey densities may be higher near water. Also, open water may be a characteristic of permanent pastures only. Water sources in permanent pastures were commonly streams or artificially constructed ponds. Watering troughs (which I did not consider open water) may have been used more often in rotational pastures.

Areas with many potential perches had higher productivity and areas with large areas of idle pasture were less productive, but still used frequently. In contrast to active pastures, idle pastures grew tall during the nestling stage, which may have made prey difficult to locate. Sites that were not reoccupied had more area in cover types with long and variable ground vegetation compared to occupied sites dominated by short active pastures.

Hayfields were structurally similar to idle pastures and may also provide a lower quality foraging habitat than active pastures. Hayfields were not as common as idle pastures and shrikes on my study area may have been able to avoid them. Grasses are difficult to mow near rock outcrops and where there are many trees and shrubs. For this reason, hayfields are kept clear of woody vegetation and are usually located on better (less rocky) soils. Thus, there are potentially fewer perches and nest trees in hayfields except along field borders and fencerows.

Rowcrops are also inferior shrike breeding habitat compared to active pastures. Productivity was not significantly correlated with the area of rowcrop in breeding areas, but vacant sites had more area in rowcrop, suggesting that these fields are marginal shrike habitat. Kridelbaugh (1982) found that shrike territory size was positively correlated with amount of rowcrop and negatively correlated with the amount of grassland present. This is further evidence that rowcrops provide poor quality breeding habitat.

Shrikes appear to be sensitive to small changes in the successional stage of foraging areas and changes in grazing or mowing intensity or phenology can lower foraging habitat quality. Similarly, rowcrops such as corn are poor foraging habitat (Kridelbaugh 1982) and I found them less likely to be reoccupied than active pastures. The lack of available perches can render otherwise quality shrike foraging habitat unsuitable. Removal of fences, hedgerows, and woody vegetation would eliminate potential perches, lowering habitat quality. Shrikes can make use of a variety of nest support species; however nest trees could become limiting on intensively managed farms where woody vegetation is removed. Thus, quality shrike breeding habitat in Virginia consists of short grass habitats, particularly pastures that are grazed throughout the year, with many perches and red cedar or hawthorn nest trees.

HABITAT PHENOLOGY AND STABILITY

The timing of shrike habitat selection and the seasonal changes in ground vegetation structure could produce situations where shrikes would commonly choose marginal breeding habitats. For example, shrikes may select breeding areas based on vegetation structure, in late winter or early spring--well before ground vegetation begins rapid spring growth. In early spring, Idle grasslands and, to a lesser degree rowcrop fields, are structurally similar to active pastures and shrikes may not be able to avoid these habitats because they cannot predict the changes that will occur later. Similarly, juveniles dispersing in late summer may choose territories in habitats that grow tall the following spring because long grass habitats are sometimes kept short in late summer by mowing.

Breeding early is one way that shrikes could avoid having to feed dependent young in tall, densely vegetated habitats; however, other factors such as temperature and prey abundance might prevent shrikes from breeding earlier. Avoiding areas with vegetation that would grow tall is another way of ensuring that the habitat in the nest vicinity would be quality foraging habitat. In parts of the range where vegetation structure can change dramatically after breeding sites are se-

lected, shrikes may only avoid marginal habitats by returning to or remaining at sites that were productive in the past.

While habitat quality can influence occupancy and productivity, the abundance of apparently suitable but unoccupied habitat patches confounds the link between habitat limitation and shrike declines on my study area. My searching technique probably did not locate all shrikes at random points, however, if all suitable habitats were occupied, I would have expected a higher find rate than 1 of 79 given the number of high quality sites searched by the study team. Perhaps my measurements did not detect important differences between shrike breeding territories and quality habitat at random points. Prey densities and habitat stability are two characteristics that were not measured but may prove to be important. Low prey abundance could render structurally good shrike habitat unsuitable. While a large percentage of random points had apparently suitable habitat, the habitat quality of these points could be drastically changed in only one year if left idle.

The relatively frequent use of idle grasslands suggests that shrikes may become "trapped" into selecting idle habitats in the early spring while they appear suitable. Shrikes breeding where they spend the winter and where the growing season is essentially continuous would be less likely trapped because: 1) year-round residents could continually evaluate habitat suitability, and 2) seasonal habitat changes are less dramatic in other areas. Changes in the location, intensity, or phenology of cattle grazing could decrease the predictability of habitat suitability in some patches. This could ultimately lower reproductive rates and may increase mortality rates of dispersing juveniles. Rotational grazing practices such as those described by Semple (1970:120) may produce such an effect. With rotational grazing, there may be a relatively stable amount of short grass habitat in an area, but the placement of the habitat would be dynamic.

My results show that shrikes in active pastures produced twice as many young as shrikes in other habitats. By holding mortality constant, I showed that lowered productivity in marginal habitats could produce population declines similar to the empirical trends found using Breeding Bird Survey data. These results, however, assume that there are no compensatory changes in mortality. This may be an unrealistic assumption and research should be conducted to estimate mortality rates of adult and juvenile shrikes. Lowered reproduction and possibly higher mortality

in marginal habitats are probably partially responsible for the shrike decline in Virginia. This hypothesis is consistent with the latitudinal nature (greater declines in the North) of the decline and would explain why some apparently suitable habitat remains unoccupied.

"Island" effects may have also been a problem on my study area. Suitable habitat did not occur in large contiguous tracts, but instead was composed of many isolated patches. Localized extinctions may have occurred in some patches and the rate of recolonization may be low. Perhaps more important, however, is the probability with which dispersing juveniles find quality sites for overwintering and/or breeding.

FACTORS REGULATING REPRODUCTION

The ultimate factor regulating reproduction in many bird species is food supply (Lack 1966). Shrikes seem to have evolved several behavioral adaptations that increase the chances of producing young. Early breeding, habitat selectivity (including philopatry), and adjustment of brood sizes (brood reductions via asynchronous hatching and cannibalism) to energy availability are some important ones. Early breeding and habitat selectivity are adaptations that, in pasture habitats, make habitat structure and prey availability more predictable. Brood reduction allows some young to be produced in the face of energy shortages. This, and the ability of shrikes to have multiple nests in one season are adaptations that increase the chances of successfully reproducing in unstable habitats. Loggerhead shrikes exhibit reproductive "plasticity" in that they can opportunistically take advantage of favorable conditions by producing more young. Individuals breeding in more predictable habitats produce more young and by returning to or remaining in a productive territory adults may be at an advantage compared to those that are "trapped" by poor quality habitats. Food limitation in these habitats may have been a result of high vegetation and lack of perches rather than low prey densities.

HABITAT CHANGES IN VIRGINIA

Several changes in farm habitat characteristics could have contributed to shrike declines in Virginia. Average farm size in Virginia between 1950 and 1982 increased 77%; however average farm size appeared to stabilize in 1974 (USDC 1982). During the same period, the estimated area of farmland in Virginia decreased 40%, the area of pastureland and rangeland decreased 48%, and the area of harvested cropland declined 26% between 1950 and 1969, and then increased 22% between 1969 and 1982 (USDC 1982). Thus, the trend has been toward fewer and larger farms growing more rowcrops. Increasing farm size would be a detriment to shrike populations only if farming practices also changed. Field size has probably increased to accommodate modern farming equipment. Fewer, larger fields provide less foraging habitat for shrikes because field borders sometimes provide the only perches for shrikes and field edge per unit area declines as area is increased. Conversion of pastures to other uses such as for crops and changes in grazing practices are habitat alterations that would lower habitat quality more drastically.

Less land used as pastures and more land used for growing rowcrops has reduced the amount of suitable habitat in Virginia. Kridelbaugh (1982) reported similar findings in Missouri. The changes outlined above, however, may be more severe in the Piedmont region of Virginia than in the Ridge and Valley province. Also, a large amount of suitable but unoccupied shrike habitat is available on my study area. While habitat loss is a threat to the ridge and valley populations, something other than lack of grassland habitats seems to be limiting shrike numbers on my study area; however changes in grazing practices, such as pasture rotations or lowered grazing intensity, would decrease the chances of birds choosing quality breeding habitat and may be at least partially responsible for the decline. Shrikes had relatively high reproductive success in 1985 and 1986, but both years were warm and dry. Several more years of data would provide the information necessary to evaluate hypotheses relating habitat quality to productivity, survival, and the shrike decline in Virginia.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Research and management measures should be enacted to protect loggerhead shrike populations in Virginia and in other areas where populations have declined. The first step toward preventing further declines and local extinctions is to place the shrike on state and federal threatened or endangered lists. Listing would provide formal recognition of the severity of declines and would alert state and federal agencies that protection is warranted. Listing may also generate interest among additional states to begin studies aimed at understanding the causes of the decline in various parts of the shrike's range. More information is needed before other management actions are begun.

For example, habitat protection or enhancement may prove to be a difficult and perhaps unnecessary management action. Altering land-use practices to increase the amount of stable, short grasslands with adequate perches and nesting cover would provide more breeding habitat; however, shrikes in the eastern U.S. use habitats that are managed primarily by private landowners, making direct management difficult. Educating landowner about the importance of retaining pastures with woody vegetation may provide indirect techniques of altering farm habitats. However, habitat changes may not be completely responsible for shrike declines. Certainly, shrikes are less produc-

tive in marginal habitats, but some apparently suitable habitat patches remain vacant. Thus, the links between habitat loss, lowered reproduction, and shrike declines are not certain and the efficacy of increasing reproductive rates in the absence of a clear understanding of shrike mortality rates is open to question.

Understanding the mechanisms regulating shrike numbers in the Ridge and Valley province could provide needed insights into the causes of the decline. Certainly, information on the wintering ecology, including causes and rates of mortality, will be necessary to understand the population dynamics of Virginia's loggerhead shrikes.

Comparing population parameters and habitat use information in declining and stable populations is the most direct method of finding where the problem(s) are. Coordinating research efforts to make productivity and mortality estimates comparable would make future results most useful. Ideally, a large scale comparative study of shrike demography in declining and stable populations should be conducted. Demographic characteristics and habitat use patterns could then be compared. Management actions could then be chosen that would maximize the chances of successfully reversing the decline. This also may prove to be the most cost effective plan, especially given that choosing management actions prior to having thorough knowledge of the causes of decline (i.e. a scatter-shot approach) will likely lead to many failures.

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APPENDICES

Appendix I. Virginia shrike banding records (1958-1983). The United States Fish and Wildlife Service banding office provided the data.

Latitude ¹ Degrees-Minutes	Longitude ¹ Degrees-Minutes	Date Month-Year
36-30	81-50	2-1970
36-50	76-50	1-1972
37-00	75-50	10-1966
37-00	75-50	10-1969
37-00	75-50	8-1977
37-00	76-50	1-1972
37-00	76-50	1-1973
37-10	76-00	1-1975
37-10	76-40	1-1974
37-10	80-20	2-1978
37-30	75-40	1-1974
37-30	75-40	1-1974
37-30	77-30	12-1966
37-30	77-30	1-1971
37-30	78-50	1-1974
37-30	78-50	12-1974
37-30	78-50	12-1974
37-30	78-50	2-1975
37-40	77-40	1-1967
37-40	77-40	3-1968
37-40	77-40	1-1969
37-40	78-30	1-1963
37-40	78-30	12-1963
37-40	78-30	1-1964
37-40	78-30	1-1965
37-40	78-30	2-1965
37-40	78-50	1-1974
37-40	79-20	11-1976
37-50	75-20	1-1970
37-50	78-10	12-1975
37-50	79-30	10-1965
38-00	78-10	1-1965
38-00	78-10	12-1965
38-00	78-10	1-1967
38-00	78-20	12-1958
38-00	78-20	9-1961
38-00	78-20	10-1962
38-00	78-20	4-1963
38-00	78-30	3-1962
38-00	78-30	9-1962
38-00	78-30	9-1964
38-00	78-30	10-1964
38-00	78-30	2-1965
38-00	78-30	10-1965
38-00	78-30	9-1966
38-00	78-30	9-1968
38-00	78-30	8-1969
38-00	78-30	11-1972
38-00	78-30	10-1973
38-00	78-30	11-1975
38-10	77-20	12-1968

Appendix I. (Continued).

Latitude ¹ Degrees-Minutes	Longitude ¹ Degrees-Minutes	Date Month-Year
38-30	77-20	4-1971
38-30	77-20*	7-1971
38-40	77-20	2-1968
38-40	77-20	12-1968
38-40	77-50	2-1970
38-50	77-00	5-1963
38-50	77-20	7-1968
38-50	77-20	2-1969
38-50	77-20	8-1969
38-50	77-20	11-1969
38-50	77-20	12-1969
38-50	77-20*	5-1970
38-50	77-20	6-1970
38-50	77-20	12-1971
38-50	77-30	3-1969
38-50	77-30*	5-1974
38-50	78-20	12-1961
38-50	78-30	1-1981
39-00	77-20	1-1962
39-00	77-20	9-1962
39-00	77-20	10-1963
39-00	77-30	5-1967
39-00	77-30	5-1967
39-00	77-30	6-1969
39-00	77-50	9-1982
39-00	78-10	11-1978
39-00	78-10	10-1979
39-00	78-10	11-1979
39-00	78-10	1-1980
39-00	78-10	1-1981
39-00	78-10	1-1982
39-00	78-10	11-1983
39-00	78-10	1-1984
47-40	77-40	11-1967

¹Latitude-longitude coordinates represent the south-east corner of the ten minute block where birds were banded.

*Confirmed breeding records (nestlings or fledglings banded).

Appendix II. Shrike sightings along breeding bird survey routes in Virginia (1968-1983).

Latitude ¹ Degrees-Minutes	Longitude ¹ Degrees-Minutes	Date Month-Year
36-36	77-09	6-1968
36-36	77-09	6-1969
36-36	77-09	6-1970
36-36	77-09	6-1971
36-36	77-09	6-1972
36-36	77-09	6-1973
36-36	78-00	6-1973
36-36	78-00	6-1974
36-36	78-00	6-1975
36-36	78-00	6-1977
36-36	78-00	6-1979
36-36	78-00	6-1980
36-50	78-40	6-1976
36-53	81-57	6-1973
36-54	81-35	6-1977
37-14	77-38	6-1968
37-14	77-38	6-1969
37-14	77-38	6-1970
37-14	77-38	6-1971
37-14	77-38	6-1972
37-14	77-38	6-1973
37-14	77-38	6-1974
37-14	77-38	6-1975
37-14	77-38	6-1976
37-14	77-38	6-1977
37-14	77-38	6-1980
37-16	77-51	6-1968
37-16	77-51	6-1969
37-16	77-51	6-1970
37-16	77-51	6-1974
37-16	77-51	6-1975
37-16	77-51	6-1982
37-20	78-59	6-1968
37-20	78-59	6-1970
37-20	78-59	6-1971
37-20	78-59	6-1972
37-20	78-59	6-1973
37-20	78-59	6-1974
37-20	78-59	6-1975
37-20	78-59	6-1976
37-20	78-59	6-1977
37-20	78-59	6-1978
37-20	78-59	6-1979
37-20	78-59	6-1980
37-30	79-59	6-1968
37-30	79-59	6-1970
37-32	79-18	6-1968
37-32	79-18	6-1969
37-32	79-18	6-1970
37-32	79-18	6-1974
37-32	79-18	6-1977
37-37	77-17	6-1968

Appendix II. (Continued).

Latitude ¹ Degrees-Minutes	Longitude ¹ Degrees-Minutes	Date Month-Year
37-37	77-17	6-1969
37-37	77-17	6-1970
37-37	77-17	6-1971
37-37	77-17	6-1972
37-37	77-17	6-1973
37-37	77-17	6-1974
37-37	77-17	6-1979
37-37	79-14	6-1977
37-39	79-38	6-1975
37-39	79-38	6-1981
37-39	79-38	6-1982
37-39	79-38	6-1983
37-42	78-48	6-1969
37-42	78-48	6-1973
37-42	78-48	6-1975
37-42	78-48	6-1976
37-54	78-41	6-1974
37-54	78-41	6-1975
37-54	78-41	6-1981
37-55	78-28	6-1968
37-55	78-28	6-1969
37-55	78-28	6-1970
37-55	78-28	6-1973
37-55	78-28	6-1974
37-55	78-28	6-1976
37-55	78-28	6-1977
37-55	78-28	6-1979
37-59	77-50	6-1972
37-59	77-50	6-1980
37-59	77-50	6-1982
38-27	78-11	6-1973
38-27	78-11	6-1980
38-33	78-33	6-1969
38-33	78-33	6-1971
38-38	77-35	6-1968
38-49	78-34	6-1972
38-50	78-45	6-1973
38-50	78-45	6-1975
39-03	78-28	6-1980
39-03	78-28	6-1981
39-14	77-35	6-1982

¹Latitude-longitude coordinates represent the starting location of each route (not where birds were sighted).

Appendix III. Shrikes sighted during Christmas bird counts 1959-82. Data for years 1959-79 were taken from Milburn (1981). Data for years 1980-82 were taken from *The Raven*.

Route name	Years sighted
Augusta Co.	1964,66,67,69,71,72,73,74,75,76,77,78,79,80,81,82
Back Bay	1959,60,62,63,65,66,67,68,69,70,71,72,73,75
Big Flat Mt.	1961,63
Blacksburg	1959,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,82
Bristol	1981
Brooke	1960,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,78,79
Cape Charles	1965,66,67,68,69,70,71,72,74,75,76,77,78,79
Chancellorsville	1979,82
Charlottesville	1959,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,80,81,82
Chincoteague	1964,65,67,68,70,71,77,78,81
Clifton Forge	1973,74,75,76,77,78,79,82
Danville	1970,71,72,73,74,75,76,77,78,79
Fort Belvoir	1961,63,65,66,69,76
Fincastle	1975,76,77,78,79,80,81,82
Glade Spring	1959,61,62,72,73,74,75,77,78,79,80,81
Gordonsville	1977,78,79,80,82
Hopewell	1959,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,79
Kerr Reservoir	1974,75,77
Lexington	1959,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82
Little Creek	1959,60,61,65,66,68,69,72,73,75
Lake Anna	1981
McDowell	1960,61
Lynchburg	1960,61,62,63,64,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82
Mathews	1970,71,72,80
Nansemond R.	1959,60
Newport News	1962,65,66,67,68,69,70,71,72,73,74,77
Nickelsville	1968,69,70,71,72,73,74,75,76,77,78,79,80,81,82
Norfolk	1959,60
No. Shenandoah Valley	1975,76,77,78,79,80,81,82
Peaks of Otter	1970,72,80
Powhatan	1968,70,71,72,73
Roanoke	1966,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82
Rockingham Co.	1959,60,61,63,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,81,82
Sweet Briar	1961,62,65,66,69
Shenandoah N.P.	1962,69,70,71,72,73,74,75,76,77,78,79,80,81,82
Tazewell	1971,72,73,74,76,78,79,80,82
Warren	1959,60,61,62,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82
Waynesboro	1967,68,69,70,72,73,74,75,76,77,78,79,81,82
Williamsburg	1981
Wise Co.	1971,72,73,74,75,76,77,78,79,80

Appendix IV. Verified¹ breeding locations provided by Milburn (1981) .

County	Location	Date	Original Source
Augusta	Churchville	5 May 1973	Cornell Nest Records
Augusta	Churchville	6 May 1973	Cornell Nest Records
Augusta	Waynesboro	1962	Yulee Lerner
Augusta	Waynesboro	May 1972	Yulee Lerner
Augusta	-	1977	Raven
Goochland	-	26 May 1978	Am. Birds
Giles	-	June 1965	Redstart
IC ²	Hampton	1962	Aud. Field Notes
IC	Harrisonburg	1970's	Rockingham Bird Club
James City	Lightfoot	21 May 1954	Raven
IC	Lexington	16 May 1939	Murray (1952)
Loudoun	Dulles Airport	23 May 1970	Raven
Loudoun	Lake Anne	1 June 1980	Am. Birds
Loudoun	Leesburg	21 April 1946	Museum Records
Loudoun	Leesburg	17 June 1967	Audubon Field Notes
Loudoun	Marbury	20 April 1946	Museum Records
Loudoun	-	June 1978	Am. Birds
IC	Lynchburg	-	Birds of the Lynchburg Area
Mecklenburg	Kerr Reservoir	11 June 1977	Am. Birds
Montgomery	Blacksburg	8 May 1955	Patuxent Nest Records
Montgomery	Blacksburg	May 1979	Jerry Via
Nelson	-	24 April 1899	Museum Records
Orange	Orange	27 April 1909	Museum Records
Pittsylvania	Westbrook	13 April 1951	Raven
IC	Richmond	8 April 1944	Raven
Roanoke	-	5 May 1962	Birds of Roanoke Co.
Rockbridge	California	16 May 1970	Raven
Rockbridge	-	20 April 1930	Raven
Rockbridge	-	2 May 1938	Raven
Rockbridge	-	27 April 1940	Raven
Scott	Nicklesville	16 April 1966	Raven
Shenandoah	Strasburg	8 June 1967	Raven
Warren	Front Royal	11 June 1911	-
Washington	Bristol	26 April 1965	Raven
IC	Williamsburg	1972	Mitchell Byrd

¹Verified (= confirmed) breeding localities refer to sightings of a nest or adult(s) with fledglings (Milburn 1981).

² Independent cities.

Appendix V. Potential¹ breeding locations provided by Milburn (1981).

County	Location	Date	Original Source
IC ²	Alexandria	3 June 1917	Patuxent
IC	Lynchburg	11 May 1904	Patuxent
Albemarle	-	23 May 1949	Raven
Amelia	-	21 June 1966	Raven
Augusta	Several locations	1975-1980	Yulee Larner
Bland	Wolfcreek	June 1972	Raven
IC	Charlottesville	June-August 1913	Patuxent
IC	Charlottesville	16 June 1949	Raven
Clarke	Berryville	1918	Patuxent
IC	Emporia	24 May 1954	Raven
Fauquier	Warrenton	1 June 1945	Museum Records
Fairfax	Dranesville	22 July 1950	
Goochland	East Leake	June 1921	Am. Birds
Hanover	-	18 May 1980	Am. Birds
Highland	-	21 June 1978	Raven
James City	-	2 June 1961	Williamsburg Bird Club
King George	-	12 June 1969	Raven
Lee	-	1-4 June 1964	Raven
IC	Lynchburg	8 May 1905	Patuxent
IC	Lynchburg	8 June 1974	Lynchburg Bird Club
IC	Lynchburg	7 June 1975	Lynchburg Bird Club
IC	Lynchburg	5 June 1976	Lynchburg Bird Club
IC	Lynchburg	3 June 1978	Lynchburg Bird Club
IC	Lynchburg	2 June 1979	Lynchburg Bird Club
IC	Lynchburg	7 June 1980	Lynchburg Bird Club
Madison	Camp Rapidan	May 1942	Raven
Mecklenburg	Clarksville	24 May 1954	Raven
Mecklenburg	Kerr Dam	10 June 1973	Raven
Montgomery	Blacksburg	14 June 1938	Cornell Nest Records
Nelson	Wingina	2 May 1898	Murray
IC	Newport News	13 May 1961	Raven
IC	Petersburg	March 1936	Raven
Prince William	Haymarket	22 May 1938	Raven
Rockbridge	Lexington	May 1939	Raven
Rockbridge	California	April-August 1969	Raven
Rockbridge	California	April-August 1970	Raven
Rockbridge	-	27 July 1970	Raven
Scott	-	May 1965	Raven
Shenandoah	Shenandoah N.P.	18 June 1954	Raven
Smyth	Saltville	1974	Raven
Smyth	Saltville	21 June 1975	Raven
Southampton	Courtland	24 May 1954	Raven
Surry	Hog Island	6 May 1974	Williamsburg Bird Club
Surry	Hog Island	June-July	Williamsburg Bird Club
Warren	Warren	10 May 1958	Raven
Warren	Warren	9 May 1959	Raven
Warren	Warren	6 May 1961	Raven
Washington	Abingdon	June 1966	Raven

¹ Potential records include all sightings of adult shrike(s) during the breeding season (Milburn 1981).

² Independent cities.

Appendix VI. Other shrike sightings found in literature or by personal communications.

County	Location	Date	Source
Albemarle	Browns Cove 7-1/2' Quad	-	BBA Project*
Amelia	Amelia	21 June 1966	Audubon Field Notes
Amelia	Chula 7-1/2' Quad	-	BBA Project
Amherst	Piney River	September 1971	L. Wikswo
Appomattox	Appomattox	4 March 1939	Museum Records
Augusta	Churchville 7-1/2' Quad	1985	BBA Project
Augusta	Deerfield 7-1/2' Quad	1985	BBA Project
Augusta	Deerfield 7-1/2' Quad	-	BBA Project
Augusta	Elliot Knob 7-1/2' Quad	-	BBA Project*
Augusta	Greenville 7-1/2' Quad	-	BBA Project*
Augusta	Parnassus 7-1/2' Quad	-	BBA Project*
Augusta	Staunton 7-1/2' Quad	-	BBA Project
Augusta	Stokesville 7-1/2' Quad	-	BBA Project*
Augusta	Waynesboro east 7-1/2' Quad	-	BBA Project*
Bedford	Sedalia 7-1/2' Quad	1985	BBA Project
Bland	Bland	21 February 1940	Museum Records
Botetourt	Rt. 81 North, Buchanan exit	15 April 1985	M.B. Moss
Botetourt	Oriskany 7-1/2' Quad	-	BBA Project
Brunswick	Broadnax	11 March 1983	L.G. Whitby
Brunswick	Broadnax	26 April 1983	L.G. Whitby
Charles City	37-17'-30'',77-06'-15''	28 January 1987	M. Byrd
Charles City	Shirley	16 May 1934	Museum Records
Chesterfield	Hopewell 7-1/2' Quad	1985	BBA Project*
Culpepper	-	Fall 1935	Museum Records
Dinwiddie	Petersburg	4 March 1939	Museum Records
Dinwiddie	Petersburg	4 March 1939	Museum Records
Dinwiddie	Petersburg	4 March 1939	Museum Records
Dinwiddie	Petersburg	4 November 1939	Museum Records
Dinwiddie	Poole Siding	4 March 1939	Museum Records
Fairfax	-	13 September 1912	Museum Records
Fairfax	-	24 January 1912	Museum Records
Fairfax	-	10 May 1939	Museum Records
Fairfax	Arlington	2 March 1898	Museum Records
Frederick	Stephenson 7-1/2' Quad	-	BBA Project
Frederick	Rt. 622,6Mi. SW Middletown	22 June 1975	E. Bassett
Frederick	39-08',78-11'	24 May 1981	J. Smith*
Frederick	Rt. 11	12 May 1978	R. F. Whiting
Frederick	White Hall 7-1/2' Quad	-	BBA Project
Frederick	Winchester 7-1/2' Quad	-	BBA Project
Giles	Pembroke	22 August 1939	Museum Records
Grayson	Fairwood	Oct.-Nov. 1969	A. Decker
Greensville	Emporia	3 March 1939	Museum Records
Greensville	Emporia	3 March 1939	Museum Records
Greensville	Emporia	3 March 1939	Museum Records
Greene	Standardsville	15 April 1984	B. Thomas
Halifax	-	June 1986	D. Stauffer
Highland	Snowy Mtn 7-1/2' Quad	-	BBA Project*
Loudoun	39-01'-04'',77-52'-40''	9 June 1985	B. Swift*
Loudoun	Bluemont 7-1/2' Quad	-	BBA Project*
Madison	Old Rag Mtn 7-1/2' Quad	-	BBA Project
-	Mechimus River	4 September 1909	Museum Records*

Appendix VI. (Continued).

County	Location	Date	Source
Montgomery	Blacksburg	3 May 1936	Museum Records
Montgomery	I 81 between exits 35&36	24 November 1984	S. Bentley
Nelson	-	24 April 1899	Museum Record*
Nelson	Greenfield 7-1/2' Quad	19 July 1985	BBA Project*
Northhampton	Franktown 7-1/2' Quad	-	BBA Project
Northhampton	Rt. 618 south of Exmore	September 1984	J. Abbott
Nottoway	Burksville	4 March 1939	Museum Records
Page	Arrowhead Lake	23 March 1975	R. Simpson
Page	Arrowhead Lake	3 April 1975	K. Ramsey
Prince George	Camp Lee	2 November 1939	Museum Records
Prince William	-	12 February 1939	Museum Records
Prince William	-	28 December 1901	Museum Records
Prince William	Nokesville 7-1/2' Quad	1985	BBA Project
Pulaski	Newbern	1 January 1985	S. Bentley
Pulaski	Intersection 626&611	November 1984	S. Bentley
Pulaski	Rt. 738	September 1984	S. Bentley
Pulaski	Rt. 611 near Tiny Town	Aug.-Nov. 1984	S. Bentley
IC	Richmond	4 June, 29 Aug. 1982	Am. Birds*
IC	Roanoke	7 January 1985	S. Bentley
Roanoke	Roanoke 7-1/2' Quad	-	BBA Project
Rockbridge	Rt. 677, 1 Mi. beyond 612	June 1983	J.B. Dixon
Rockbridge	Lexington	23 May 1942	Museum Records
Rockbridge	Lexington	16 May 1939	Museum Records
Rockbridge	Lexington 7-1/2' Quad	-	BBA Project
Rockingham	Dayton	5 October 1939	Museum Records
Rockingham	Fulks Run 7-1/2' Quad	-	BBA Project*
Rockingham	Harrisonburg 7-1/2' Quad	-	BBA Project*
Scott	Dungannon 7-1/2' Quad	1985	BBA Project
Scott	Hilton 7-1/2' Quad	1985	BBA Project
Shenandoah	Conicville 7-1/2' Quad	-	BBA Project
Smyth	Grindstone Campground	3 December 1969	A. Decker
Smyth	Konnarock	10 March 1966	A. Decker
Smyth	Konnarock	3 February 1970	A. Decker
Smyth	Marion 7-1/2' Quad	-	BBA Project
Smyth	Saltville	27 December 1974	A. Decker
Smyth	Saltville	May-September 1982	A. Decker
Smyth	Saltville	3 June 1984	J. McDonald
Smyth	St. Claire Creek	5 February 1962	A. Decker
Smyth	Sugar Grove	23 April 1969	A. Decker
Smyth	Sugar Grove	10 November 1969	A. Decker
Southampton	Southampton	3 March 1939	Museum Records
Surry	Cobham	20 November 1889	Museum Records
Surry	Cobham	22 November 1889	Museum Records
Surry	Cobham	19 November 1890	Museum Records
Surry	Cobham	20 November 1890	Museum Records
Surry	Cobham	21 November 1891	Museum Records
Sussex	Littleton 7-1/2' Quad	-	BBA Project*
Sussex	Yale	1954	Raven
Tazewell	Asberry	21 February 1940	Museum Records
Warren	Front Royal 7-1/2' Quad	1985	BBA Project
Warren	Middletown	23 April 1975	C. Hupp
Warren	Reliance	25 November 1980	L. R. Stewart
Washington	Damascus	8 January 1965	A. Decker

Appendix VI. (Continued).

County	Location	Date	Source
Washington	Glade Spring	5 May 1985	G. W. Kelley
Washington	Glade Spring	20 October 1985	G. W. Kelley
Washington	Meadoview	14 January 1963	A. Decker
Washington	Wyndale 7-1/2' Quad	-	BBA Project
IC	Waynesboro (airport)	29 May 1982	Ruth Snyder
Wise	-	22 February 1975	Am. Birds
Wise	Norton 7-1/2' Quad	-	BBA Project

* Confirmed breeding records.

Appendix VII. Shrike territories under observation by the study team in 1985 and 1986.

Site Number	County	Status ¹ 1985	Status ¹ 1986
1	Lunenburg	Breeding Pair	Unknown
2	Rockingham	Breeding Pair	Breeding Pair
3	Augusta	Breeding Pair	Unoccupied
4	Rockingham	Breeding Pair	Breeding Pair
5	Rockingham	Breeding Pair	Breeding Pair
6	Augusta	Breeding Pair	Unoccupied
7	Montgomery	Breeding Pair	Breeding Pair
8	Rockingham	Breeding Pair	Breeding Pair
9	Montgomery	Breeding Pair	Breeding Pair
10	Augusta	Breeding Pair	Breeding Pair
11	Augusta	Breeding Pair	Breeding Pair
12	Rockingham	Breeding Pair	Unoccupied
13	Rockingham	Breeding Pair	Breeding Pair
14	Augusta	Breeding Pair	Unoccupied
15	Rockingham	Breeding Pair	Unoccupied
16	Augusta	Breeding Pair	Unoccupied
17	Augusta	Breeding Pair	Unoccupied
18	Augusta	Breeding Pair	Breeding Pair
19	Highland	Breeding Pair	Breeding Pair
20	Augusta	Breeding Pair	Breeding Pair
21	Rockingham	Occupied	Occupied
22	Rockingham	Unoccupied	Unoccupied
23	Rockingham	Unoccupied	Unoccupied
24	Augusta	Unknown	Breeding Pair
25	Augusta	Unknown	Breeding Pair
26	Shenandoah	Unknown	Breeding Pair
27	Augusta	Unknown	Breeding Pair
28	Augusta	Unknown	Breeding Pair
29	Rockingham	Unknown	Occupied
30	Shenandoah	Unknown	Breeding Pair
31	Shenandoah	Unknown	Breeding Pair
32	Highland	Unknown	Breeding Pair
33	Highland	Unknown	Breeding Pair
34	Bath	Unknown	Breeding Pair
35	Augusta	Unknown	Breeding Pair
36	Augusta	Unknown	Breeding Pair
37	Augusta	Unknown	Breeding Pair
38	Warren	Breeding Pair	Breeding Pair
39	Rockingham	Unknown	Breeding Pair
40	Augusta	Unknown	Breeding Pair
41	Augusta	Unknown	Breeding Pair
42	Shenandoah	Unknown	Breeding Pair
43	Shenandoah	Unknown	Breeding Pair
44	Augusta	Unknown	Breeding Pair
45	Bath	Unknown	Breeding Pair
46	Rockingham	Unknown	Breeding Pair

Appendix VII. (Continued):

Site Number	County	Status ¹ 1985	Status ¹ 1986
47	Augusta	Unknown	Breeding Pair
48	Shenandoah	Occupied	Occupied
49	Shenandoah	Unknown	Occupied

¹Breeding Pair = Nest built and pair observed; Occupied = bird observed during breeding season; Unoccupied = previously occupied territory not occupied; Unknown = Status unknown.

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