FACTORS AFFECTING
LOGGERHEAD SHRIKE MORTALITY
IN VIRGINIA

by

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(ABSTRACT)

I studied loggerhead shrikes (*Lanius ludovicianus*) in the Shenandoah Valley in Virginia from April 1987 to April 1988; factors affecting mortality rates during the breeding season, fall dispersal, and winter were investigated. The high reproductive success in this study was similar to that reported by other researchers in the United States. Reproductive success was different among varying grass heights and varying amounts of bare soil areas within 100 m of shrike nests; success was highest in habitats with numerous bare soil areas and medium grass. I radio-harnessed fledglings at a mean age of 56 days to document dispersal, fall home-range areas, and survival rates. During the postfledging dispersal period, survival rates were 100%, fledglings dispersed at a minimum of 78 days of age, and fall home-ranges typically contained medium grass and numerous bare soil areas. These habitat characteristics may provide shrikes with increased invertebrate availability. Winter negatively affected the loggerhead shrike population in Virginia; raptor predation was the primary cause of subadult and adult mortality, and road kill was secondary. Shrikes moved from grassland areas to shrub-forest areas during inclement weather and preyed on small birds. Home-range sizes were larger during the winter than at other times of the year. I documented the occurrence of low levels of organochlorine and organophosphates in all birds analyzed for pesticide contamination. Also, I present statistical models to predict age and sex of loggerhead shrikes; wing chord and tail white on rectrix 5 were the most useful variables in discriminating sexes and wing chord was used in discriminating ages. More research is needed on the effects of raptors on shrike populations and on the role of foraging habitat on winter areas.

Acknowledgements

I extend my deepest gratitude to Dr. James Fraser for his guidance throughout the study. His friendship and advice have been invaluable. I also thank Drs. Roy Kirkpatrick, Dean Stauffer, and Roddy Young for their help during various stages of the project.

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I would like to thank Virginia Polytechnic Institute and State University, the Virginia Department of Game and Inland Fisheries, the U.S. Fish and Wildlife Service, the Bailey Research Trust, and the Rockingham Bird Club for providing funding on the project.

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INTRODUCTION

Loggerhead shrike (*Lanius ludovicianus*) populations have been declining throughout North America since 1966 at a 3.7% annual rate as determined by Breeding Bird Survey data (Robbins et al. 1986, Luukkonen 1987). Blue-listed since 1972 by the National Audubon Society, the loggerhead shrike is a "candidate for prompt study and evaluation for listing" under the U.S. Endangered Species Act (Arbib 1972, Tate 1986). The decline has been most severe along the eastern portion of the shrike's range and has proceeded from north to south (Morrison 1981). In fact, population numbers are so low in the Northeast that the U.S. Fish and Wildlife Service considers the northern migrant subspecies (*L. l. migrans*) to be most threatened (Dodd et al. 1985). The reasons for the decline are unknown; habitat loss, human disturbance, road kill, weather, and toxic chemical exposure have been suggested as contributing factors (Miller 1931, Kridelbaugh 1982, Cadman 1985, Luukkonen 1987, Gawlik 1988).

Recent studies have focused on the dynamics of loggerhead shrike populations on their breeding grounds (Kridelbaugh 1982, Luukkonen 1987, Brooks 1988, Gawlik 1988, Novak 1989). These studies suggested that availability of breeding habitat is not limiting, and that the decline in shrike populations may be caused by factors occurring outside the breeding season.

There has been increasing concern about the population decline in Virginia. Breeding Bird Survey data showed an estimated 10% annual decline in the number of shrikes in Virginia between

1968 and 1983 (Luukkonen 1987). These alarming rates prompted Virginia to add loggerhead shrikes to the State's Endangered Species List in 1987 (K. Terwilliger pers. commun.).

Previous research in Virginia has included a study by Luukkonen (1987) conducted during the summers of 1985 and 1986. He provided information on the status of breeding loggerhead shrikes, estimated reproductive rates, and described nesting habitat. I expand on Luukkonen's (1987) study and document factors that affect mortality rates from April 1987 through April 1988. The overall goal was to identify factors that affect mortality rates in loggerhead shrikes during the breeding season, fall dispersal, and winter that may be contributing to the decline of loggerhead shrike populations. Specifically, the objectives of this study were as follows:

1. Determine the relationship between reproductive success and habitat types for loggerhead shrikes;
2. Document postfledging dispersal and survival rates of radio-harnessed shrikes;
3. Document the rates and causes of mortality for loggerhead shrikes during the winter.

STUDY AREA

The study was conducted in the Shenandoah Valley in northwest Virginia. The study area was defined as the area bounded on the east by the foothills of the Blue Ridge and Massanutten mountains, and on the west by the Shenandoah Mountain (Figure 1). This area includes Rockingham, Augusta, Shenandoah, and Highland counties where grain and hay crops, and pasture land for livestock are primary economic resources. Small hardwood woodlots and old fields are interspersed throughout the Valley.

Average monthly temperatures during the study ranged from -2.2°C in January to 26.9°C in July. Precipitation was lowest in February and March 1988 and highest in September; 2.26

cm and 24.7 cm, respectively. Snowfall occurred between November and March, and ranged from 0.5 to 17.8 cm. (Table 1.).

Table 1. Temperature and precipitation in the Shenandoah Valley, March 1987 to April 1988 and departure from 1951 to 1980 average from the Dale Enterprise Weather Station (NOAA 1987, 1988).

	Temperature (^oC)				Precipitation (cm)		
	Average Maximum	Average Minimum	Average	Departure From Average	Total Rainfall	Departure From Average	Total Snowfall
March	14.7	-1.5	6.6	0	7.67	0	0.00
April	17.6	4.3	11.0	-1.6	15.27	+8.74	0.00
May	26.9	11.2	19.1	+1.1	7.01	-1.52	0.00
June	32.0	17.0	24.5	+2.0	6.20	-2.11	0.00
July	34.4	19.4	26.9	+2.1	3.66	-5.69	0.00
August	33.3	18.2	25.8	+1.7	5.72	-4.19	0.00
September	27.2	14.7	21.0	+0.8	24.67	+16.46	0.00
October	19.3	3.1	11.2	-2.3	2.59	-4.67	0.00
November	15.5	2.5	9.0	+1.7	7.06	+0.94	10.16
December	9.6	-1.1	4.3	+2.2	6.35	+0.76	1.52
January	3.8	-8.3	-0.4	-2.1	4.98	-0.08	17.78
February	8.3	-4.7	1.8	+0.5	2.26	-3.00	0.51
March	14.9	-0.2	7.6	+1.0	2.26	-5.01	2.54
April	12.1	4.3	12.1	-0.6	3.56	-2.97	0.00

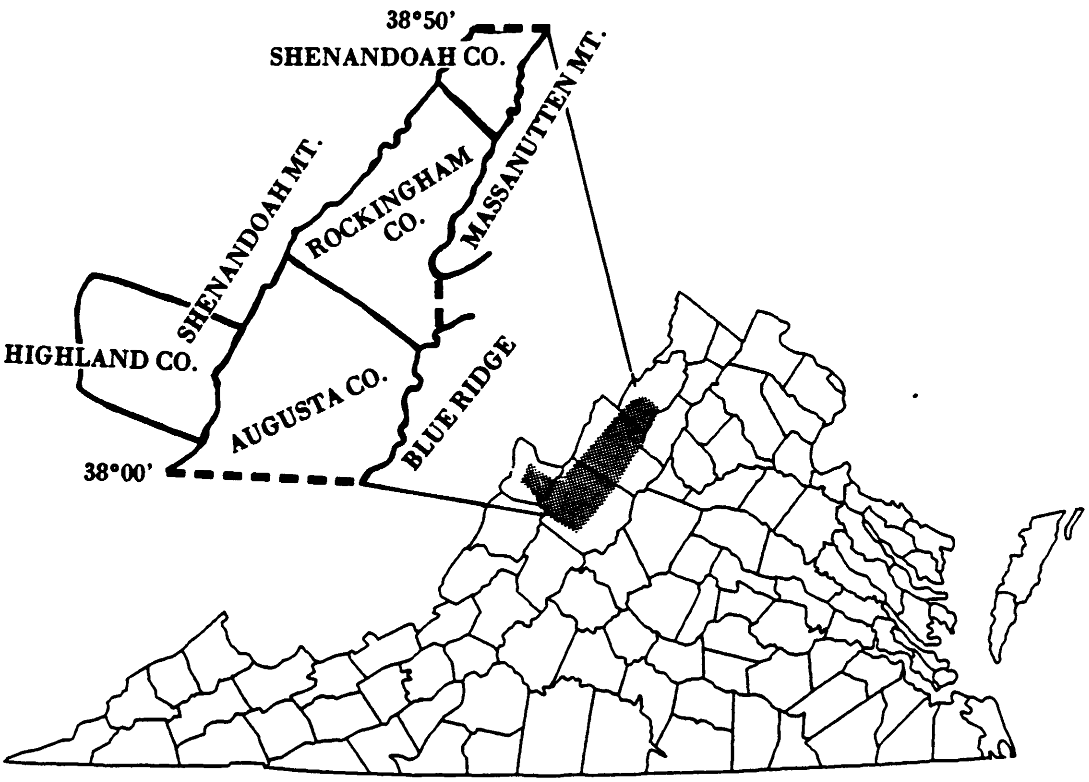

Figure 1. Study area in northwest Virginia. The enlarged map shows the Shenandoah Valley study area.

CHAPTER 1: RELATIONSHIP BETWEEN REPRODUCTIVE SUCCESS AND HABITAT TYPES

INTRODUCTION

The selection of nesting habitat is critical for breeding birds to provide for the energy and nutritional requirements of their offspring (Martin 1987). Habitat selection and the adjustment of brood sizes by asynchronous hatching and cannibalism allow adult loggerhead shrikes to meet the increasing energy and nutritional demands imposed by growing young.

Physical features vary among habitats and these differences influence the availability of food and foraging success. Studies of avian foraging have emphasized the importance of plant cover in relation to prey accessibility. Toland (1987) reported that American kestrels (*Falco sparverius*) were attracted to pastures and fields with low vegetation that allowed good visibility of insects and small mammals. He found that kestrel hunting success declined with increasing vegetation height and density. Craighead and Craighead (1956) reported higher buteo densities in habitats with shorter vegetation and sparser ground cover. Vegetation cover also was found to be more important than prey abundance in the selection of hunting sites by Swainson's hawks (*Buteo swainsoni*; Bechard 1982). Mills (1979) studied loggerhead shrike foraging patterns during the fall and winter and reported that shrikes avoided hunting in areas of tall, dense vegetation. However, if higher prey availability or greater prey size occurred in tall grass areas, shrikes selected these lower visibility areas over short grass habitats. Because foraging success affects reproductive success, shrikes may be selecting vegetation structures that would provide the highest forage success rates.

Studies by Luukkonen (1987) and Gawlik (1988) showed that shrikes that selected active pasture (i.e., areas grazed by cattle throughout the shrike's breeding season) as breeding sites had higher reproductive success than those that selected other habitats (Luukkonen 1987, Gawlik 1988). During 1985 and 1986, Luukkonen (1987) found that active pastures provided consistently short vegetation, and may therefore have made prey easier to detect. Similarly, Gawlik (1988) reported that shrikes foraged in recently plowed or mowed fields, and that higher nesting success occurred when birds nested within 100 m of these habitats. Increased hunting efficiency because of shorter vegetation would be especially important when adults are providing insects for nestlings.

In this chapter, I examine reproductive success in relation to nesting habitat for loggerhead shrikes in the Shenandoah Valley during 1987. In contrast to qualitative habitat descriptions (active or inactive pasture), I used a more specific habitat definition based on grass heights and a quantitative measure of the amount of bare soil area. I tested the hypothesis that reproductive success in loggerhead shrikes is different for short, medium, and tall grass habitats and that reproductive success differs between at least 2 habitat types. I also tested whether reproductive success differs in areas with varying amounts of bare soil areas.

METHODS

Reproductive Success

Nest searches began in early April in what appeared to be suitable habitat (e.g., pastureland areas with perch sites and trees or shrubs for nesting) and in nesting areas found during 1985 and 1986 (Luukkonen 1987). A nesting site was defined as an area where singing, nest-building, adult incubating, or brooding occurred. An area with a mated pair was considered an occupied nesting site. Observations of loggerhead shrikes were made from a vehicle or by foot with binoculars and a spotting scope.

Visits to nest sites were made twice weekly to determine dates of clutch initiation, clutch size, hatching, and fledging. I determined clutch initiation dates for shrike nests either by a visit to a nest where the female was sitting on her incomplete clutch or back-dating from known hatching or fledging dates. I back-calculated laying dates allowing 4 days for laying, 17 days for incubation and 19 days from hatching to fledging (Kridelbaugh 1982, Luukkonen 1987). Hatching success was defined as the number of eggs that hatched. Nests were considered successful if 1 or more young fledged. Young, at 9-10 days of age, were fitted with U.S. Fish and Wildlife Service aluminum leg bands and a unique color combination of plastic bands (A. C. Hughes, Hampton Hill, Middx.)

I defined brood reduction (i.e., death by cannibalism, starvation or carcass remains were found in the nest or impaled nearby) as the loss of 1 or more nestlings < 10 days of age. Nestling reduction within a clutch generally was not instantaneous, but often occurred over a 3 to 5 day period. After 10 days of age, young became more active and it was difficult to determine the cause of mortality. Unless there was evidence of brood reduction (i.e., carcass remains found in the nest or impaled nearby) or predation (i.e., feathers in a pile or destroyed leg bands near the nest site) the cause of mortality was listed as "unknown".

I estimated nesting success using MICROMORT, a computer program developed by Heisey and Fuller (1985) based on the Mayfield (1961) method. I assumed that the daily survival rates remained constant and divided the nesting cycle into 2 periods; egg laying through hatching (incubation stage), and nestling through fledging (nestling stage). All nests within a class (i.e., egg or nestling) for which estimates were being made were assumed to have the same survival probabilities. Reproductive success rates were calculated in different grass heights and bare soil areas. Z tests were used to compare success rates between classes of grass heights and between classes of bare soil areas.

Habitat

Grass heights within nest territories were classified as short (0.1-9.0 cm), medium (9.1-18.0 cm) or tall (≥18.1 cm). The classification of medium grass height also included those areas where tall grass was interspersed with short or medium grass. This mixed grass height appeared to be common in areas that were not heavily grazed; cattle were dispersed over a large area and perhaps selected specific grasses over others. Vegetation was sampled using 4 1-m^2 plots placed within homogeneous habitats. Plots were located at randomly selected compass bearings at a random distance within 100 m from each nest site. Percent cover by height class was estimated for each plot. When > 1 habitat type was encountered (i.e., tall grass and short grass habitat) within 100 m from a nest, the area was classified by the habitat type most frequently used by foraging shrikes. Foraging observations were made twice weekly for at least 1 hour in areas with more than 1 habitat type.

I recorded the presence of bare soil areas (i.e., livestock travelways, bare soil patches generally created by cattle, eroded drainages, rock-outcroppings, driveways and roads) that were approximately 100^2 m or larger, within 100 m from the nest. Nest sites were categorized as low in bare soil areas (< 2 bare soil areas) or high in bare soil areas (≥2 bare soil areas).

RESULTS

Reproductive Success

In 1987, 35 nests were initiated by 26 breeding pairs over all habitats. Eggs were laid from April to June. More than 40% of first nests were initiated in late April. A second nesting peak occurred in late May and early June as a result of renesting after failures and second nests (Figure 2). Mean clutch size was 5.22 ($N = 32$, SE = 0.13; Figure 3) and hatching success was 85.8% (109 of 127 eggs hatched) for all nests. In successful nests, on average 4.58 eggs were hatched ($N = 19$, SE = 0.31). One of 15 (6.7%) pairs with successful first nests initiated a second nest and 5 of 11 (45.5%) unsuccessful pairs renested.

Eighty-seven hatched eggs produced 68 fledglings (78.2%) from 19 successful nests. Nest success was 55.2% (Table 2) and 3.57 young fledged per successful nest ($N = 19$, SE = 0.38). An average of 2.62 young fledged per breeding pair ($N = 26$, SE = 0.45). Brood reduction occurred in 10 of 24 nests (41.7%).

Grass Heights

On 24 breeding territories active during the nestling stage, 5 nests were located in short grass habitat, 12 in medium grass of which 5 contained mixed grass heights, and 7 nests were located in tall grass habitat. Only 1 territory contained more than 1 habitat type (i.e., short grass and tall grass habitat) and from foraging observations, it was clear that adult shrikes were using only the short grass habitat area.

Success rates during the nestling stage were significantly greater for medium grass heights than for short grass heights (Table 3). Brood reduction occurred in 3 of 5 (60.0%) clutches in short grass habitats, 4 of 7 (57.1%) clutches in tall grass areas, and 3 of 12 (25.0%) clutches in medium grass. Although there was a tendency for brood reduction to occur most frequently in short and tall grass habitats and less in medium grass, the null hypothesis that brood reduction was independent of habitat failed to be rejected ($x^2 = 2.753$, df = 2, $P = 0.253$). These results were unexpected because previous studies by Kridelbaugh (1982), Luukkonen (1987) and Gawlik (1988) documented high reproductive success in short grass pastures.

Bare Soil Areas

Reproductive success was significantly higher in nest territories that had ≥2 bare soil areas (Table 4); livestock travelways and bare soil patches were the most common bare soil type (Table 5). During the incubation stage, survival rates were not significantly different; however, the probability that a hatchling survived to fledge was significantly higher in habitats with numerous bare soil areas. Similarly, brood reduction occurred most frequently in territories with low bare soil areas versus territories in high bare soil areas ($x^2 = 4.608$, df = 1, $P < 0.0050$; 8 of 13 (62.0%) clutches and 2 of 11 (18.0%) clutches, respectively.

DISCUSSION

Reproductive Success and Habitat

Reproductive success for Virginia loggerhead shrikes in 1987 was similar to that reported by other researchers in the United States (Table 6). Kridelbaugh (1983) reported that loggerhead shrike productivity is high for an open-nesting passerine in the North Temperate Zone and concluded that factors other than reproductive success were responsible for the population decline in Missouri.

During the incubation stage, hatch success rates were not related to grass heights nor bare soil area. Foraging demands for adult shrikes are low during this stage. However, during the nestling stage habitat physiography is most critical when adult shrikes must provide for nestlings and it was during this stage that success rate is related to bare soil area and different grass heights.

During the nestling stage adult shrikes must forage as efficiently as possible; thus, food availability is critical to reproductive success. Luukkonen (1987) presented evidence that shrike productivity was limited by food; he reported a positive correlation between nestling weights and brood size, and observed cannibalism of young loggerhead shrikes by adults. Habitats with high prey accessibility, visibility, and abundance would allow shrikes to forage efficiently and lessen the likelihood that food is a limiting factor. Habitats with numerous bare soil areas may provide increased accessibility and visibility of prey items. In addition, medium and tall grass habitats may provide insects with a high quality habitat, therefore increasing shrike prey items. However, prey may become inaccessible to shrikes in tall grass habitats. The small sample of nests in this study prohibited testing for possible interactions between grass heights and bare soil areas.

Although these results differ from those of Luukkonen (1987), the difference may be attributable to the definition of active pastures among years. The breeding season in 1985 and 1986 in the Shenandoah Valley was warm and dry (NOAA 1985, 1986) and active pastures typically had short and sparse grass cover (Luukkonen pers. commun.; Figure 4 and 5). In contrast, Spring 1987 was exceptionally wet (NOAA 1987; Figure 4 and 5) and active pastures contained a wide range of grass heights, some reaching 100 cm.

Weather Effects

Clearly, loggerhead shrike productivity varies among habitats and these differences may be attributed to food abundance and foraging success. However, weather factors including rainfall and temperature also may cause variation in avian productivity (Bryant 1975, Murphy 1983, Hannon et al. 1988). Inclement spring weather can delay the onset of breeding and cause reproductive failures in first brood attempts. Extremely high rainfall levels could directly affect food resources by negatively affecting the hatching, development, and growth of insects. DeSante and Geupel (1987) found that birds most affected were those species that feed their young on insects.

In this study, the peak of clutch initiation in 1987 was delayed by at least 1 week compared with the previous 2 years, and the delay coincided with heavy rainfall during April (NOAA 1987; Fig. 6). Delayed egg laying in 1987 may have caused clutch initiation to be compressed into 1 week compared with 3 weeks in 1985 and 1986(see Luukkonen 1987), and may be responsible for the low numbers of second nests; 6.7% pairs with successful first nests initiated a second nest in 1987 compared with 73.7% loggerhead shrike pairs in 1986. Variation in the timing of rainfall appears to be an important extrinsic factor influencing the timing of reproduction in loggerhead shrikes.

Table 2. Probability of loggerhead shrike nest survival in the Ridge and Valley province of Virginia.

	Incubation Stage	Nestling Stage	Nest Survival
Probability of Survival	0.6887 (34)[1]	0.8020 (24)	0.5524
Standard Error	0.0010	0.0162	0.0009

[1] Number of nests.

Table 3. Probability of loggerhead shrike nest survival for short, medium, and tall grass height classes, Shenandoah Valley 1987.

Class	Incubation Stage	Nestling Stage	Nest Survival
Short grass	0.8656 (7)[1]	0.4882 (5)	0.4226
Medium grass	0.6201 (23)	0.9174 (12)	0.5689
Tall grass	0.7626 (4)	0.8645 (7)	0.6593
Comparison of short vs medium	P = 0.1236	P = 0.0478	P = 0.4902
Comparison of short vs tall	P = 0.6672	P = 0.1142	P = 0.3898
Comparison of medium vs tall	P = 0.5352	P = 0.7188	P = 0.6892

Results from comparisons using Heisey and Fuller (1985) method.

[1] Number of nests.

Table 4. Probability of loggerhead shrike nest survival for high (≥2 bare soil areas) and low (< 2 bare soil areas) bare soil areas, Shenandoah Valley 1987.

Class	Incubation Stage	Nestling Stage	Nest Survival
Low	0.6153 (20)[1]	0.6512 (13)	0.4007
High	0.7936 (14)	1.0000 (11)	0.7936
P-value[2]	0.1340	0.0052	0.0078

[1] Number of nests.

[2] Results from comparisons using Heisey and Fuller (1985) method.

Table 5. Bare soil frequency within 100 m from the nest during the nestling stage.

Types	CLASS		Total
	Low[1]	High[2]	
Cattle travelways	4	6	10
Bare soil patches	1	7	8
Rock outcrops	3	3	6
Roads/driveways	1	4	5
Exposed drainages	1	3	4
None	3	0	3

[1] Territories with <2 bare soil areas.

[2] Territories with $\geq$2 bare soil areas.

Table 6. Reproductive success of loggerhead shrikes in recent studies in the United States.

Location	Number of Nests[1]	% Nest Success	Source
Virginia	35	55.2	This study
Virginia	57	62.1	Luukkonen 1987
Missouri	55	69.1	Kridelbaugh 1982
Minnesota	47	62.0	Brooks 1988
S. Carolina	49	65.3	Gawlik 1988
Colorado	77	66.2	Porter et al. 1975
Alabama	37	43.2	Siegel 1980
Illinois	20	80.0	Graber et al. 1973
Illinois	13	71.9	Anderson & Duzan 1978
New York	5	50.0	Novak 1989

[1] Number of nests used to calculate nest success.

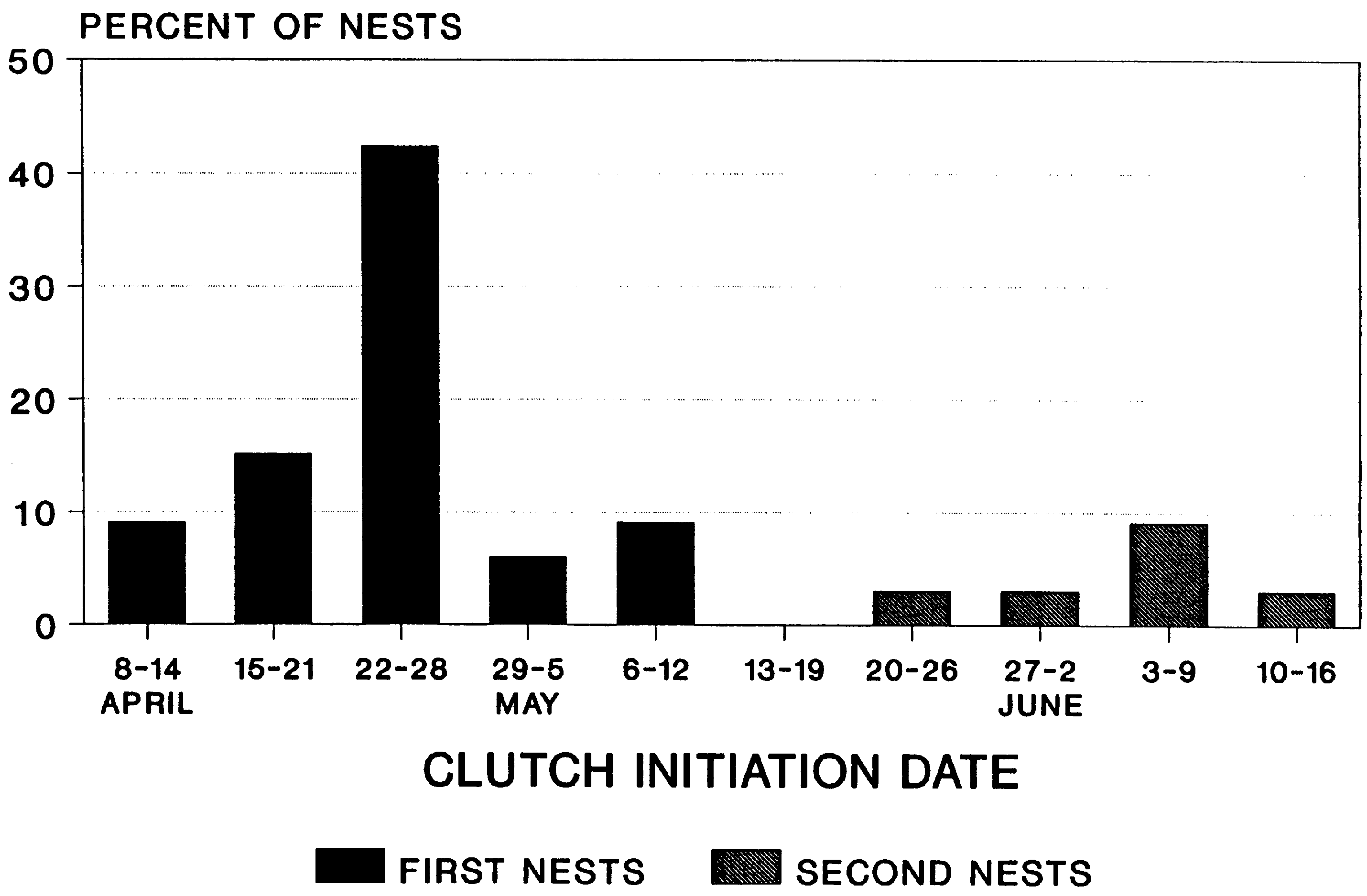

Figure 2. Weekly distribution of clutch initiation among 35 loggerhead shrike nests in Virginia 1987.

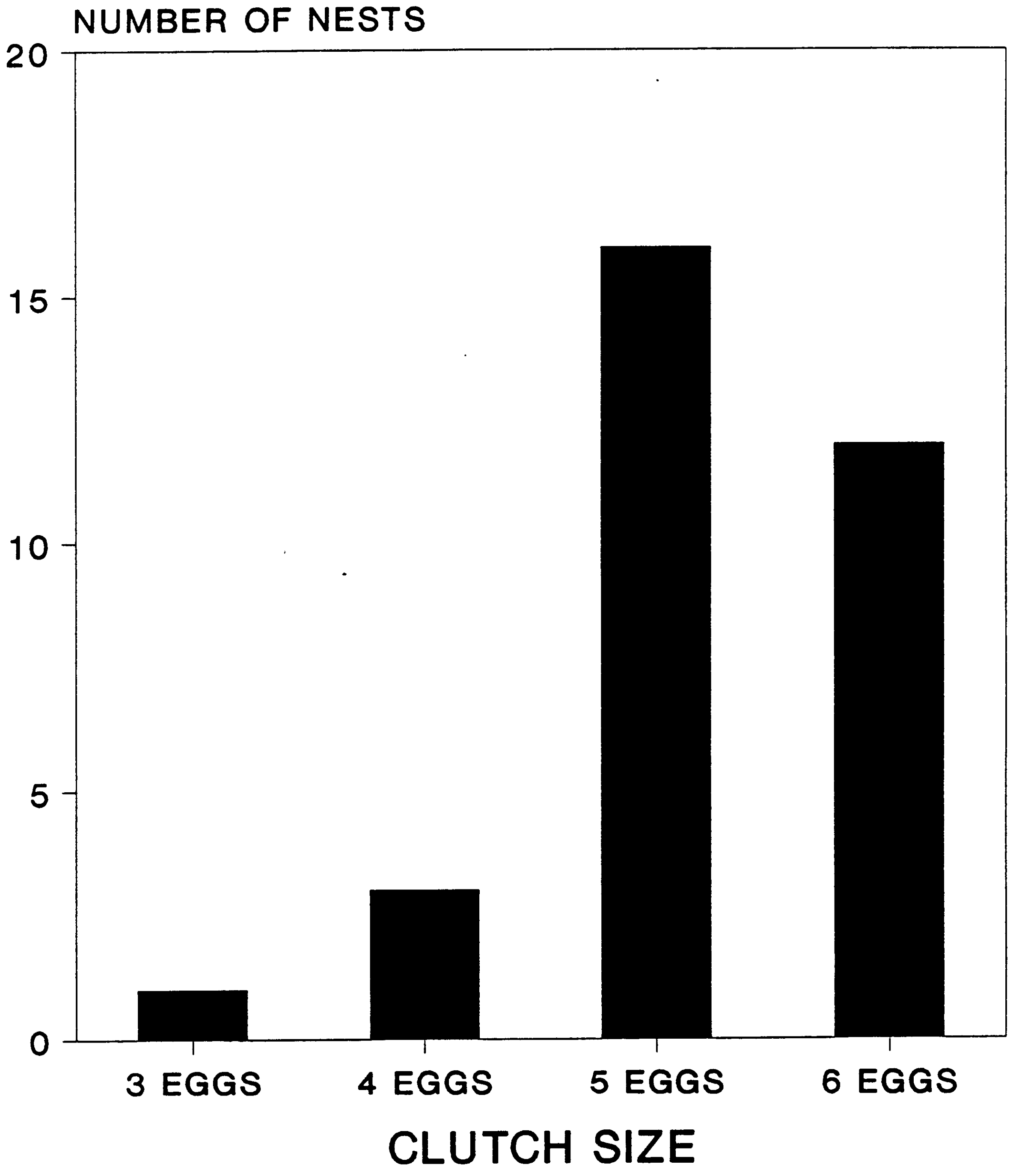

Figure 3. Distribution of clutch sizes from 32 nests in the Shenandoah Valley 1987.

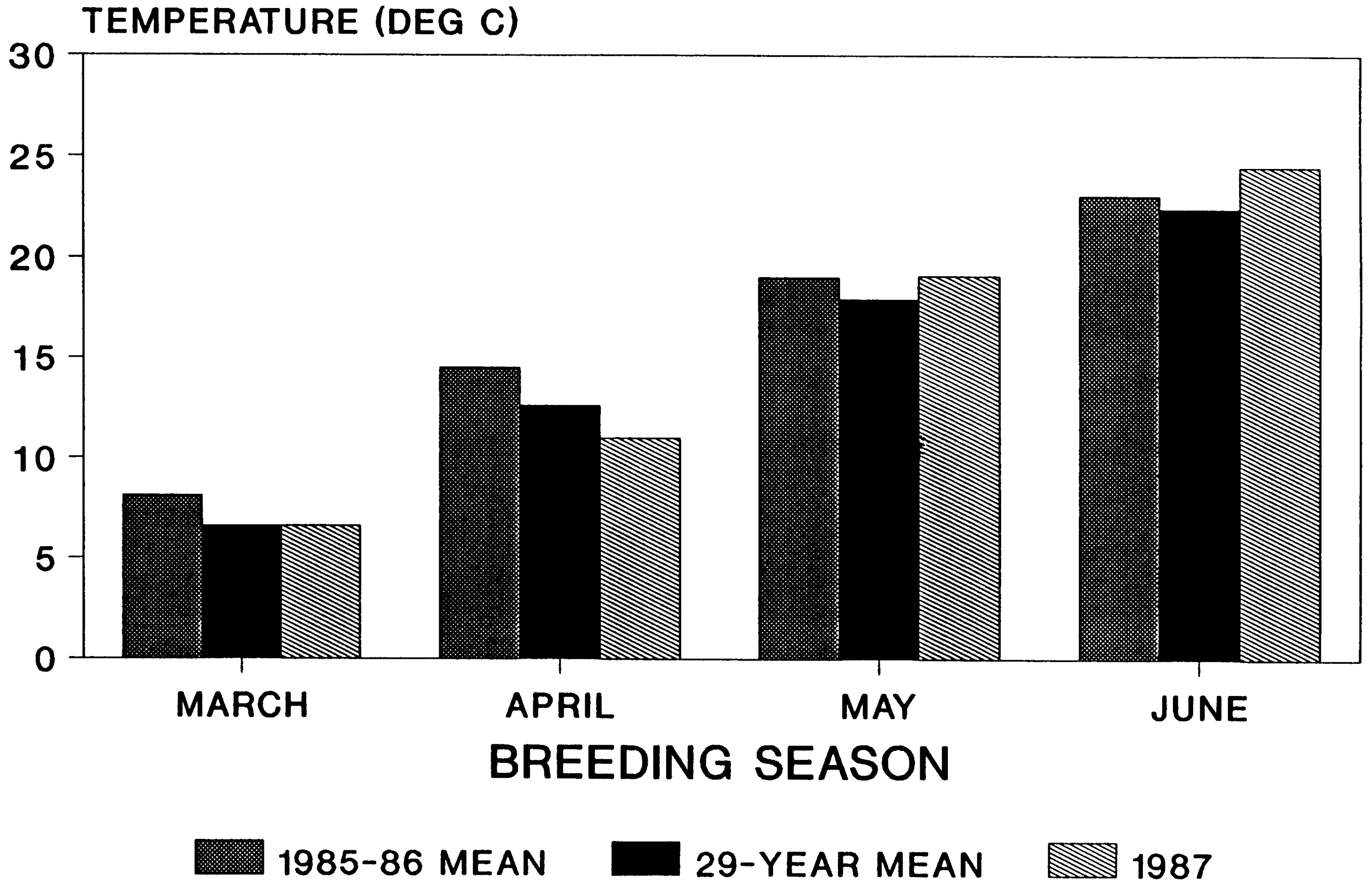

Figure 4. Temperature for 1985-88 breeding seasons compared with 1951-80 averages (NOAA 1985-88).

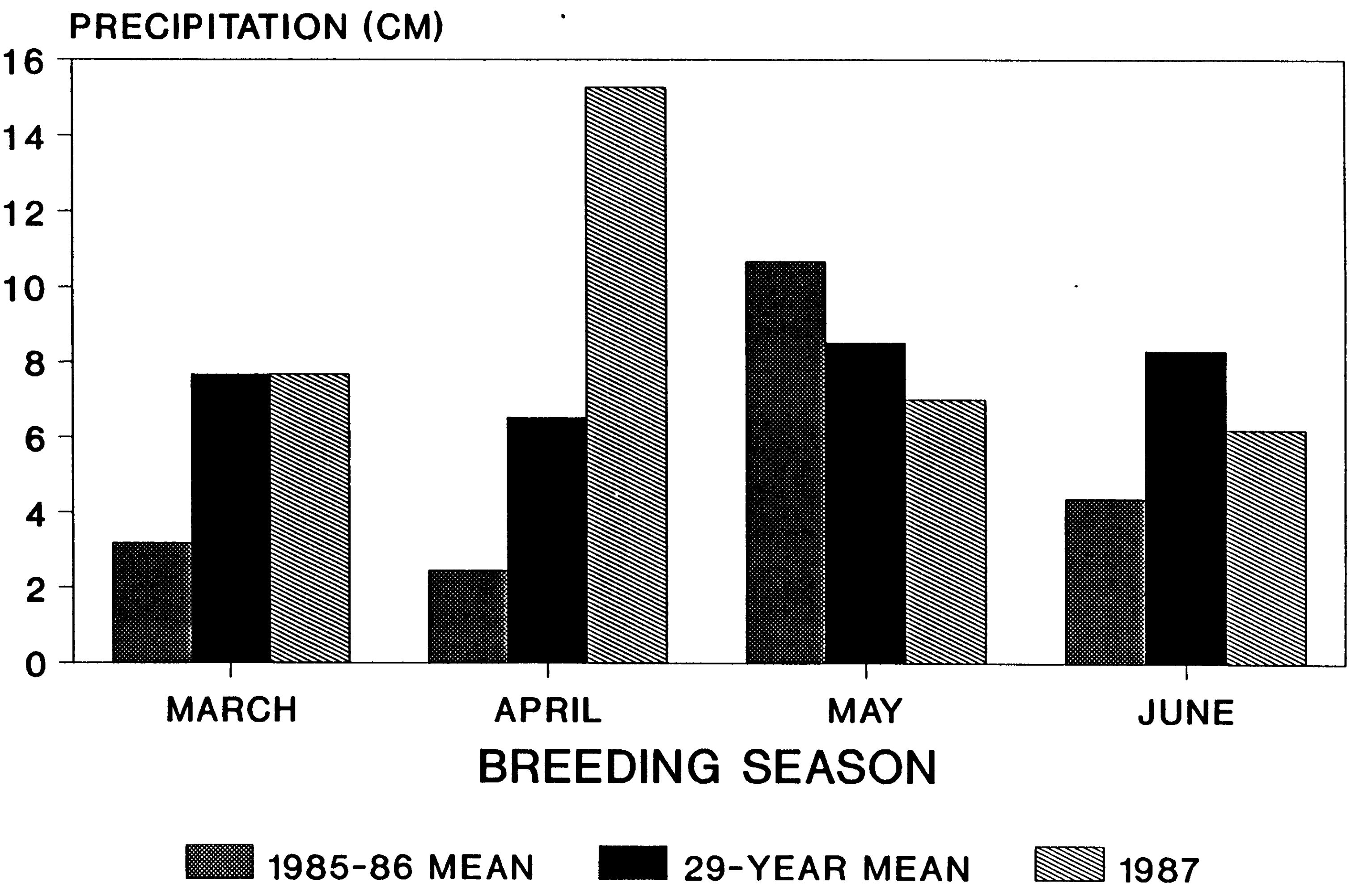

Figure 5. Precipitation for 1985-88 breeding seasons compared with 1951-80 averages (NOAA1985-88).

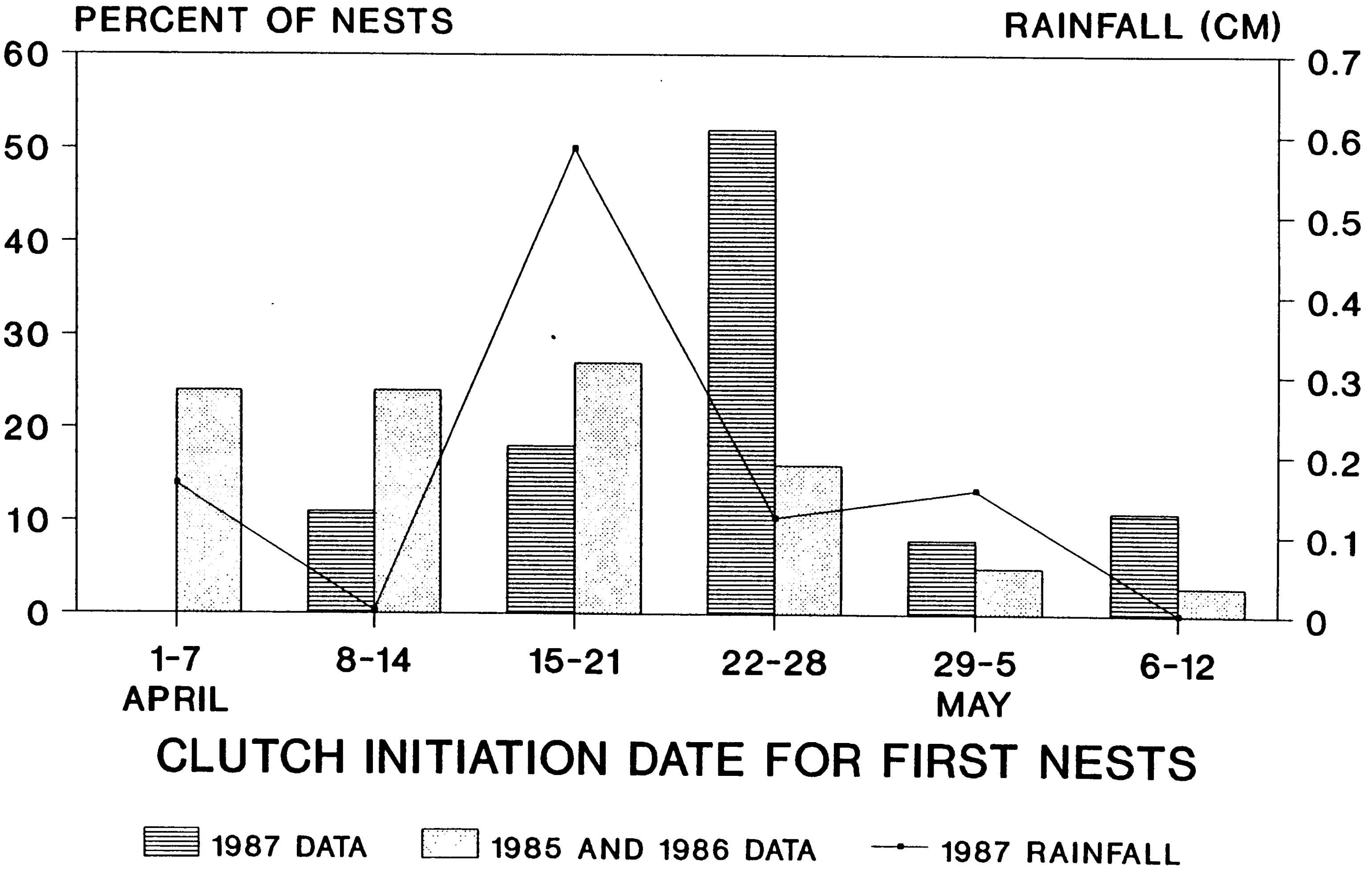

Figure 6. Weekly distribution of clutch initiation in relation to rainfall patterns for 37 nesting attempts in 1985 and 1986 (Luukkonen 1987) and 29 nests in 1987.

CHAPTER 2: POSTFLEDGING DISPERSAL

INTRODUCTION

Although dispersal can greatly affect the population structure of a species, it has received little attention, primarily because of the practical difficulties in following dispersing individuals. Thus, little is known about the consequences of dispersing from the natal area. It is likely that individuals that move through or settle in habitat that is unfamiliar or unsuitable increase their risk of predation. Greater mortality for dispersers has been documented in blackbirds (*Turdus merula*; Greenwood and Harvey 1976), but has not been found in great tits (*Parus major*; Greenwood et al. 1979) or spruce grouse (*Canachites canadensis*; Keppie 1979, Beaudette 1988).

Both genetic and environmental factors appear to influence dispersal (Greenwood et al. 1979, Weise and Meyer 1979, Fleischer et al. 1984, Newton 1986). Competition, foraging skills, habitat suitability, and age and sex of an individual may affect subadult dispersal patterns (Lack 1954, Kenward et al. 1981, Greenwood and Harvey 1982, Newton and Marquiss 1983, Gonzalez et al. 1989).

Loggerhead shrikes, banded during breeding studies and later recovered, have provided the only information concerning dispersal. Of 236 nestlings banded in the Shenandoah Valley between 1985 and 1987 only 4 individuals were located in later years (Luukkonen 1987 and this study). With so few band recoveries such studies provide little information on the effects of post-fledging dispersal from natal areas. The objectives of this chapter were to document the timing, distance, and direction of postfledging movements from natal areas through the establishment of fall home-range areas, describe fall home-range areas, and determine the ultimate fate of hatch-year birds. I tested the hypothesis that fall dispersal negatively affects survival of subadult loggerhead shrikes.

METHODS

Capture Techniques

Successful trapping efforts required lures, live bait, and a reliable capture device. Bal-chatri traps (Burger and Mueller 1959) often were ineffective for capturing shrikes, but were excellent luring devices when used with house mice (*Mus musculus*) or zebra finches (*Poephila guttata*). I captured shrikes using a Potter trap (Blake 1951), a single-cell wire box trap with a treadle trip bar and baited with mice.

I harnessed a mouse to the back side of the Potter trap using an adjustable wire collar that fit around the mouse's neck and attached a leash constructed of linked fishing swivels. The mouse could move freely, but the length of the leash prevented it from triggering the trap. Shrikes would often land near the back side of the trap or perch on top and to entice the bird to the trap entrance I placed live juvenile mice (i.e., preweaning stage) near the door. Shrikes would readily impale the mice and immediately return to the trap site.

I trapped 95 loggerhead shrikes from April 1987 to April 1988 using this technique and attribute capture success to the use of baiting with young mice. Hesitancy of some birds to enter the Potter trap was greatly reduced by using live bait; therefore, this technique was especially effective for trap-shy individuals.

Banding

All birds were fitted with U.S. Fish and Wildlife Service aluminum leg bands and unique color combination of plastic bands (A.C. Hughes, Hampton Hill, Middx.). Seams of colored bands were sealed with acetone to prevent their removal. Birds were weighed and morphometric measurements were recorded (Appendix 1).

Transmitter Attachment

Radio transmitters (Holohil Systems, Woodlawn, Ontario) were activated by removal of an external magnet. Transmitters had a 150-152 MHz frequency range, a 70-90 day battery life, and a 0.5-2.0 km ground range. The combined weight of the transmitter, battery, antenna, and harness was 1.8-2.5 g, approximately 3.5-5.0% of shrike body weight.

Radio transmitters were attached using a backpack harness consisting of cotton embroidery thread. Two lines, approximately 30 cm long, traversed the width of the transmitter at the anterior and posterior ends (Figure 7). Five-minute epoxy (Duro epoxy, Locite Corp., Cleveland, OH) was used to secure the lines onto the transmitter and was allowed to dry for 12-24 hours. A second application was used to create a smooth surface. Five transmitters with tubes encased in the potting material at posterior and anterior ends were used with poor success.

Tubes pulled free from the potting material causing the transmitter to break free from the harness.

While one person held the bird, another person positioned the transmitter on the bird's back (Figure 8). Two lines were placed anteriorly and posteriorly around each wing and threaded through a small rubber o-ring (0.3 cm inside diam. and 0.65 cm outside diam.) at the breast. A hood, covering the shrike's eyes, aided in subduing the bird. The bird was then placed on its back and one person held it in place while the other person slid aluminum foil under the o-ring to prevent tangling with the feathers. First the 2 anterior lines and then the 2 posterior lines were tied to the o-ring with equal tension (Figure 9).

The harness fit loosely, but tight enough to prevent the transmitter from slipping. To test if the harness fit, I was able to insert a small pen, about 0.4 cm diam., between the bird and the transmitter. The transmitter placement and harness attachment were checked and adjustments were made. Additional half hitches and 1 drop of super glue (Duro superglue, Locite Corp., Cleveland, OH) were used to secure knots; excess line was clipped. After the glue dried the aluminum foil was removed, and the harness preened into the feathers (Figure 10). The bird was held in an upright position for a few minutes and then released. This method seldom required more than 20 minutes.

Movements and Home-Range Areas

I radio-harnessed subadult shrikes >40 days of age to evaluate movements, home-range size, survival rates, and habitat use from 18 June to 10 November 1987. Shrikes that died during the first day after release ($N = 3$) were excluded from survival analyses. Subadults were identified from 1) known hatch dates, 2) juvenal plumage, and 3) incomplete prebasic molt. Statistical models, based on linear measurements taken on live birds, were used for aging those individuals that had undergone a complete molt (Appendix 1).

I located shrikes daily by driving roads surrounding the study area in an automobile with a roof-mounted omni-directional antenna and a portable receiver (Telonics Inc., Mesa, AZ). Once a signal was detected I tracked the birds on foot using a hand-held 2-element yagi antenna and portable receiver (Telonics Inc.) and located each bird visually. When birds were not located by ground searching, I traversed areas surrounding the study area in a Cessna 172 fixed-wing aircraft equipped with strut-mounted antennas. After determining the general location of dispersing subadults, I attempted to locate shrikes from the ground. I plotted each location to the nearest 25 m on a 1:24,000 U.S. Geological Survey map and recorded the Universal Transverse Mercator coordinates.

Predispersal movement was defined as the movement of a family from the nest site soon after the young fledge. Interactions between parents and offspring (e.g., subadults "begging" for food from their parents) continued throughout this period. I measured the distance from the nest to the home-range center during the predispersal stage. Means and their standard errors are reported as $\bar{x} \pm$ SE.

I defined subadult dispersal as the movement of individuals from their natal area, i.e., the departure of young from their parents, to a new location irrespective of whether they reproduced after dispersal. Because subadult shrikes were radio-harnessed, the dispersal date (i.e., that day when a shrike no longer was observed on its natal territory and no longer observed with its parents) was easily detected. I measured dispersal distance and direction from the nest to the center of the bird's home-range area during the fall.

An area was recognized as a bird's fall home-range if, during a 5-day observation period the bird used repeated perch sites and distances on consecutive location days between perch sites were generally < 300 m. I defined a movement as "exploratory" when subadults temporarily moved outside their home-range area but were relocated within their home-range in the following observation period.

I estimated home-range sizes by using the minimum convex polygon method (Mohr 1947), based on 95% of the locations with program HOME RANGE (B. B. Ackerman, M. D. Samuel, Univ. Idaho, Moscow). A curve of the number of locations versus area was drawn and home-range size was calculated for areas with an asymptotic curve. I present home-range size based on at least 25 locations per individual, which accounted for approximately 80% of the asymptotic home-range size.

I described the habitat type (by grass height and bare soil area), land-use practice (e.g.,pasture, rowcrop), and the presence or absence of drainage areas for each area. I also recorded vegetation height and bare soil area for each telemetry location, using methods described in Chapter 1.

RESULTS

Predispersal Movements

Fledging occurred about 19 days after hatching (Kridelbaugh 1982, Luukkonen 1987, pers. obs.). For the next 2 months, fledglings remained within 1 km from of the nest, ranging from no movement to 0.85 km (*N* = 7 families). During the 2 months following fledging I captured and radio-harnessed 13 young loggerhead shrikes from 9 different families within 600 m of the nest. Captures occurred from 18 June to 25 August; 5 fledglings from 5 different families and 8 fledglings from 4 families (2 per family) were captured. Individuals were fitted with transmitters at a mean age of 56 days (range = 41-75 days). The 2 months after fledging represents the time required to master flying and learning to forage independently (Miller 1931, Smith 1972 and 1973, Busbee 1976, pers. obs.) and, although intensive monitoring of subadults revealed little or no apparent influence of transmitter and harness on behavior of birds, older birds (i.e., > 50 days of age) were able to adapt to the harness and transmitter more quickly (i.e., resumed normal activities within 1 or 2 hours of being released) than younger, less experienced birds. Properly harnessed loggerhead shrikes exhibited no apparent difficulty in obtaining food and behaved like their siblings without transmitters. During this period, subadults often were located within 100 m of adults.

Of 7 families with known nest locations, 2 moved < 200 m of the nest and were in short grass habitats with high bare soil area. The 5 families that moved ≥200 m, were located an average of 600 ± 90 m from nests. Three of these families moved from nest sites that were in tall grass habitats and 2 families moved from medium grass habitats. Three of 5 nests were located in low bare soil areas. No fledglings remained in tall grass habitats; they moved from these nest sites to shorter grass habitats with high bare soil areas.

Timing and Distance of Dispersal

Seven fledglings dispersed from the nest area at a mean age of 78 ± 3.5 days. The mean dispersal date was 9 August, ranging from 23 July to 10 September. Six birds remained in natal areas up to 110 days of age ($\bar{x}$ = 93, range = 74-110), and because of the loss of radio signal or visual contact I was unable to determine if dispersal occurred. The 78 day average dispersal age may be biased low because it was likely that some birds dispersed after radio failure.

I followed 4 birds from their natal site to their fall home-range. When birds could not be located by ground searching, locations were made from the air. Dispersal direction varied and mean dispersal distance was 5.5 ± 1.8 km (Figure 11). Birds reached fall home-range areas on average in 8 days, ranging from 1-17 days.

Generally, young shrikes made short, daily movements (Table 7). Sibling pairs (*N* = 2) were observed traveling in the same direction; in one case, the pair traveled together and in the second, dispersal was 17 days apart, but in the same general direction. The latter pair maintained fall home-range areas 5.2 km apart. In at least one case, a subadult was observed in the territories of other shrikes (Figure 12). Resident shrikes often attempted to chase the dispersing subadult from the area.

Color-Band Observations

Color-band observation data showed 2% of the nestlings banded between 1985 and 1987 were sighted in later years (Luukkonen 1987 and this study). One female moved 23 km and 197° from her natal site in 1985 and produced successful nests in 1986 and 1987. One male was relocated at 2 years of age 12 km and 244° from his natal area. A 2-year old male returned to breed at his natal site, replacing his father. A nestling banded in 1987 was recovered 1.5 years later and 40 km northeast from its natal nest (Figure 13).

Fall Home-Ranges

On average, subadults reached permanent locations at 88 days of age, ranging from 71 to 104 days. Mean arrival date on fall home-ranges was 16 August, ranging from 23 July to 12 September. Mean home-range size for 6 subadults was 17.5 ± 4.8 ha during the fall (Table 8). After establishing fall home-range areas, exploratory movements were observed for 3 radio-harnessed shrikes.

Three of 6 radio-harnessed shrikes had home-range areas adjacent to other shrikes and boundaries were patrolled; if one shrike flew into the others′ home-range area it was chased until the intruding shrike returned to its own home-range area. I was unable to determine if the remaining 3 home-range areas bordered another shrikes′ area. Besides intraspecific territoriality, shrikes occasionally reacted aggressively toward northern mockingbirds (*Mimus polyglottos*), house sparrows (*Passer domesticus*), and American robins (*Turdus migratorius*).

Pastureland (i.e., grassland areas) was the predominant land-use type, although 2 home-range areas contained up to 30% area in rowcrops. Four of 6 home-ranges contained predominantly medium grass height and 2 areas were short grass habitats. Five of 6 home-ranges contained drainage areas that were eroded by cattle. Of these 5 home-range areas, 37% of the birds′ locations (range = 30-48%) were within 100 m of drainages (Table 8).

Survival Rates

The survival rate from fledging through establishment of fall home-ranges ($N = 19$) was 100%. Beyond the fall period, the ultimate fate of 11 subadults was undetermined because I was unable to recapture them and replace their failed radio transmitters. However, 4 subadults that survived throughout the fall died during the winter; the causes of their mortality are discussed in Chapter 3.

DISCUSSION

Predispersal Movements

Young loggerhead shrikes remained on natal areas on average 59 days postfledging; however, some birds remained on natal areas up to 91 days, which suggests that the average dispersal age may be biased low because it was likely that some shrikes dispersed after radio failure. Movements ≥200 m from the nest occurred most frequently when nests were located in tall grass habitats and in areas with < 2 bare soil areas. During the 2 months before dispersal, shrikes most often were located in habitats with short or medium grass height and with numerous bare soil areas. These habitat qualities may provide an abundant and accessible prey source that is critical to subadult shrikes during the fledging period when hunting skills are poorly developed and birds are dependent on insects as their primary prey.

Luukkonen (1987) and Gawlik (1988) reported that fledged young often were difficult to locate and that the number of fledglings may have been underestimated. With the use of radio-harnessed fledglings, I was able to document movements up to 900 m from the nest. Fledgling "disappearance", reported by Luukkonen (1987), is likely to be misinterpreted as mortality, when in fact the survival rate of radio-harnessed subadults was high.

Dispersal

Shrikes, about 78 days of age, dispersed from natal areas in varying directions. Newton and Marquiss (1983) observed that sparrowhawks (*Accipiter nisus*) dispersed in random directions and speculated that this lack of directional preference was because individuals of this species were likely to find suitable habitat in any direction traveled.

Dispersal movement usually consisted of short, daily flights and sometimes subadults would spend several days in a particular area before moving on. Similar to sparrowhawk dispersal observations by Newton (1986), subadult shrikes often appeared to wander and even double-back on themselves. For example, the straight-line distance for one individual from the natal site to the fall home-range was 5.5 km; however, the actual route traveled was 19.6 km and the farthest point visited was 10.9 km from its nest area. Newton (1986) suggested that dispersal distance in sparrowhawks was related with success in obtaining food, availability of prey in the local environment, and habitat occupancy.

With good reproductive success and high survival during the dispersal stage, it is likely that shrike habitat occupancy would be highest during the fall. I observed that fall home-range areas often were adjacent to other shrike areas and were aggressively defended.

Home-Range Size

Fall home-range size was highly variable, ranging between 2.0 and 36.4 ha. Several authors have reported an inverse correlation between territory size and habitat quality for other species (see Franzblau and Collins 1980). Miller (1931) and Kridelbaugh (1982) found variation in loggerhead shrike territory size during the breeding season that was related to habitat quality. Kridelbaugh (1982) found that as habitat quality decreased (i.e., the amount of rowcrops increased and the amount of pastureland decreased), the area required to maintain a nesting pair increased. In this study, fall home-range areas often were located in active pasture with medium grass height and high bare soil areas. I was unable to determine if size differences were correlated with forage abundance and availability, because habitat quality was not quantified.

Survival

An unexpected high survival rate was observed from fledging through establishment of fall home-ranges. Although high mortality rates have been reported for some first-year predatory bird species (Kenward 1987, Belthoff and Ritchison 1989), it appears that winter, and not fall, had the greatest detrimental effect on shrike survival in this study.

Table 7. Daily distance (km) traveled from the nest during fall dispersal.

	Day From Dispersal Date																
Bird	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	3.2(1)																
2a	2.3	2.9	4.3	5.1	---	---	---	---	10.7(1)								
3a	---	---	---	---	9.5	9.5	---	7.8	---	---	---	---	9.2	---	9.2	---	5.5(1)
4	---	---	4.5(2)														
5b	1.9	1.9	2.6(1)														
6b	1.9	1.9	2.6(2)														
N	4	3	4	1	1	1	0	1	1	0	0	0	1	0	1	0	1
$\bar{X}$	2.3	2.2	4.0	5.1	9.5	9.5	---	7.8	10.7	---	---	---	9.2	---	9.2	---	5.5

(1) = fall home-range area.
(2) = last sighting.
a,b = Like letters denote siblings.
--- = no location information.

Table 8. Fall home-range size and percent locations within 100 m of drainage areas for subadult loggerhead shrikes.

Birds	Relocations[1]	Home-range size (ha)	% Drainage locations	Grass height[2]/ Bare soil[3]
1	50	16.8	30	M/H
2	67	17.4	38	M/H
3	40	22.3	30	S/H
4	36	10.0	48	S/H
5	25	36.4	40	M/H
6	25	2.0	0	M/H

[1] Daily locations taken at random times between 0600 and 1800 hours.

[2] Grass height: S = short (0.1 - 9.0 cm), M = medium (9.1 - 18.0).

[3] Bare soil areas: H = high (≥2 bare soil areas).

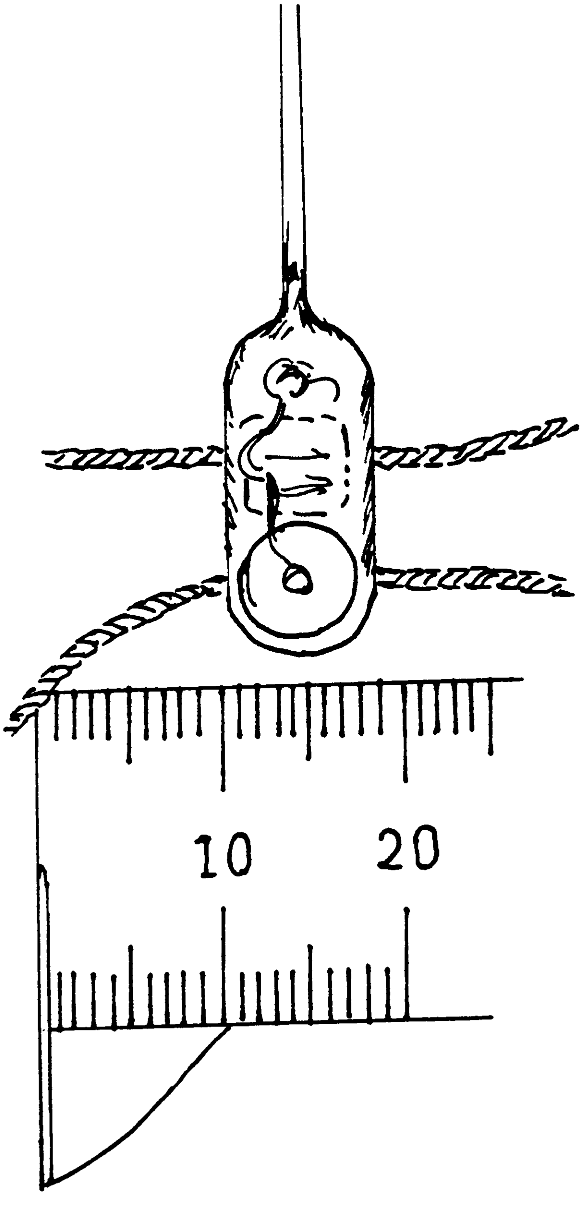

Figure 7. Radio-transmitter with cotton line attached for use as a backpack harness on loggerhead shrikes.

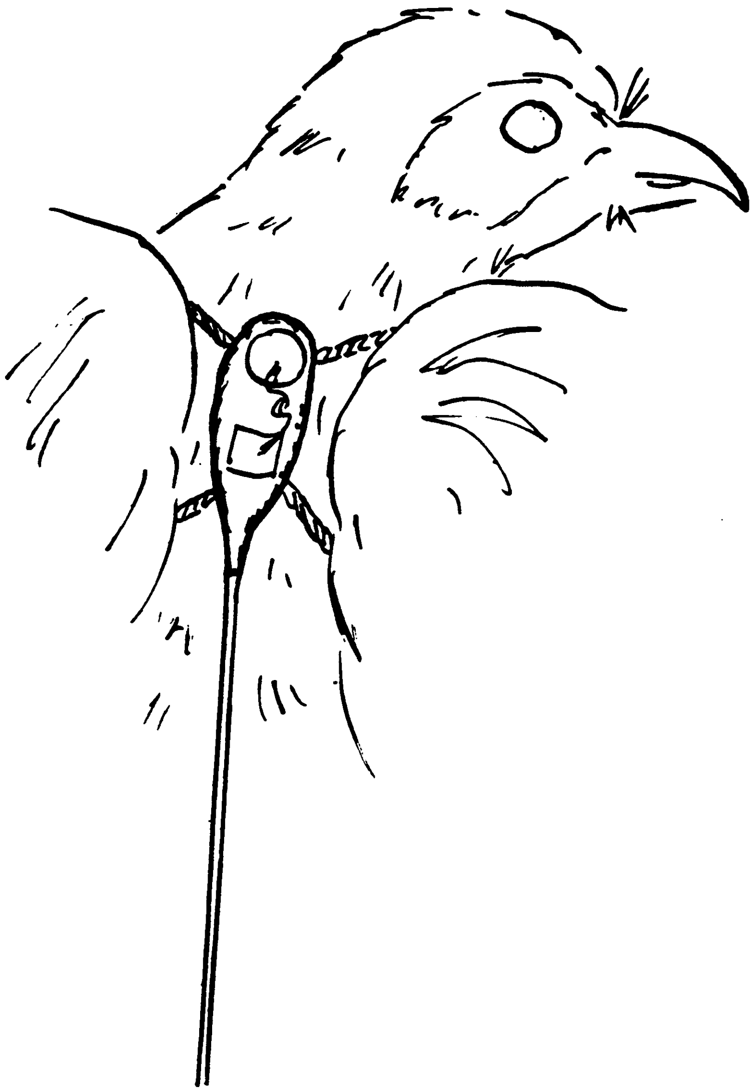

Figure 8. Placement of transmitter on bird.

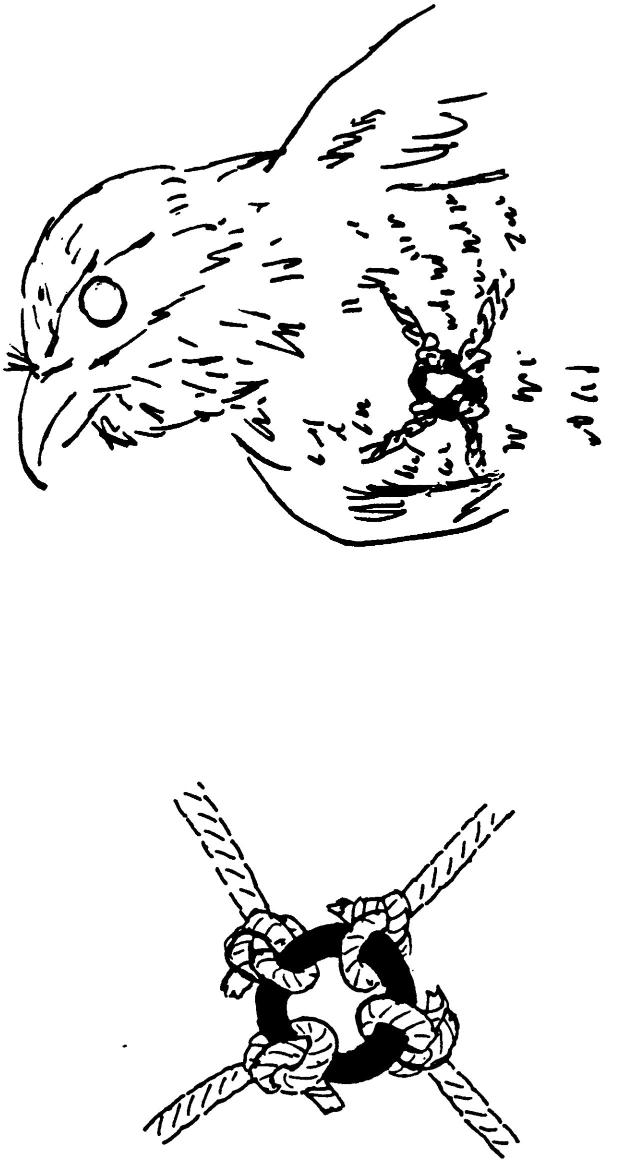

Figure 9. Harness attached to o-ring.

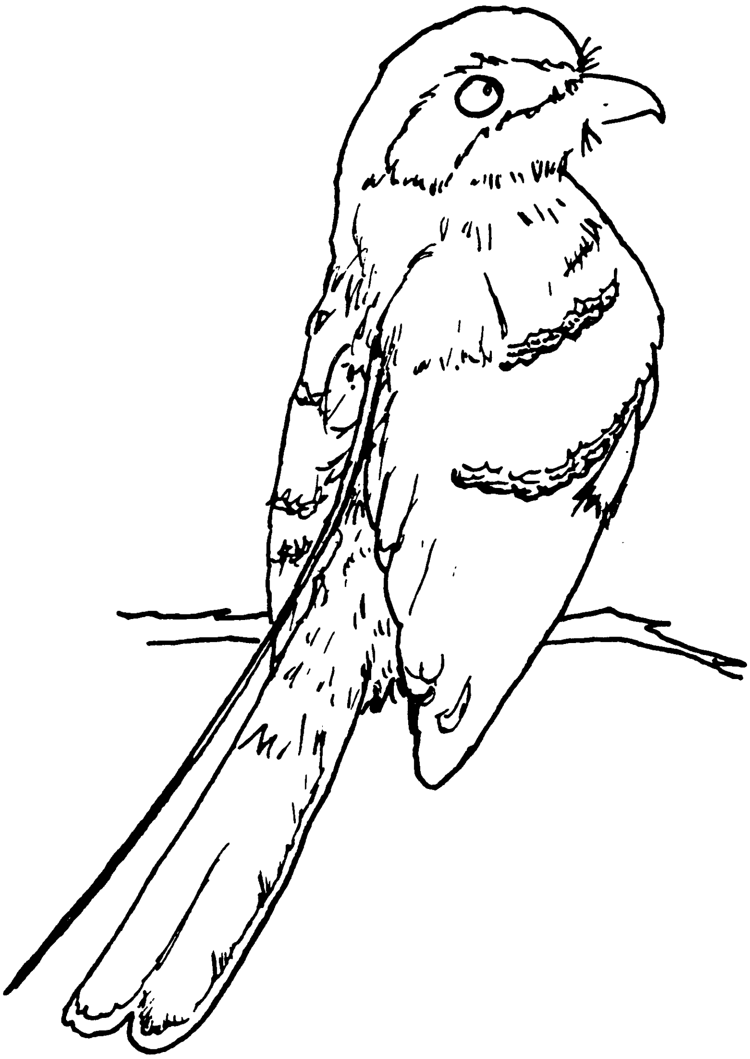

Figure 10. Radio-harness preened into feathers.

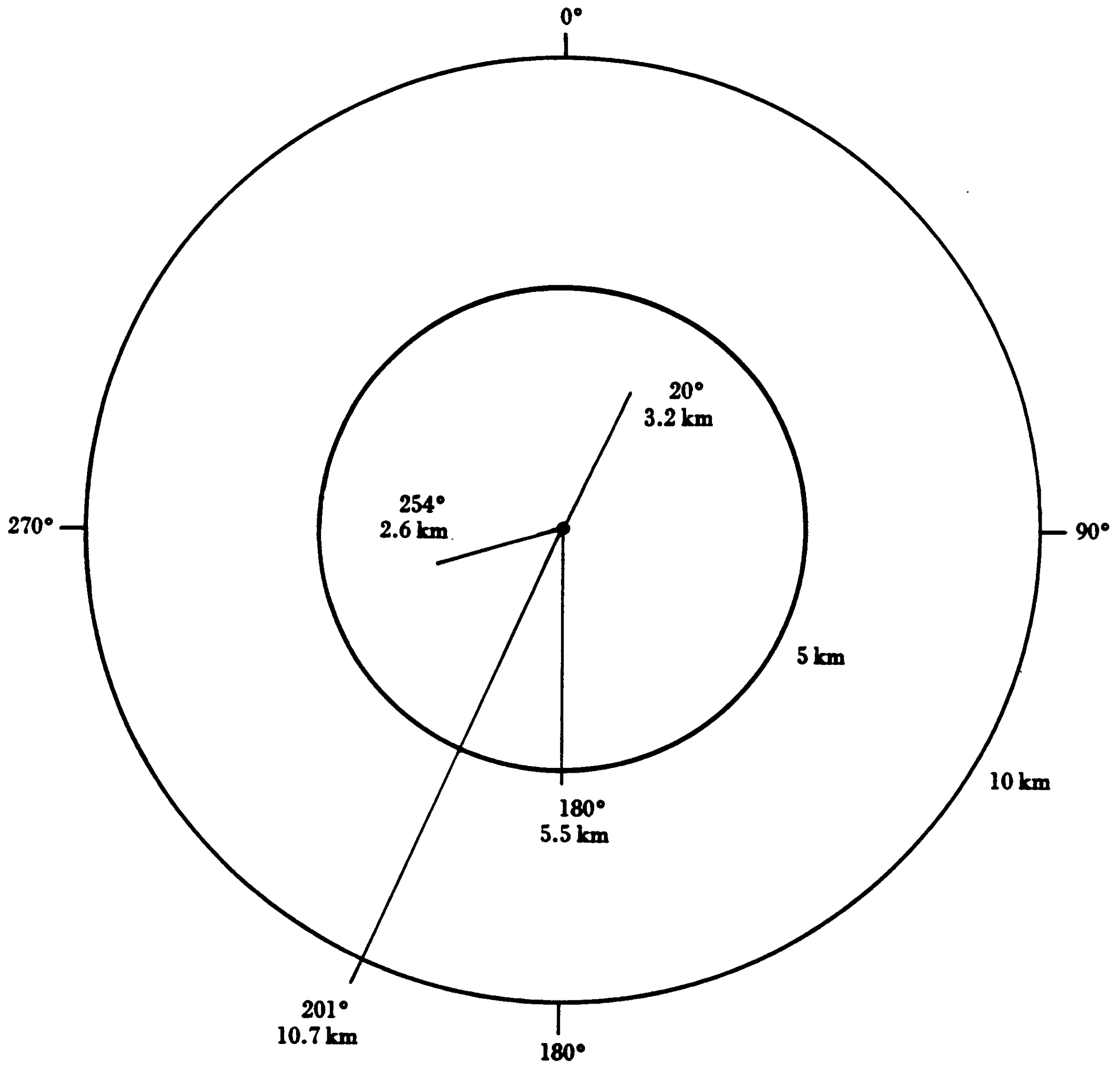

Figure 11. Dispersal distance and direction of radio-harnessed subadult loggerhead shrikes from nest areas.

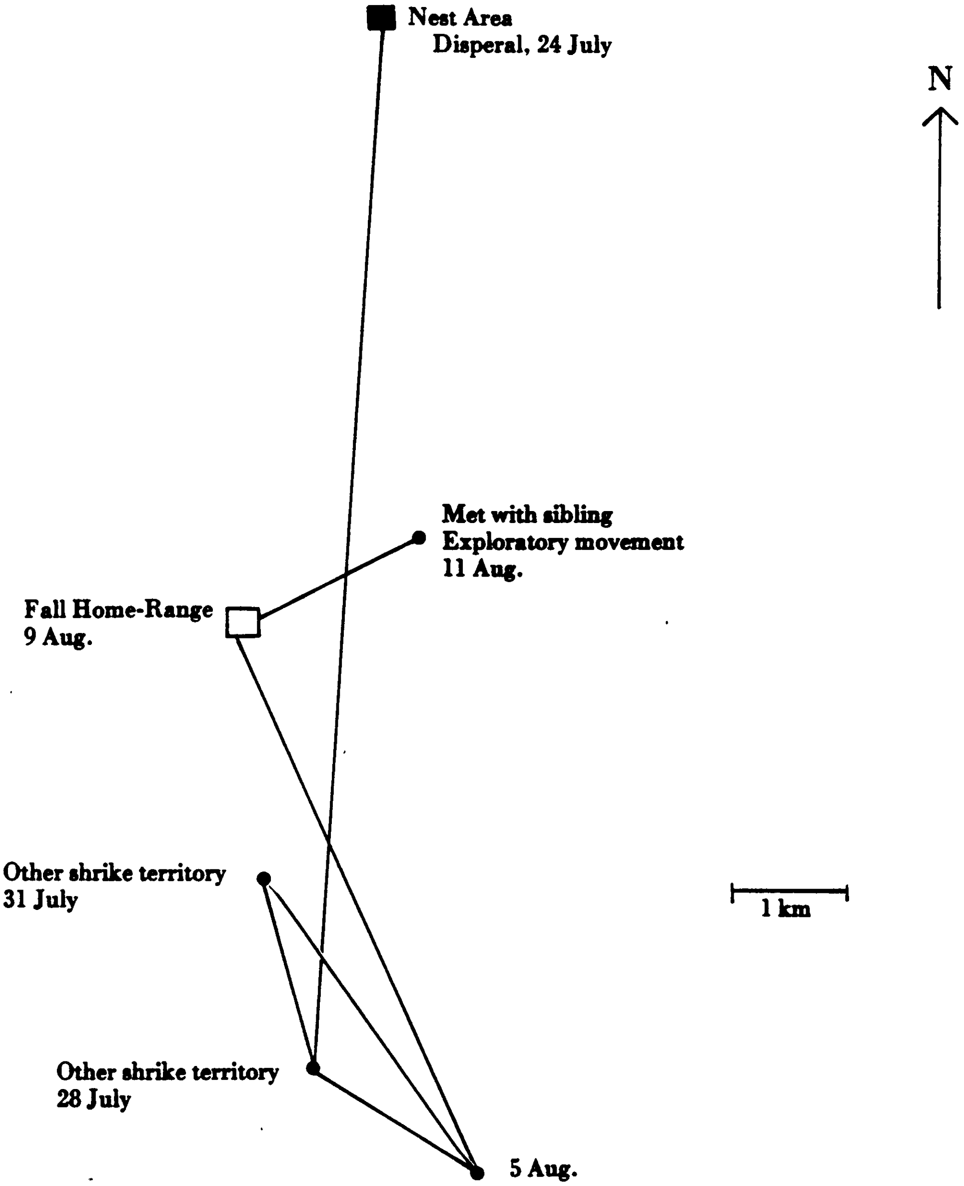

Figure 12. Dispersal pattern by a subadult shrike in the Shenandoah Valley.

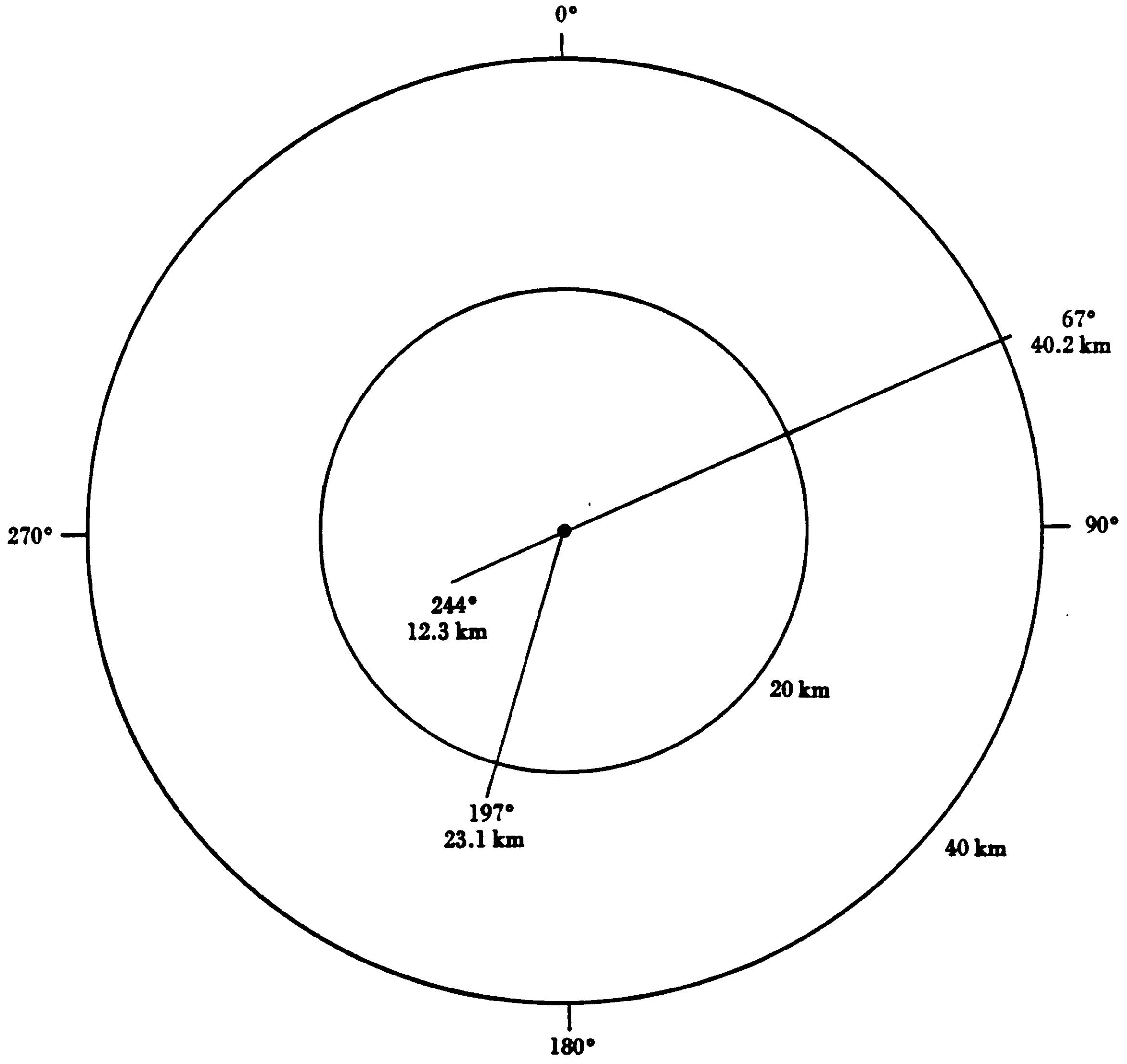

Figure 13. Dispersal distance and direction of banded loggerhead shrikes form nest areas.

CHAPTER 3: WINTER MORTALITY

INTRODUCTION

Numerous studies have addressed loggerhead shrike breeding ecology (Seigel 1980, Kridelbaugh 1982, Luukkonen 1987, Brooks 1988, Gawlik 1988, Novak 1989), but the winter ecology of shrikes has received little attention. Most winter shrike studies have been restricted to seasonal population trends (i.e., road surveys; Kridelbaugh 1982, Gawlik 1988) and annual population trends from Christmas Bird Count data provided by the National Audubon Society (Milburn 1981, Morrison 1981, Luukkonen 1987). Although Christmas Bird Count data possess limitations (Milburn 1981), these data are the primary source used in documenting winter population trends in the Northeast, and from these data it is evident that wintering shrike populations in Virginia are declining (Milburn 1981, Luukkonen and Fraser 1988). There are no previous studies that have determined whether loggerhead shrike breeding populations in Virginia overwinter or migrate. However, Miller (1931) speculated that populations breeding in regions that have more than 10 days annually of snow cover in winter will migrate to regions with little or no snow. In other bird species, overwinter survival is affected by food supply, adverse weather, and predation (Lack 1954, 1966, Newton 1979, Brittingham and Temple 1988).

The objectives of the study reported in this chapter were to document movement patterns, describe winter habitat, and determine causes of mortality.

METHODS

Capture and Transmitter Attachment Techniques

Loggerhead shrikes were captured, banded, measured, and observed for the study of winter ecology using the methods outlined in Chapter 2. Between 11 November 1987 and 1 March 1988, daily locations were obtained for 25 radio-harnessed shrikes (see Chapter 2). In addition, approximately twice each month, breeding territories occupied in the spring and summer of 1987 by banded birds were searched to determine if males or females without radios remained on their breeding territory throughout the winter.

Home Range

Home-range size was estimated using the minimum convex polygon method (Mohr 1947) based on 95% of the locations. A curve of the number of locations versus area was drawn and home-range size was calculated for areas with an asymptotic curve. In birds with asymptotic home-range curves, 30 observations accounted for approximately 85% of the asymptotic home-range value. Thus, I used data from all birds with ≥ 30 observations. A grassland area was defined by connecting only locations in grassland-pasture habitat. Grassland size was estimated using the same methods described for home-range size estimation. The Wilcoxon 2-sample test was used to test for differences between home-range size and grassland size. Areas were considered significantly different when $P < 0.05$. Means and their standard errors are reported as $\bar{x} \pm$ SE.

Shrub-forest habitats were characterized by a sparse overstory of eastern red cedar (*Juniperus virginiana*), oak (*Quercus* spp.) and pine (*Pinus* spp.), a dense shrub complex dominated by coralberry (*Symphoricarpos orbiculatus*) and multiflora rose (*Rosa multiflora*) and a sparse ground cover of grasses. Shrub-forest habitats were easily distinguished from grassland area habitats, which were typically pastures, hayfields, or old-fields. I defined movements to shrub-forest locations as "shifts" in habitat. I described these habitat shifts and measured the distances and directions from the center of an animal's grassland area to shrub-forest habitats located outside an individual's grassland area. Also, I calculated the proportion of an individual's radio locations observed in shrub-forest habitats for those shrikes for which I was able to obtain > 10 locations between the first and last snowfall day.

Survival Rates

I estimated loggerhead shrike survival rates for all birds and by age class and sex using the Mayfield (1961) method incorporated in the microcomputer program MICROMORT (Heisey and Fuller 1985). I divided the year into 3 periods based on the occurrence of snowfall. Summer-fall included the day that I radio-harnessed the first loggerhead shrike through the day before the first snowfall (18 June - 10 November). Winter included the first day day of snowfall through the last day of snowfall (11 November - 22 March), and spring included the day after the last day of snowfall until my field work was completed (23 March - 18 April). Estimated daily survival, s, was calculated as: $s = (x-y) \div x$

where x is the number of transmitter days in the interval and y is the number of deaths. Differences between survival rates were tested with a Z test. I excluded a bird from survival analyses if radio contact and visual observation were lost, because this loss may be caused by transmitter failure, or natural or predator induced emigration.

I assumed mortality was due to raptor predation if I observed a kill or if I found partially consumed birds, feathers in a pile, feathers and feces at a perch site, or neatly decapitated shrikes. Mortality was attributed to collisions with automobiles if birds were found dead along the roadside and severe impact was verified as the cause of death by necropsy and histological examinations preformed by The Wildlife Center of Virginia, Weyers Cave, Virginia and John Hopkins University Medical School, Department of Comparative Medicine, Baltimore, Maryland. Harness-related mortalities always occurred within 24 hours of transmitter attachment, were verified by necropsy, and were excluded from analyses. After necropsies and histological examinations were preformed on all dead birds, carcasses were analyzed for pesticide contamination by the Pesticide Residue Lab, Blacksburg, Virginia (Appendix 2).

Weather

I used weather data from Dale Enterprise Weather Station, a National Oceanic and Atmospheric Administration weather station located within the study area, to examine the effect of temperature and snow cover on movements and survival rates. Snow days (days on which snow covered the ground) occurred between 11 November 1987 and 22 March 1988 (Table 9). Wilcoxon 2-sample tests were used to test for differences between mean daytime (maximum) temperatures during the winter and mean daytime (maximum) temperatures during habitat shifts and day of death.

RESULTS

Home Range

I obtained ≥ 30 radio locations per individual to conduct home-range analyses for 8 shrikes (5 subadult females and 3 adult males). Mean home-range area was 51.7 ± 12.8 ha ($N = 8$) during the winter. Subadult home-range areas tended to be larger during the winter ($\bar{x} = 45.3 \pm 15.6$ ha; $N = 5$) than in the fall ($\bar{x} = 17.5 \pm 4.8$ ha; $N = 6$; Wilcoxon 2-sample test, $P = 0.0828$). However, grassland areas for subadults during the winter ($\bar{x} = 27.3 \pm 4.4$ ha; $N = 5$) were not significantly different from home-range areas in the fall (Wilcoxon 2-sample test, $P = 0.5228$; Table 10).

Home-range and grassland size during the fall and winter in Virginia substantially exceeded the home-range size reported for nesting shrikes by Miller (1931), Kridelbaugh (1982), and Novak (1989; Table 11). These authors obtained data on areas used by adult shrikes (banded, but not radio-tagged) during the nesting period. They plotted perch locations on aerial photographs and connected outside observation points to form a convex polygon. Kridelbaugh (1982) reported home-range size fluctuations during the breeding season with a larger home-range size during the incubation stage (8 ha) than during the nestling stage (3 ha), and an increase during the postfledgling stage (5 ha).

Five of 8 (63%) shrikes established grassland home-range areas that shared a common boundary with 1 other shrike. Grassland areas never overlapped and, although I observed shrikes defending their grassland areas, I never detected boundary disputes in shrub-forest areas.

Habitat Shifts

Fourteen radio-harnessed shrikes with > 10 locations were used in habitat shift analyses. During the winter period, 11 shrikes moved an average of 1.0 ± 0.2 km from the center of their grassland area to shrub-forest habitats located outside their grassland area; 3 birds shifted habitat within their grassland area. On average, 23.0 ± 3.1% of the radio locations from 14 birds were observed in shrub-forest habitats (Table 12). All birds were observed at least once in shrub-forest habitats and, in some cases, these locations were within the shrike's grassland area. Shrikes that shifted habitat more than once, moved in the same general direction, i.e., toward the same shrub-forest location. For example, one adult male used 4 different shrub-forest areas, moving southeast from the center of his grassland area 0.35, 0.85, 1.00, and 1.85 km.

Timing of Movements

Habitat shifts were related to temperature and snow cover. Omitting the days that habitat shifts occurred, maximum daytime temperatures in the Shenandoah Valley averaged 12.6° ± 0.6°C during the winter period. However, the average temperatures when shrikes moved to different habitats was 4.2° ± 0.9°C (Wilcoxon 2-sample test, $P = 0.0001$; Figure 14). Although the Shenandoah Valley had only 26 days of snow, 45% of the radio locations in shrub-forest habitats occurred when snow was on the ground.

Mortality Factors

Eighteen shrikes were used in estimating winter survival rates. Winter survival rates for adults and subadults were 0.13 ($N = 6$) and 0.01 ($N = 12$), respectively. No difference between adults and subadults in survival rates was detected during the winter (Z test, $P = 0.1802$). Adult mortality only occurred in January, while subadult mortality occurred throughout the winter. Winter survival rates for males and females were 0.03 ($N = 10$) and 0.04 ($N = 8$), respectively (Z test, $P = 0.8414$). The estimated survival rate for all birds during winter was 0.0302 ± 0.0066. Fifty-seven percent (8 of 14) of the mortality was due to predation by raptors, 29% (4 of 14) to road-kill, and 14% (2 of 14) was due to undetermined causes.

Pesticide analyses revealed residues of pp-DDE in each of 7 carcassess analyzed at levels varying from 0.03 to 2.03 ppm. Organophosphates were detected in 43% of the tissue samples (Appendix 2).

Timing of Mortality

All mortality occurred on days when average daytime temperature was 1.8° ± 2.1°C. This was significantly lower than the average daytime temperatures during the winter ($\bar{x} = 9.6° \pm 0.6°C$; Wilcoxon 2-sample test, $P = 0.0041$; Figure 14). The highest mortality rates occurred in January and coincided with the coldest temperatures ($\bar{x} = -2.2°C$).

Mortality and Habitat

Radio-harnessed shrikes with > 10 locations and known outcomes (i.e., alive or dead) were used in the following analyses. Shrikes killed by raptors ($N = 8$) were located an average of 24.5 ± 3.3% of the time in shrub-forest habitats compared with an average of 18.2 ± 6.3% for all other shrikes ($N = 5$; Wilcoxon 2-sample test, $P = 0.3413$). Birds that survived the winter ($N = 3$) were located an average of 11.0% in shrub-forest habitat versus 24.5% for raptor killed shrikes (Wilcoxon 2-sample test, $P = 0.10$). Of 10 shrikes found dead, 8 were found in shrub-forest habitat and 2 in pasture habitat; 26.6% of their locations (from the 10 shrikes) were in shrub-forest habitat and 73.4% in pasture habitat. Dead birds were found more frequently in shrub-habitat than in pasture habitat ($x^2 = 16.41$, df= 1, $P < 0.001$).

Annual Survival Rates

Survival rates for radio-harnessed shrikes during summer-fall ($N = 15$), winter ($N = 18$), and spring ($N = 3$) were 100%, 3%, and 100%, respectively. I calculated return rates for birds that were banded on breeding territories from 1985 through 1987 (Luukkonen 1987 and this study) and returned to the same areas in subsequent years. Fifty percent (16 of 32) of the breeding birds returned to the same areas in 1988. Males (11 of 17; 64.7%) returned significantly more often to breeding territories the following year than females (5 of 15; 33.3%; $x^2 = 8.78$, df= 1, $P < 0.0050$). Ten of 32 banded adults, 5 males and 4 females, remained on breeding territories throughout the winter. The tenth bird, a female, was located in February, 5.1 km southeast of her breeding territory.

DISCUSSION

Habitat Shift

During the winter period, shrikes move from pasture habitats to shrub-forest habitats for several reasons. Shrub-forest habitats may provide shelter and food during inclement weather. When temperatures drop below the overall average daytime temperature or when the ground is snow-covered, the availability of invertebrates declines and shrikes begin to prey on small birds. These small birds also are attracted to shrub-forest habitats for cover and food during inclement weather, and shrikes take advantage of this abundant prey. I often observed radio-harnessed shrikes perched on limbs of deciduous trees scanning the area for possible prey. I also observed shrikes actively pursuing and capturing passerine species (e.g., song sparrows *Melospiza melodia*, northern cardinals *Cardinalis cardinalis*, tufted titmice *Parus bicolor*, and European starlings *Sturnus vulgaris*) in dense shrub areas during inclement weather. Hence, the search for shelter and food during inclement weather appears to result in shifts to shrub-forest habitats which, in turn, create the larger home-range sizes of subadult shrikes in the winter compared to the fall.

Mortality

The major source of mortality for loggerhead shrikes in Virginia during the winter of 1987-1988 was raptor predation, accounting for 57% of shrike mortality. Red-tailed hawks (*Buteo jamaicensis*), Cooper's hawks (*Accipiter cooperii*), sharp-shinned hawks (*Accipiter striatus*), American kestrels (*Falco sparverius*), great horned owls (*Bubo virginianus*) and common screech owls (*Otus asio*) were common during the winter. In one case, I flushed a Cooper's hawk from a freshly-killed, radio-harnessed subadult female. Raptors and shrikes alike, tend to seek out shrub-forest habitats during inclement weather for shelter and their primary prey, song birds. Shrikes' susceptibility to predation increases when forage areas overlap. These conditions may be more likely during less severe winters when raptors tend to remain in the Shenandoah Valley. Furthermore, birds that move into unfamiliar surroundings, searching for suitable habitat that can support them throughout the winter period, may be more vulnerable to predation. Rappole et al. (1989) found that mortality rates of wandering wood thrushes (*Hylocichla mustelina*) was significantly higher than rates for sedentary birds.

Undetermined causes of death included one subadult that was found on the ground, protected from snow by a down log. The bird appeared emaciated, but the cause of death could not be identified. The transmitter signal from a second subadult came from beneath a porch. Cat tracks led to this area, but the small crevice beneath the porch prohibited me from recovering the bird and verifying the cause of death. Both deaths occurred during the first snow storm of winter. A severe winter likely would reduce shrikes' food resources and may have detrimental affects on the birds' physical condition. In a weakened condition, birds that move to shrub-forest habitat in pursuit of food may be more vulnerable to predation. In this study, the highest mortality rates occurred during January and coincided with the coldest temperatures. In addition, the average temperature during January 1988 was substantially below the 29-year average (Table 1).

Data indicate that trends were in the direction of increased mortality for birds that shifted habitat, but my sample of birds that shifted habitat was inadequate to detect differences in survival probabilities, and because birds were located no more than once per day, shifts in habitat may have gone undetected.

Survival

Seasonal estimates of survival show that the probability of survival was lowest during winter. These findings, however, may be biased because it seems likely that transmitters affect predation rates, as was observed with radio-tagged Columbian sharp-tailed grouse (*Tymphanuchus phasianellus columbianus*; Marks and Marks 1987) and with wood thrushes (Rappole et al. 1989) during the winter period. Shrikes banded on breeding territories in 1987, but not radio-harnessed, showed a 50% return rate to breeding territories the following year. This is an estimate of the minimum known alive and, clearly differs from the 3% estimated annual survival rate for radio-harnessed shrikes. Radio-harnessed shrikes provide useful information on habitat selection, causes of mortality, and potential risks of mortality due to avian predation, but may not provide an accurate survival rate estimate.

Table 9. Temperature and snowfall in the Shenandoah Valley, November, 1987 to March, 1988 from the Dale Enterprise Weather Station (NOAA 1987, 1988).

	Average Maximum Temperature (°C)	Total Snowfall (cm)
November	15.5	10.2
December	9.6	1.5
January	3.8	17.8
February	8.3	0.5
March	14.9	2.5

Table 10. Winter home-range and grassland sizes for loggerhead shrikes using the 95% minimum convex polygon.

			Home Range[3]		Grassland Area[4]	
Bird	Age[1]	Sex	N[2]	Size(ha)	N[2]	Size(ha)
1	Sub	F	37	14.3	36	14.3
2	Sub	F	30	22.5	30	22.5
3	Sub	F	58	42.8	46	11.7
4	Sub	F	46	43.4	42	32.1
5	Sub	F	37	103.5	31	28.8
6	Ad	M	41	23.3	40	23.3
7	Ad	M	38	54.1	35	50.3
8	Ad	M	39	109.7	34	35.7

[1] Sub = subadult, Ad = adult.

[2] Number of radio relocations.

[3] Home Range includes shrub-forest and grassland areas.

[4] Grassland Area is defined by connecting only locations in pasture-grassland habitat.

Table 11. Home-range size estimates for loggerhead shrikes.

Location	Season	Home-Range Size (ha) $\overline{x}$±SE	N[1]	Source
California	spring	7.6 ± 1.3	10	Miller 1931
Missouri	spring	4.6 ± 0.7	23	Kridelbaugh 1982
New York	spring	6.7 ± 1.0	5	Novak 1989
Virginia	fall	17.5 ± 4.8	6	This study
Virginia	winter	51.7 ± 12.8	8	This study

[1] Number of home-range areas.

Table 12. Number of shrike observations (with > 10 radio locations) in all habitats and in shrub-forest habitat during the winter.

Bird	Over All Habitats	Shrub-Forest Habitat	Percent in Shrub-Forest	Status
1	25	1	4.0	alive
2	21	1	4.8	alive
3	11	1	9.1	raptor kill
4	38	5	13.2	raptor kill
5	15	3	20.0	road kill
6	24	5	20.8	raptor kill
7	33	8	24.2	alive
8	19	5	26.3	raptor kill
9	37	10	27.0	raptor kill
10	51	16	31.4	raptor kill
11	15	5	33.3	raptor kill
12	46	16	34.8	unknown
13	20	7	35.0	raptor kill
14	37	14	37.8	road kill
Total	392	97		
Mean	28	7	22.9	

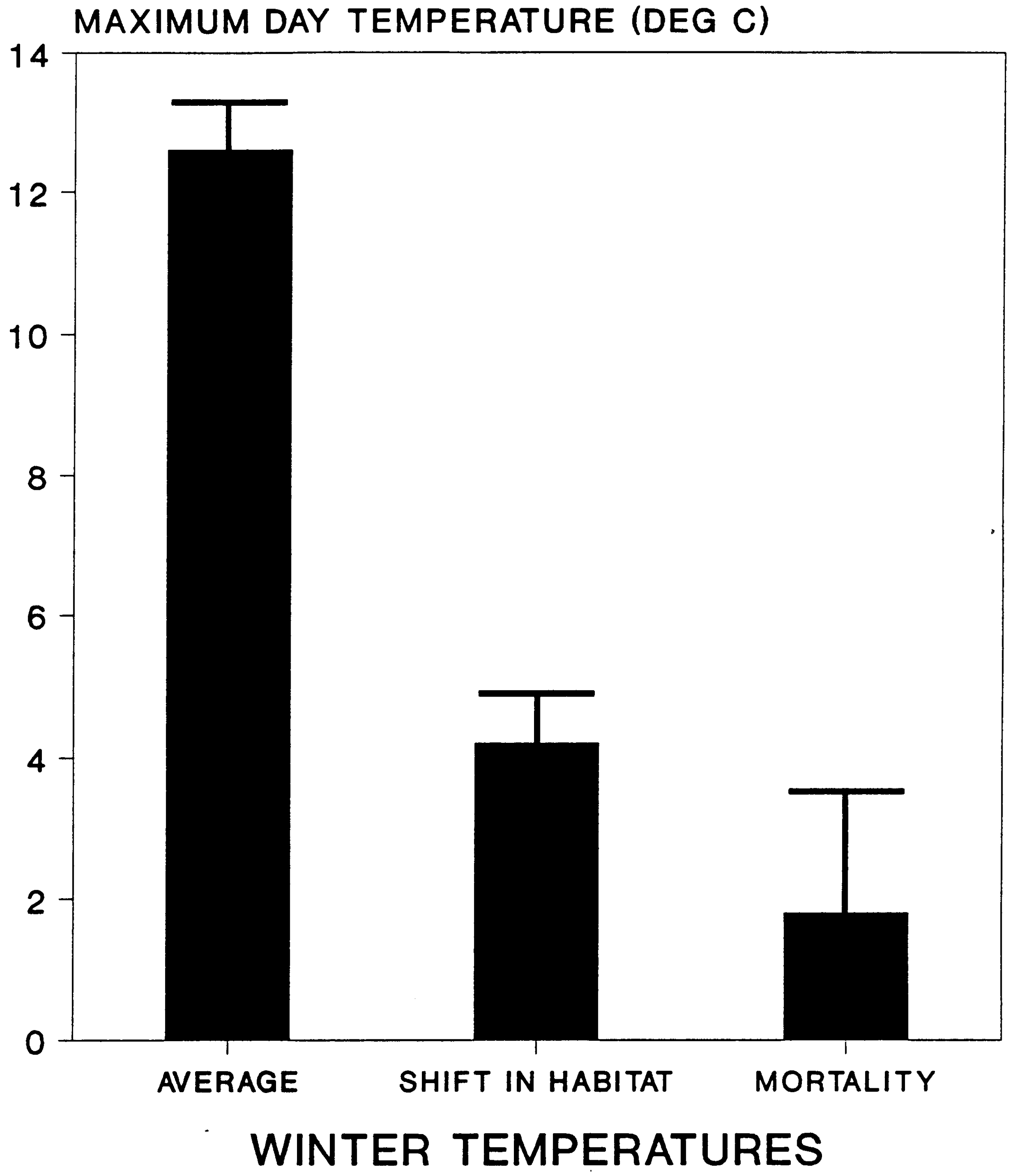

Figure 14. Mean daytime (maximum) temperatures and standard errors during the winter in the Shenandoah Valley.

CONCLUSION

Loggerhead shrike populations have been declining throughout their North American range and have been most affected along the eastern portion of their range. Novak (1989) reported that a viable breeding population no longer exists in New York and predicted that loggerhead shrikes are soon to be extirpated from the state. The high reproductive success reported for shrikes shows that mortality outside the breeding period may be responsible for the dramatic decline rates. Researchers have suggested that high postfledging mortality and low overwinter survival (as indicated by the low return rates for banded birds) may be limiting population growth. I have identified factors that affect mortality rates during the breeding season, fall dispersal, and winter that may be contributing to the decline of loggerhead shrike populations.

Reproductive success for loggerhead shrikes in Virginia was similar to that reported by other researchers. However, success was influenced by grass height and bare soil area. Reproductive success was highest in habitats with numerous bare soil areas and success rates during the nestling stage were higher in medium grass habitats than in short grass. These habitats may provide shrikes with greater invertebrate abundance and availability than other habitat types. These results support Luukkonen's (1987) hypothesis that shrike productivity may be limited by food in Virginia.

Survival rates were high during the fall period in the Shenandoah Valley. Typically, fall home-range areas contained numerous bare soil areas and medium grass height; these habitats may provide shrikes with high prey accessibility and abundance. With good reproductive success and high survival during the dispersal stage, it is likely that shrike habitat occupancy would be highest during the fall. I observed that fall home-range areas often were adjacent to other shrike areas and it is likely that some birds were forced into suboptimal habitats (i.e., areas with reduced prey availability) by more dominant shrikes. Poor foraging success by birds in suboptimal habitats during the fall may negatively affect winter survival.

Loggerhead shrike survival rates were lowest during the winter for all ages and sexes; raptor predation was the primary cause of mortality and road-kill was secondary. During the winter, when invertebrates become less accessible, shrikes moved from pasture habitats to shrub-forest habitats and preyed on small birds. A lack of adequate shrub-forest habitat may cause shrikes to travel large distances to obtain prey, thereby increasing energy requirements, vulnerability to raptor predation, and the probability of collision with automobiles. Also, a reduction of shrub-forest habitats would increase the probability that raptors and shrikes have overlapping forage areas, thus, increasing the shrikes' risk of predation.

Because loggerhead shrikes inhabit farmland areas and prey on invertebrates and some vertebrates, they risk exposure to pesticide contamination. Low levels of organochlorines and organophosphates were detected in all birds analyzed for pesticide contamination and, although the effects of contamination are unclear, it is unlikely that pesticide contamination contributes to the population decline in my study area.

Data from radio-harnessed and banded shrikes show that the breeding population in Virginia overwinter in this state and therefore, could be greatly affected by land-use changes. Pasture rotation (altering grass heights and bare soil areas), grasslands converted to woodland habitat or rowcrops, removal of hedgerows, and housing developments may reduce the amount of optimal breeding habitat and, likewise, affect the habitat that would provide food and shelter for winter survival. Extensive hedgerows might support small birds and mammals, but allow greater dispersion and, therefore, fewer encounters with Cooper's hawks and other predators.

Besides land-use changes, wet springs and harsh winters can reduce prey availability; it is the combination of these events that may have detrimental affects to shrikes' survival.

Little is known about shrike ecology outside the breeding period. Future research should be conducted to 1) determine habitat use and availability during the winter, 2) study the effects of hedgerow and shrub-forest habitat on loggerhead shrike survival, 3) determine whether movements to shrub-forest habitats are prey-driven by designing and conducting controlled feeding experiments, and 4) document mortality differences from year to year to determine the effects of variable winter weather.

Because it was recently placed on Virginia's Endangered Species List, information regarding the status and habitat requirements of loggerhead shrikes should be provided to landowners and especially to farmers. Management agencies should provide information that would promote the benefits of hedgerow habitat to wildlife species and encourage hedgerow management practices. Education may help retain hedgerow and shrub areas around pastures and benefit not only shrikes, but many other wildlife species. In addition to State listing, I recommend that loggerhead shrikes be placed on the Federal Threatened Species List to insure range-wide protection.

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APPENDIX 1: SEXING AND AGING OF LOGGERHEAD SHRIKES BY DISCRIMINANT ANALYSIS OF MORPHOMETRIC CHARACTERS

INTRODUCTION

Several attempts to sex and age loggerhead shrikes (*Lanius ludovicianus*) based on external characters have been only moderately successful. Miller (1931) examined museum skins and reported overlapping linear measurements and similarities in plumage color between ages and sexes. Pyle et al. (1987) developed criteria for age discrimination of loggerhead shrikes based on plumage characteristics alone. Although an incomplete prebasic molt identifies loggerhead shrikes as subadults, a complete molt does not reliably identify the bird as an adult (Miller 1931, Pyle et al. 1987, pers. obs.). I am unaware of any studies beyond Miller (1931) that distinguish the sexes and ages of loggerhead shrikes using morphometric measurements. The purpose of this article is to identify those morphological characteristics that distinguish shrikes by age and sex and to present models to separate age and sex classes using linear measurements taken on live birds.

METHODS

I captured and banded 95 loggerhead shrikes (*L. l. ludovicianus*) from April 1987 to May 1988 in the Shenandoah Valley of Virginia. Birds were captured using bal-chatri and potter traps baited with house mice (*Mus musculus*) or zebra finches (*Poephila guttata*). All birds were fitted with U.S. Fish and Wildlife Service aluminum leg bands and a unique color combination of plastic bands (A. C. Hughes, Hampton Hill, Middx.).

Nine linear measurements were recorded for each bird following techniques of Baldwin et al. (1931): 1) tail length, from the distal end of the uropygial gland to the tip of the longest rectrix; 2) wing chord, from the wrist to the tip of the wing, with the wing unflattened and flexed at the wrist; 3) bill length, from the anterior margin of the nares to the tip of the upper mandible; 4) bill width, from the outside edges of the bill opposite the anterior end of the nares, with mandibles closed; 5) bill depth, the greatest dorso-ventral distance at the nares, with mandibles closed; 6) tail white, for the length of white on the inner web of the distal end, on the outermost rectrix 6, rectrix 5, and rectrix 4; and 7) tarsus length, with the leg flexed, from the middle point of the joint between the tibia and metatarsus to the distal edge of the last scale that completely encircles the dorsal surface of the foot. All measurements were taken to the nearest 0.05 cm with calipers except tail length and white and wing chord, which were measured with a flat ruler and a wing chord measurer (Chris N. Rose, Cedar Grove, NJ), respectively.

Sex was identified during the breeding season from 1) the presence of a cloacal protuberance or brood patch, 2) behavioral observations, (i.e., singing by males, incubation by females, or a male carrying food to a begging female), and 3) postmortem examinations. Age was identified from 1) known hatch dates, 2) juvenal plumage, 3) incomplete prebasic molt, and 4) postmortem examination to reveal skull pneumitization.

Birds with known ages were grouped into three classes: 1) juveniles, birds before their prebasic molt; 2) subadults, birds typically classified as hatch year or second year; and 3) adults, birds typically classified as after-hatch year or after-second year. Juveniles were omitted in the data set because plumage characteristics easily identified this age class ($N = 23$).

All morphometric variables were checked for normality. T-tests were used to test the equality of means of the nine variables between ages (subadult and adult) and sexes. I compared morphometric variation between males ($N = 22$) and females ($N = 20$), and between subadults ($N = 32$) and adults ($N = 6$). Stepwise discriminant analysis procedure with forward selection was initially used to determine which variables were most significant in distinguishing ages and sexes (PROC STEPDISC; SAS Inst. 1985). I then examined combinations of these variables to determine if linear discriminant equations could be derived. Final model selection was based on variables meeting the assumptions necessary to estimate linear discriminant functions, and the variables that provided the highest correct classification.

I was unable to validate the models because the number of birds with known sexes and ages was so small that reserving any portion of them for validation would have endangered model development while providing only a weak validation test. Small sample sizes also precluded investigation of morphometric variation within a known age/sex cohort. However, I used two-way multivariate analysis of variance (MANOVA) to determine if overall external morphology of shrikes varied with age or sex.

RESULTS

Age

Based on univariate analysis adult shrikes had longer wings ($P = 0.0003$) and tails ($P = 0.0025$) than subadults (Table 13). In distinguishing age classes, wing chord had the greatest discriminating power. The linear function correctly classified 87.5% of the subadult birds and 66.7% of the adults. For wing measurements > 9.62 cm, birds were classified as adults, and less than 9.62 cm as subadults; age was indeterminate for wing measurements of 9.62 cm.

Sex

Univariate analyses also suggested that males were larger than females for all morphological characters ($P < 0.008$) except tarsus length ($P = 0.0542$), bill depth ($P = 0.0626$) and bill width ($P = 0.7937$, Table 14).

Discriminant analysis revealed that the length of the wing and tail white on rectrix 5 (hereafter called white) were good predictors of sex and that the covariance matrix of these variables met the assumption of homogeneity critical to deriving linear discriminant functions. Therefore, the pooled covariance matrix was used to develop discriminant functions (Table 15).

To determine the combinations of wing chord and white that identify either sex, it is necessary to define the relationship between these two variables. This relationship is obtained by setting equation 1 equal to equation 2 and solving for 1 variable (Table 15). Figure 15 illustrates the relationship between wing chord and white. The line represents the combinations of wing chord and white for which sex is indeterminate. For combinations of wing chord and white falling to the left of the line, birds are classified as females, and to the right as males. The model correctly classified 88.2% of the females and 93.3% of the males.

Interactions

The results of MANOVA provided no evidence for interaction between sex and age ($F = 0.19$, df = 2,26, $P > 0.8311$). This implied that age effects were similar for both sexes, and supported the use of separate models for distinguishing ages and sexes.

DISCUSSION

Model results indicate that morphological measurements can be used to identify the sex and age of loggerhead shrikes. Although wing chord alone showed the most discriminating power between ages, wing chord and tail white on rectrix 5 provided strong discrimination between sexes. Alatalo et al. (1984) and Smith et al. (1986) also found significant differences in wing chord between ages in great tits (*Parus major*), collared flycatchers (*Ficedula albicollis*), coal tits (*Parus ater*), dunnocks (*Prunella modularis*), and song sparrows (*Melospiza melodia*). Differences in tail white and wing chord between sexes have been reported by Dohmann (1980) and Miller (1931) for great grey shrikes (*Lanius excubitor*) and loggerhead shrikes.

The most accurate identification of sex can be made during the breeding period when males and females can be identified by behavioral differences. Likewise, subadults are most accurately aged by an incomplete prebasic molt. Therefore, I recommend model application only when these conditions do not exist.

Table 13. Age variation in size for loggerhead shrikes (mean and standard error).

	Subadults			Adults			
Variable[1]	N	Mean	SE	N	Mean	SE	P-value
Tail white							
Rectrix 6	25	3.63	0.16	5	4.38	0.51	0.0855
Rectrix 5	25	2.82	0.12	5	3.38	0.27	0.0711
Rectrix 4	25	1.88	0.09	5	2.30	0.18	0.0677
Tail length	31	9.62	0.06	5	10.12	0.14	0.0025
Wing chord	32	9.41	0.04	6	9.83	0.11	0.0003
Bill length	32	1.26	0.02	6	1.33	0.06	0.1724
Bill depth	31	0.93	0.01	6	0.96	0.08	0.7728
Bill width	32	0.67	0.01	6	0.72	0.05	0.4084
Tarsus length	32	2.53	0.02	6	2.58	0.07	0.4709

[1] Measurements in cm.

Table 14. Sex variation in size for loggerhead shrikes (mean and standard error).

	Males			Females			
Variable[1]	N	Mean	SE	N	Mean	SE	P-value
Tail white							
Rectrix 6	17	4.20	0.16	15	3.25	0.13	0.0001
Rectrix 5	17	3.36	0.12	15	2.61	0.15	0.0004
Rectrix 4	17	2.10	0.11	15	1.64	0.12	0.0076
Tail length	20	10.17	0.05	20	9.60	0.09	0.0001
Wing chord	21	9.83	0.04	20	9.45	0.05	0.0001
Bill length	22	1.32	0.02	20	1.23	0.01	0.0021
Bill depth	22	0.97	0.03	20	0.92	0.01	0.0626
Bill width	22	0.67	0.02	20	0.66	0.01	0.7937
Tarsus length	22	2.58	0.02	20	2.52	0.02	0.0542

[1] Measurements in cm.

Table 15. Linear discriminant functions for distinguishing between female and male loggerhead shrikes in the Shenandoah Valley of Virginia.

Variables	Wing chord (wing) Tail white rectrix 5 (white)	
Models	Equation 1 = -1000.0644 + 22.9242 (white) + 196.1269 (wing) Equation 2 = -913.1905 + 19.8481 (white) + 188.0513 (wing)	
Sex determination	Equation 1 > Equation 2 = male Equation 2 > Equation 1 = female Equation 1 = Equation 2 = indeterminate	
% cases correctly classified	male = 93.33	female = 88.24

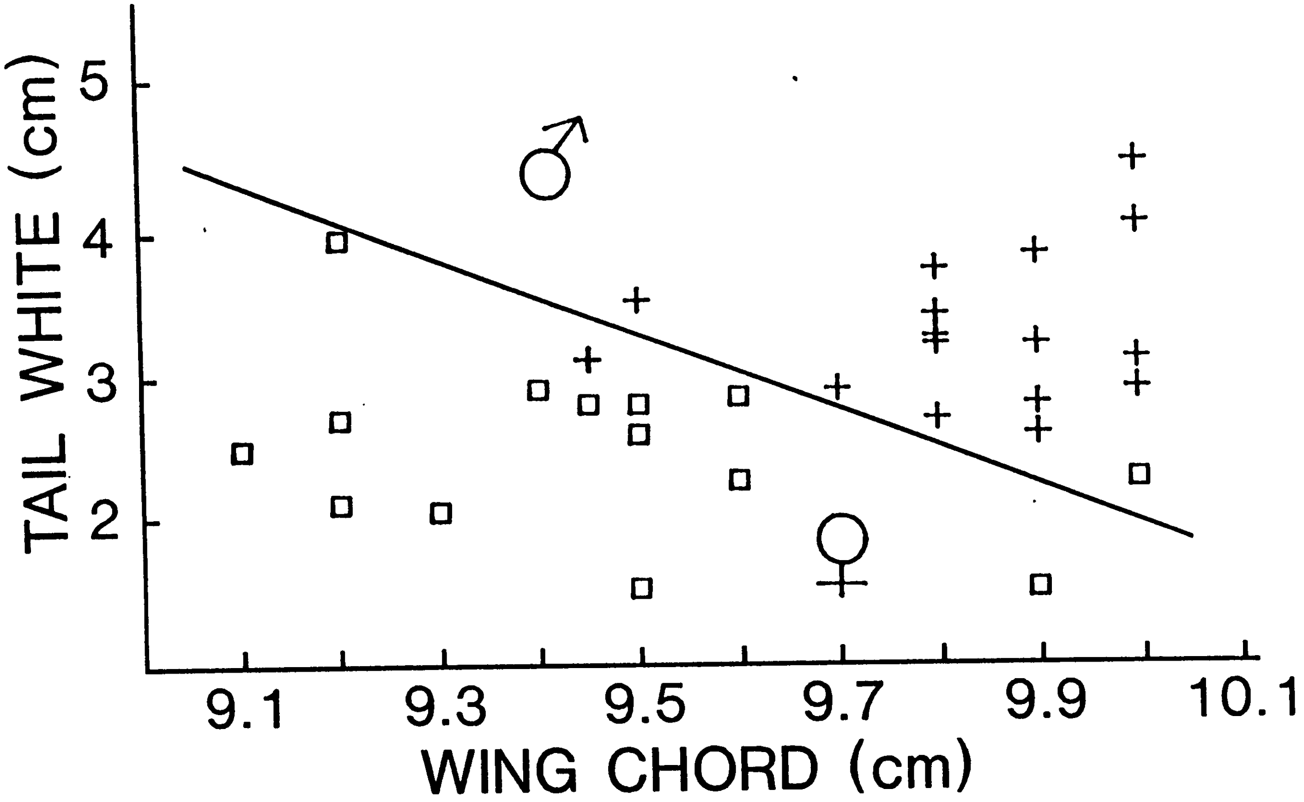

Figure 15. Relationships between wing chord and tail white (rectrix 5) in loggerhead shrikes. The line represents the discriminant function for both sexes.

APPENDIX 2: PESTICIDE AND PCB RESIDUES FOR LOGGERHEAD SHRIKES IN THE SHENANDOAH VALLEY, VIRGINIA, 1985-88

INTRODUCTION

The decline in loggerhead shrike (*Lanius ludovicianus*) populations is widespread and coincides with the use of organochlorines that began in the late 1940's and increased until the 1970's (Morrison 1981, Robbins et al. 1986, Tate 1986). An inhabitant of farmland areas, loggerhead shrikes prey on invertebrates and small vertebrates (Bent 1950), and thus risk exposure to pesticides and other agricultural chemicals. The role of contaminants in the decline of loggerhead shrikes has only been partially assessed. Studies report that organochlorines have been found in high concentrations in some shrikes, reduce eggshell thickness, and inhibit behavioral development of young (Busbee 1977, Anderson and Duzan 1978, Morrison 1979, Rudd et al. 1981).

Studies of the nesting and winter ecology of loggerhead shrikes (Luukkonen 1987, this study) during 1985-88 in the Shenandoah Valley, Virginia provided the opportunity to collect eggs and carcasses for contaminant residue analysis. In this paper I provide pesticide and polychlorinated biphenyl (PCB) residue data for eggs and carcasses collected.

MATERIALS AND METHODS

From 1985 through 1987 I removed eggs from 8 nests that had been abandoned during the incubation stage or had failed to hatch. The nests were located in Highland, Augusta, Rockingham and Shenandoah counties in northwest Virginia. The egg contents from each nest were combined and placed in acetone-rinsed glass jars, frozen and stored at -20°C before chemical analysis.

Egg contents collected in 1985-86 ($N = 18$) were shipped to Weyerhauser Analytical and Testing Services, Tacoma, Washington for chemical residue analysis under quality assurance from Patuxent Wildlife Research Center, Laurel, Maryland. Egg samples were homogenized, extracted in a Soxhlet apparatus, and cleaned on a Florisil column. Pesticides and PCBs were fractionated on a Silicar column (Cromartie et al. 1975). Samples were analyzed on a Hewlett-Packard 5880A gas chromatograph (GC) equipped with dual capillary column/dual electron-capture detectors (ECD) used for organochlorine and PCB analysis. Residue confirmation on the sample containing 26.00 ppm pp′-DDE was done using GC/mass spectrometry.

Eggs collected in 1987 ($N = 12$) were sent to the Pesticide Residue Lab, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Egg contents were analyzed for pesticides and PCBs using procedure described by Bertuzzi et al. (1967). Thawed samples were homogenized, extracted on a Polytron Ultrasonic Generator Model PCU-1 using 65% acetonitrile/water. The pesticides were extracted from the acetonitrile/water using petroleum ether (PE) liquid/liquid partitoning with sample clean-up on a Florisil column. The samples were eluted from the Florisil column with 6% ethyl ether (EE)/PE, 15% EE/PE and 50% EE/PE, respectively. Egg contents were analyzed, on a wet weight basis, using a Tracor 540 GC equipped with ECD and 1219 mm x 2 mm glass column packed with 5% OV-101 on 80/100 mesh Supelcoport.

Seven shrikes, equipped with radio transmitters, died between October 1987 and March 1988 in Augusta and Rockingham counties. Specimens were taken to The Wildlife Center of Virginia, Weyers Cave, Virginia, and necropsies were performed. Histological examinations were performed at John Hopkins University Medical School, Department of Comparative Medicine, Baltimore, Maryland.

Following necropsy, liver, kidney, and brain were removed and placed in individually labeled polyethylene bags and frozen. Pesticide analyses, using procedure described by Bertuzzi et al. (1967), were conducted by the Pesticide Residue Lab, Blacksburg, Virginia. Tissues from birds were analyzed using a Tracor 540 equipped with ECD and 1829 mm x 4 mm column packed with 1.5% SP-2250/1.95% SP-2401 on 100/120 mesh Supelcoport. Samples were analyzed for carbofuran using a Tracor 540 GC equipped with a 1.5% OV-17/1.95% OV-210 column on 100/120 mesh Chromosorb. All results are reported in parts per million (ppm) wet weight.

RESULTS AND DISCUSSION

Oxychlordane and pp′-DDE were present in all samples (Table 16). Residues of pp′-DDE varied almost 600% between the 8 clutches: 26.00, 2.30, 1.63, 1.40, 1.24, 0.57, 0.55, and 0.46 ppm. The highest pp′-DDE residue (26.00 ppm) was detected in a 5-egg clutch abandoned less than 7 days after laying in Augusta County, in 1985. Anderson and Duzan (1978) collected 104 shrike eggs in southern Illinois and reported pp′-DDE residues averaging 3.09 ppm; one clutch had a mean of 17.00 ppm. The authors concluded that eggshell thickness had been adversely affected by pp′-DDE residues.

In this study, 63% of the samples contained detectable residues of heptachlor epoxide, pp′-DDD, methoxychlor, dieldrin, hexachlorobenzene, mirex, trans-nonachlor, and PCB (arochlor 1260, Table 1). Except for PCB, residue levels were below 0.12 ppm. Eggs collected in 1985 and 1986 contained levels of PCB ranging from 0.24 to 1.30; however, PCB was not detected in samples collected in 1987. This may reflect differences in analytical laboratories or actually show a decrease in PCB concentrations.

Necropsies of 7 loggerhead shrikes found no abnormalities that would suggest pesticide or PCB contamination. Mortalities were attributed to collisions with automobiles ($N=4$), predation by raptors ($N=2$), and complications caused by radio transmitter attachment ($N=1$). Histological results were consistent with necropsy conclusions.

Residues of pp′-DDE occurred in all carcass samples (Table 16). An adult male contained 0.07 ppm and 6 subadults contained 2.03, 0.81, 0.33, 0.09, 0.06, and 0.03 ppm. Anderson and Duzan (1978) showed median concentrations of 13.88 ppm pp′-DDE to be present in 88% of 69 shrikes examined from southern Illinois. When samples of fat were analyzed from birds collected during September and January the median level pp′-DDE detected for 7 adult females was 2.38 ppm (range <0.01-66.60), 10 adult males contained 3.31 ppm (range <0.01-28.57), and 3 subadults contained <0.01 ppm (range <0.01-33.33). However, higher levels of pp′-DDE were detected in shrikes collected during April and July (local breeders and their young); 23 adult females contained 15.00 ppm (range 3.07-75.00), 18 adult males contained 26.39 ppm (range <0.01-150.00), and 8 subadults contained 9.25 ppm (range 5.45-33.33). These results show that Illinois breeders may be obtaining most of their DDE body burden south of Illinois on their wintering areas.

Other organochlorines detected in the order of percent frequency were; op′-DDE, lindane, op′-DDT, mirex, oxychlordane, and pp′-DDT. The frequency of detection for other compounds was less than 50%. Organophosphates were detected in 43% of the tissue samples (Table 16).

Twelve of 18 (67%) organochlorines detected in eggs occurred in bird tissue samples (Table 1). However, there was no significant relationship between residue levels in eggs and bird tissues (Spearman rank correlation, $R = 0.31$, $P = 0.1906$). This may be due to the fact that egg clutches were not analyzed from the same nests of birds analyzed.

In this study, loggerhead shrikes contain appreciable levels of pesticide residues; the pp′-DDE level in one clutch was critically high. The effects of contamination on this species, as well as other wildlife, is unclear, primarily because the pesticide concentrations required to reduce populations are unknown. Loggerhead shrike populations in Virginia have declined to a level that has justified this species being added to the State Endangered Species List in 1987.

Table 16. Residues of organochlorine, organophosphate, and carbamate pesticides and PCB in eggs from 8 clutches[1] and tissue samples[2] from 7 loggerhead shrikes from the Shenandoah Valley, VA, 1985-88.

	Residues, ppm wet weight					
	Eggs			Birds		
Compound	Percent Freq. of Detection	Median[3]	Range	Percent Freq. of Detection	Median	Range
ORGANOCHLORINES						
oxychlordane	100	0.06	0.02-0.10	57	0.03	0.01-0.05
op-DDE	38	0.04	0.02-0.05	86	0.09	0.02-0.25
pp-DDE	100	1.37	0.46-26.00	100	0.09	0.06-2.03
op-DDT	25	0.03	0.02-0.04	71	0.03	0.01-0.21
pp-DDT	50	0.10	0.05-0.43	57	0.04	0.01-0.29
pp-DDD	63	0.05	0.01-0.11	0		
heptachlor	13	0.01		29	0.01	
heptachlor epoxide	63	0.02	0.01-0.03	29	0.01	
methoxychlor	63	0.07	0.01-0.10	0		
endrin	13	0.02		14	0.04	
dieldrin	63	0.02	0.01-0.05	14	0.01	
hexachlorobenzene	63	0.02	0.01-0.03	14	0.01	
mirex	63	0.04	0.01-0.04	71	0.12	0.02-0.14
lindane	38	0.02	0.01-0.04	86	0.02	0.01-0.08
cis-nonachlor	50	0.01		0		
trans-nonachlor	63	0.02	0.01-0.02	0		
alpha chlordane	0			14	0.02	
beta chlordane	0			14	0.08	
cis-chlordane	13	0.01		0		
trans-chlordane	23	0.01		0		
ORGANOPHOSPHATES						
dursban	0			29	0.02	0.01-0.03
diazinon	0			29	0.15	0.09-0.20
ethyl parathion	0			43	0.20	0.18-0.23
CARBAMATES						
carbofuran	0			14	0.64	
PCB						
arochlor 1260	63	0.94	0.24-1.30	0		

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[1] Clutch = 2 to 6 eggs (mean = 3.75 eggs).

[2] Tissues = kidney, liver, and brain.

[3] Median is based on detectable residue samples ($\geq$ 0.005 ppm wet weight).