The Auk 111(3):756–759, 1994

Habitat-specific Nutritional Condition in Loggerhead Shrikes (*Lanius ludovicianus*): Evidence from Ptilochronology

THOMAS C. GRUBB, JR.[1] AND REUVEN YOSEF[1,2,3]

[1]*Behavioral Ecology Group, Department of Zoology, Ohio State University, Columbus, Ohio 43210, USA; and*

[2]*Archbold Biological Station, Lake Placid, Florida 33852, USA*

Over much of North America, the density of Loggerhead Shrikes (*Lanius ludovicianus*) has been steadily declining for much of the 20th century (see references in Yosef and Grubb 1992). Even populations formerly thought to be strongholds of the species (Droege and Sauer 1990) have recently been losing ground at 5 to 10% per year (Tyler 1992, Yosef 1992). Although several causal factors for the decline have been implicated (e.g. H. M. Hands, R. D. Drobney, and M. R. Ryan unpubl. report), attention has recently focused on modern agricultural practices involving either habitat destruction or introduction of herbicides and insecticides (e.g. Anderson et al. 1978, Yosef and Grubb 1992). Despite considerable recent attention to the species, little is known about the possible effects of human-modified habitats on this shrike's survival and fecundity. Here, we report evidence that nutritional condition in Loggerhead Shrikes resident in south-

[3] Present address: International Ornithological Center, P.O. Box 774, Eilat, 88000, Israel.

central Florida may be habitat specific. Our results suggest that pastures and citrus groves, respectively, may be superior and marginal habitats for the species.

We assumed that the nutritional condition of shrikes could be assessed with the technique of ptilochronology (Grubb 1989). Recognizing that each growth bar on a feather represents 24 h of growth (Brodin 1993), this technique uses the width of growth bars as an index of a bird's nutritional condition at the time the feather was being grown. The wider the growth bars, the better the nutritional condition (see Grubb 1992). Substantial experimental evidence indicates that growth-bar width is a function of a bird's nutritional condition at the time the feather was being grown (Grubb and Cimprich 1990, Waite 1990, Grubb 1991, White et al. 1991). Although Murphy and King (1991) did not measure growth-bar width, they found that daily feather growth was reduced in White-crowned Sparrows (*Zonotrichia leucophrys*) maintained on deficient diets. Despite these findings from other passerines, no experimental evidence indicates that growth-bar width reflects dietary adequacy in Loggerhead Shrikes. For our study, therefore, we assumed that growth-bar width is a valid indicator of nutritional condition in this species. The assumptions and utility of ptilochronology have been discussed further in Murphy and King (1991), Grubb (1992), and Murphy (1992).

Methods.—During March and April of 1992 and 1993, we live-trapped shrikes along 524 km of roadway through Charlotte, DeSoto, Hardee, Highlands, Glades, and Okeechobee counties, Florida. The habitat in the vicinity of each capture site was recorded as: (1) built-up urban, (2) palmetto scrub, (3) citrus, or (4) fenced pasture. At every capture site, the habitat was the same on both sides of the road. Before releasing each bird at the capture site, we determined age and sex, recorded tarsus length, and pulled and stored the right fourth (R4) rectrix. Growth bars are most easily discerned on feathers that are not pied or marked by pigment bars. While previous studies have used the outermost (sixth) rectrix, in Loggerhead Shrikes the fourth rectrix is the outermost that is predominantly monochromatic.

For each feather we measured: (1) mean width of 10 growth bars centered on a point two-thirds the distance from the proximal end of the feather (Grubb 1989); (2) total length; and (3) mass. Feathers were coded by R.Y. so that T.C.G. could measure them in a "blind" fashion without knowing from which of the four habitat types they had been taken.

We restricted analysis to feathers from birds known to be adults (after-second-year [ASY] birds at time of capture). Shrikes in southern Florida appear to spend their entire adult lives on the same territory (Yosef 1992). Therefore, we assumed that the feathers we collected from adults had been grown at the same site during the prebasic molt of the previous autumn. However, as second-year (SY) birds could have grown their R4 rectrix in a different habitat before dispersing to the site where we caught them, we omitted their rectrices from the analysis.

TABLE 1. *F*-statistics from general linear models for characteristics of R4 rectrix ($n = 64$) of Loggerhead Shrikes resident in south-central Florida.

Feather variable	Covariate: Tarsus length	Factor: Year	Factor: Sex	Factor: Habitat
Growth-bar width (mm)	1.77	0.40	5.97*	5.90***
Total length (mm)	0.17	0.26	0.43	2.11
Mass (mg)	0.36	0.80	0.88	5.19**

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; others not statistically significant ($P > 0.05$).

Analyses used general linear-regression models (GLM; Cohen and Cohen 1983, Anonymous 1991). Following GLM procedure with qualitative variables, we used *t*-test comparisons of regression coefficients between each habitat group and the mean of all habitat groups (Neter et al. 1989). Such a procedure allowed us to avoid the loss of statistical power resulting from correcting for experimentwise error (Anonymous 1991). Using standard analysis of residuals, we determined that our data met the assumptions for using GLM models (Cohen and Cohen 1983, Neter et al. 1989). Statistical significance was accepted at the 0.05 probability level. Birds of different size could have grown feathers at different rates during the molt, resulting in differences among R4 rectrices unrelated to sex or habitat type. We controlled for bird size by entering tarsus length as a covariate in our models. Finally, we checked for variation between 1992 and 1993 by including year as a factor.

Results.—The total length of the R4 rectrix was not significantly related to tarsus length, year, sex, or habitat type (Table 1). Daily growth ($P = 0.001$) and total mass ($P = 0.003$) of the feather, however, were both significantly related to habitat type, but not to tarsus length or year. Daily growth, but not total mass, was significantly related to sex ($P = 0.018$). Feathers of birds in citrus groves differed significantly in both growth-bar width and mass from the mean values of all four habitat types (Table 2). The *t*-values and the adjusted means in Table 2 indicate that the rectrices of shrikes in citrus groves grew less each day and were less massive when fully grown than the average rectrix from all four habitats. By contrast, rectrices from shrikes in pastures were longer, were heavier, and had wider growth bars than the average for the four habitats (Table 2). Growth-bar width, total length, and total mass of rectrices from urban or scrub habitats were not statistically different from the mean values for all four habitats (Table 2).

TABLE 2. General-linear-model comparisons of each of four habitat types with mean of four habitat types for characteristics of R4 rectrix of Loggerhead Shrikes resident in south-central Florida. $\bar{x} \pm SD$, with t-value in parentheses.

Feather variable	Habitat type			
	Urban ($n = 16$)	Scrub ($n = 10$)	Citrus ($n = 14$)	Pasture ($n = 24$)
Growth-bar width (mm)	3.50 ± 0.05 (1.08)	3.45 ± 0.06 (0.07)	3.28 ± 0.05 (−3.66***)	3.56 ± 0.04 (2.52*)
Total length (mm)	98.54 ± 0.83 (0.03)	97.93 ± 1.04 (−0.69)	97.51 ± 0.86 (−1.37)	100.09 ± 0.68 (2.09*)
Mass (mg)	28.88 ± 0.52 (−0.36)	28.54 ± 0.66 (−0.94)	28.13 ± 0.54 (−1.99*)	30.64 ± 0.43 (3.47***)

*, $P < 0.05$; ***, $P < 0.001$; others not statistically significant ($P > 0.05$).

Discussion.—Taken together, our findings suggest that in each of two years something about pastures and citrus groves, respectively, improved and worsened nutritional condition in molting resident shrikes. However, at least one other explanation must be considered. The birds in pastures and citrus groves, respectively, could have been of high and low quality to begin with, perhaps having been imprinted on these habitats while raised there, or having taken up residence in the two habitats because of social status. Thus, the robust feather growth in pastures and the poor growth in citrus groves could have depended on the individual birds rather than the habitat. As evidence against this explanation, however, we note that shrikes in pastures or citrus groves were not unusual in size. For example, tarsus length was not related to habitat type ($F = 0.370$, $P = 0.774$).

Assuming that the rate of feather growth in pastures and citrus groves was affected by habitat type rather than bird quality, its causation could have been direct, indirect, or both. In central Florida, shrike populations are densest in pastures, which suggests that short grass and abundant fence-post hunting perches together provide superior foraging habitat and consequent excellent nutrition for the species (Yosef 1992).

In Florida, citrus is routinely sprayed during the autumn with mitacide/insecticide compounds (T. Hurner pers. comm.) known to be toxic to nontarget organisms (Hayes and Laws 1991). Such chemicals could have had a chronic, sublethal effect on shrikes sufficient to retard feather growth. Alternatively, application of mitacide/insecticides in the groves could have reduced the shrikes' food supply, thereby reducing the birds' nutritional condition sufficiently to be detectable using ptilochronology. Also, it seems possible that nutritional condition could have been lowered by direct and indirect effects of citrus-grove management practices. While it may be of interest to separate the two classes of causation experimentally, it seems clear that feeding rates (cf. Yosef and Grubb 1992), induced feather growth (Grubb 1989), survivorship, and fecundity of shrikes living in citrus groves should be examined.

Ptilochronology may be useful for evaluating the influence of various natural and disturbed habitats on the nutritional condition of free-ranging birds. As revealed by our study, daily growth-bar width appears to be the most sensitive of the three indices investigated. Total feather length and feather mass could be less sensitive because their values change with feather wear through time, particularly in highly abrasive environments such as the sand ridges occupied by the shrikes we studied. By contrast, feather wear cannot affect the width of daily growth bars.

Acknowledgments.—We thank Susan L. Earnst, Robert A. Mauck and Vladimir V. Pravosudov for technical assistance. Comments by E. Dale Kennedy, Michael L. Morrison, Reed F. Noss, Peter R. Stettenheim, Philip C. Stouffer, and Douglas White improved earlier drafts of the manuscript. This report is contribution no. 22 of The MacArthur Agro-ecology Research Center, Archbold Biological Station.

LITERATURE CITED

ANDERSON, W. L., AND R. E. DUZAN. 1978. DDE residues and eggshell thinning in Loggerhead Shrikes. Wilson Bull. 90:215–220.

ANONYMOUS. 1991. Minitab reference manual. Release 8. Minitab, State College, Pennsylvania.

BRODIN, A. 1993. Radio-ptilochronology: Tracing radioactively labelled food in feathers. Ornis Scand. 24:167–173.

COHEN, J., AND P. COHEN. 1983. Applied multiple regression/correlation analysis for the behavioral sciences, 2nd ed. Lawrence Erlbaum Associates, Hillside, New Jersey.

DROEGE, S., AND J. R. SAUER. 1990. North American breeding bird survey annual summary, 1989. U.S. Fish Wildl. Serv. Biol. Rep. 90.

GRUBB, T. C., JR. 1989. Ptilochronology: Feather growth bars as indicators of nutritional status. Auk 106:314–320.

GRUBB, T. C., JR. 1991. A deficient diet narrows growth bars on induced feathers. Auk 108:725–727.

GRUBB, T. C., JR. 1992. Ptilochronology: A consideration of some empirical results and "assumptions." Auk 109:673–676.

GRUBB, T. C., JR., AND D. A. CIMPRICH. 1990. Supplementary food improves the nutritional con-

dition of wintering woodland birds: Evidence from ptilochronology. Ornis Scand. 21:277–281.

HAYES, W. J., JR., AND E. R. LAWS, JR. (Eds.). 1991. Handbook of pesticide toxicology. Vol. 3, Classes of pesticides. New York, Academic Press.

MURPHY, M. E. 1992. Ptilochronology: Accuracy and reliability of the technique. Auk 109:676–680.

MURPHY, M. E., AND J. R. KING. 1991. Ptilochronology: A critical evaluation of assumptions and utility. Auk 108:695–704.

NETER, J., W. WASSERMAN, AND M. H. KUTNER. 1989. Applied linear regression models, 2nd ed. Irwin, Homewood, Illinois.

TYLER, J. D. 1992. Nesting ecology of the Loggerhead Shrike in southwestern Oklahoma. Wilson Bull. 104:95–104.

WAITE, T. A. 1990. Effects of caching supplemental food on induced feather regeneration in wintering Gray Jays *Perisoreus canadensis*: A ptilochronology study. Ornis Scand. 21:122–128.

WHITE, D. W., E. D. KENNEDY, AND P. C. STOUFFER. 1991. Feather regrowth in female European Starlings rearing broods of different sizes. Auk 108: 889–895.

YOSEF, R. 1992. Territoriality, nutritional condition and conservation in Loggerhead Shrikes (*Lanius ludovicianus*). Ph.D. dissertation, Ohio State Univ., Columbus.

YOSEF, R., AND T. C. GRUBB, JR. 1992. Territory size influences nutritional condition in non-breeding Loggerhead Shrikes: A ptilochronology approach. Conserv. Biol. 6:447–449.

Received 15 September 1993, accepted 2 February 1994.