

# PTILOCHRONOLOGY: A POTENTIAL BIOMARKER FOR ASSESSING TERRITORY QUALITY AND HABITAT SUITABILITY IN SHRIKES

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**ABSTRACT.**— Concern based on reports of declining shrike populations around the world has prompted a search for new methods to evaluate habitat suitability for shrikes. North American populations of the Loggerhead Shrike (*Lanius ludovicianus*) have undergone a precipitous reduction during recent decades. Among hypothesized causes for the decline is the loss of feeding and nest sites because modern agricultural practices have removed fencerows. We examined the hypothesis that territory size and habitat suitability affect the nutritional condition, and therefore possibly the local densities, of shrikes using ptilochronology, which measures the width of daily growth bars on feathers as an index of nutritional condition. Ptilochronology demonstrated that shrikes defending smaller territories, and shrikes in habitats other than citrus groves, were in better nutritional condition than others. Daily growth of original and induced feathers has considerable potential as a "biomarker" for assessing environmental quality.

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Several factors have been implicated in the decline of the Loggerhead Shrike (*Lanius ludovicianus*) in North America (Busbee 1977, Anderson and Duzan 1978, Craig 1978, Porter et al. 1978, Kridelbaugh 1982, Bystrak 1983, Cadman 1985, Hands et al. 1989). However, loss of foraging habitat and hunting perches to modern agricultural practices now seems the most likely explanation (Cadman 1985, Hands et al. 1989). This study focuses on hunting perches as a limiting resource in a habitat where foraging substrate and nest sites are unlikely to be limited.

We use ptilochronology (Grubb 1989) to show that a reduced number of hunting perches in a territory is correlated with reduced nutritional condition in shrikes, and thus could be contributing to the population loss. Ptilochronology is a recently-developed method for monitoring the nutritional condition of a free-ranging bird by measuring the width of daily growth bars on a tail feather induced to grow by pulling out its predecessor (Grubb 1989). The correlation between growth bar width and nutritional condition is now well-established (Grubb and Cimprich 1990, Grubb 1992).

Shrikes do not search for prey on the wing.

Therefore, we hypothesized that a territorial shrike requires some minimum amount of grassland or pasture substrate within scanning distance from hunting perches. We designated this portion of the territory as the "utilizable area." Recognizing that the density of hunting perches is variable, we also hypothesized that in areas with few hunting perches, a shrike must defend a very large area, and that populations have been declining because continual removal of fencerows and other hunting perches has made utilizable areas too costly to defend due to the increased dead space. Specifically, with the continual removal of hunting perches, the benefit:cost ratio of defending a territory eventually declines below some minimum threshold value as the ratio of utilizable area to dead space decreases, and the territory is abandoned.

We tested four predictions deduced from the hunting-perch hypothesis: (1) all territories comprising a local mosaic contain a similar amount of utilizable area, (2) larger territories contain more dead space, (3) the benefit:cost ratio varies inversely with territory size, and (4) a shrike's nutritional condition, as indexed by rate of feather regeneration, varies inversely with territory size.

In general, because plumage is important for protection, thermoregulation, and locomotion, feather regeneration should proceed as rapidly as possible subject to constraints such as net

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energy intake (Grubb 1989). Thus, the reduced growth of an induced feather might indicate a reduction in nutritional condition too minor to cause the net catabolism of body tissues and resulting mass loss that have been considered the definitive indicators of 'nutritional stress' (King and Murphy 1985).

## METHODS

We studied post-breeding shrikes during June–August 1990 at the MacArthur Agro-ecology Research Center of Archbold Biological Station, Lake Placid, Florida, a 4,000-ha working cattle ranch. Territorial shrikes were captured in baited noose traps and were banded for individual recognition with USF&WS aluminum bands and color bands. We used the shrikes' aggressive responses to playbacks and taxidermic mounts to map the borders of all territories on the ranch. Territory size was calculated as the minimum polygon bounded by defended points of the habitat. During June, we pulled the R4 rectrix from territorial adult shrikes and allowed the induced rectrix to be regenerated. We recaptured the birds 5–6 weeks later, pulled the fully-grown induced rectrix, and calculated the feather's daily growth. We analyzed growth for a relationship between territory size and body size because faster daily feather growth could be due to body size.

Using a balanced sampling design, we determined activity budgets for all birds based on the following mutually-exclusive behavioral categories: LOOKOUT, scanning from an exposed perch; PREEN, maintaining the condition of the plumage; REST, remaining out of sight in a bush or tree; HANDLE, capturing, eating and/or caching prey; CHANGE, flying between lookout perches; CHASE, flying to pursue territory intruders. Benefit:cost ratios were calculated as prey captures per hour divided by percent of activity in flight (CHANGE + CHASE). To reduce the likelihood of pseudoreplication (Hurlbert 1984), we performed all analyses on a per-territory basis by averaging values for the male-female pair defending a common territory. For analysis, we employed simple regression and angular-transformed percentages (Steel and Torrie 1960).

## RESULTS AND DISCUSSION

During the study period, we mapped 21 post-breeding territories after all fledglings had departed. Territory area varied from 0.17 to 14.59 ha. The two major categories of hunting perches were barbed-wire fences and cabbage palms (*Sabal palmetto*). On average over the 21 territories, shrikes flew from a perch down to the ground to catch prey a maximum of 6.5 m from

fences and 9.2 m from the taller palms. Combining this information with tabulations of fence-line length and number of palm trees, we calculated the amount of utilizable area for each territory ( $\bar{x} = 7709 \text{ m}^2$ ; C.V. = 37.1%;  $n = 21$ ). In support of prediction 1, the amount of utilizable area was unrelated to territory size ( $r^2 = 0.08$ ,  $P = 0.47$ ). We subtracted utilizable area from total area to determine the amount of dead space in each territory. In support of prediction 2, larger territories contained more dead space ( $r^2 = 0.85$ ;  $P < 0.001$ ).

As territory size increased, shrikes spent significantly larger proportions of their activity changing perches, chasing intruders, and capturing/eating/caching prey (Table 1). The benefit index (captures/hr) was not related to territory size; however, the cost index (flight time in CHANGE + CHASE) increased significantly on larger territories (Table 1). The benefit:cost ratio and the feather-growth index of nutritional condition were both significantly negatively related to territory size (Table 1), and significantly positively related to each other ( $r^2 = 0.55$ ;  $P \pm 0.001$ ). These results support predictions 3 and 4. Finally, there was no significant relationship exists between territory size and body mass ( $r^2 = 0.73$ ;  $P = 0.48$ ). Thus, the negative relationship between feather growth and territory size was not confounded by body size.

Among the results in Table 1, the significant positive relationship between handling time and territory size is difficult to interpret. Because of our sampling methods, we cannot dissect HANDLE into its component parts. Thus, for example, we cannot investigate whether shrikes on small territories cached a larger number of prey, an activity that required less time than tearing apart and ingesting a freshly-caught item. In any case, the trend in HANDLE was the same as the trends for CHANGE and CHASE. Furthermore, increases in all three of these activities were apparently compensated for by reductions in time spent in LOOKOUT and PREEN, though changes in these two categories only approached statistical significance.

These results support the hypothesis that density of hunting perches affects nutritional condition of non-breeding territorial shrikes. Areas of the ranch with suitable short-grass pastures but without shrike territories contained few fences and trees. Thus, shrikes may

TABLE 1. Activity budgets, prey captures, and daily feather growth of territorial post breeding Loggerhead Shrikes, and their relationship with territory size. All  $n$ 's = 21.

Component	$\bar{x}$	C.V. (%)	Regression on territory area		
			$b$	$r^2$	$P$
Lookout	78.4	17			
Preen (%)	6.3	112	-0.68	0.08	0.20
Rest (%)	3.0	258	-0.76	0.14	0.10
Handle (%)	5.2	38	-0.22	0.01	0.70
Change (%)	4.7	122	0.43	0.35	0.004
Chase (%)	1.4	126	1.46	0.73	<0.001
Change + Chase (%)	6.1	112	0.44	0.33	0.006
Prey captures hr <sup>-1</sup>	7.4	8	1.52	0.79	<0.001
Benefit:cost*	2.6	72	-0.03	0.04	0.38
Daily feather growth (mm)	2.00	26	-0.41	0.77	<0.001
			-0.10	0.58	<0.001

\* (Prey captures hr<sup>-1</sup>)(Change - Chase<sup>-1</sup>)

have been avoiding these areas because of insufficient utilizable area.

We sought to evaluate habitat-specific effects on the nutritional condition of Loggerhead Shrikes but there were no significant relationships between total length of the R4 rectrix and tarsus length, sex, or habitat type (Table 2). However, daily growth ( $P = 0.013$ ) and mass ( $P < 0.001$ ) of the feather, and number of fault bars ( $P = 0.002$ ) were all significantly related to habitat type, but not to tarsus length or sex. For both growth bar width ( $P = 0.004$ ) and fault bar number ( $P < 0.001$ ), CITRUS feathers differed significantly from PASTURE feathers (Table 3). The  $t$ -values (Table 3) and means adjusted for the covariate (Fig. 1) indicate that shrikes in CITRUS grew their rectrix more slowly and with more fault bars than shrikes in PASTURE. Comparisons of growth bar width and fault bar number between URBAN, SCRUB, and PASTURE were non-significant (Table 3), except for the marginally-significant difference in fault bar number between SCRUB and PASTURE, a result which may have been spurious.

Taken together, these results suggest that

something about citrus groves caused reduced nutritional condition of resident shrikes. However, the poor feather growth in citrus groves could have been a function of the individual bird rather than the habitat. The birds in CITRUS could have been of low quality to begin with, perhaps having been habitat-imprinted on citrus while raised there, or having been excluded from better habitats by higher quality conspecifics. We do know, however, that shrikes in CITRUS were not unusually small because there was no relationship between tarsus length and habitat type ( $F = 0.40$ ,  $P = 0.75$ ).

Assuming that the reduced rate of feather growth in citrus groves was a function of habitat type rather than bird quality, its causation could have been direct, indirect, or both. In Florida, citrus is routinely sprayed with miticide/insecticide compounds (T. Hurner pers. comm.) known to be toxic to non-target organisms (Hayes and Laws 1991). Such chemicals could have had a sublethal effect on shrikes sufficiently intense to retard feather growth. Alternatively, application of miticide/insecticides in the groves could have depressed the

TABLE 2. General linear models for characteristics of the R4 rectrix ( $n = 35$ ) of Loggerhead Shrikes during winter in southcentral Florida. The first number in each cell is the  $F$  statistic and the second is the level of statistical significance.

Feather characteristic	Covariate or factor		
	Tarsus length	Sex	Habitat
Growth bar width			
Total length	0.86; 0.360	0.97; 0.333	4.28; 0.013
Mass	0.48; 0.495	0.47; 0.499	1.35; 0.278
Number of fault bars	0.47; 0.500	2.76; 0.107	8.49; 0.000
	0.02; 0.900	0.20; 0.656	6.11; 0.002

TABLE 3. Comparisons between each of three habitat types and the reference habitat, PASTURE, for characteristics of the R4 rectrix of Loggerhead Shrikes during winter in southcentral Florida. The sample size for the reference habitat is 18. The first number in each cell is the *t* value and the second is the level of statistical significance.

Feather characteristic	Habitat type		
	Urban ( <i>n</i> = 4)	Scrub ( <i>n</i> = 7)	Citrus ( <i>n</i> = 6)
Growth bar width	1.70; 0.101	-0.33; 0.743	-3.15; 0.004
Total length	-0.56; 0.578	-0.12; 0.907	-0.79; 0.433
Mass	-1.00; 0.323	1.16; 0.256	-1.66; 0.108
Number of fault bars	-0.91; 0.371	-2.26; 0.031	4.13; 0.000

shrikes' food supply, reducing the birds' nutritional condition sufficiently to be detected by the feather growth technique. It seems possible, also, that reduced nutritional condition could

have been caused by direct and indirect effects of citrus grove management practices acting in concert. While it may be of interest to separate the two classes of causation experimentally, it seems clear that feeding rates, induced feather growth (Grubb 1989), survivorship, and fecundity of shrikes living in citrus groves should be examined.

Similarly, the continuing decline of the Loggerhead Shrike may be at least partially due to withdrawal from parts of the species' range in which man's activities have reduced the density of hunting perches. Finally, this study illustrates the potential of daily feather growth as a convenient 'biomarker' for assessing environmental quality and the effects of various natural and disturbed habitats on the nutritional condition of free-ranging birds.

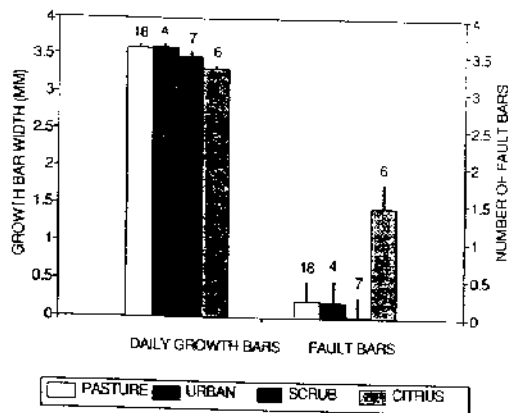


Fig. 1. Mean width of 10 growth bars and mean number of fault bars on the R4 rectrix of Loggerhead Shrikes during winter in four habitat types of southcentral Florida. Sample sizes and standard deviations are shown above the bars.

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