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GROWTH OF INDUCED FEATHERS IN PHOTOSTIMULATED AMERICAN TREE SPARROWS[1]

DOUGLAS W. WHITE AND E. DALE KENNEDY
Division of Biology, Kansas State University, Manhattan, KS 66506

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Ptilochronology, the study of feather growth rates as revealed by the width of daily growth bars, recently has been proposed as a technique to assess the nutritional status of free-ranging birds (Grubb 1989, 1991). This technique has been used in winter food supplementation studies of Downy Woodpeckers (*Picoides pubescens*; Grubb 1989), groups of woodland birds (Grubb and Cimprich 1990), and Gray Jays (*Perisoreus canadensis*; Waite 1990), and in comparisons of breeding effort in European Starlings (*Sturnus vulgaris*; White et al. 1991). However, the use of ptilochronology as a measure of nutritional status has come under scrutiny from Murphy and King (1991), who suggest that feather growth is determined by a complex of nutritional and nonnutritional factors.

In comparing induced tail feathers grown by female European Starlings rearing broods of six, four, or two nestlings, White et al. (1991) found that the width of growth bars in replacement feathers was only 69–78% of the width of growth bars in feathers formed during the annual molt. White et al. (1991) suggested that reduced feather regrowth during the breeding season was due to either (1) hormonal factors that are unfavorable for feather regrowth during the breeding period, or (2) greater nutritional demands during reproduction than during the normal molt. Here, we examine feather and ovarian growth in female American Tree Sparrows (*Spizella arborea*) exposed to short-day (8 hr of light and 16 hr of dark per day; 8L:16D) or long-day (20L:4D) conditions to determine whether reproductive hormones slow feather regrowth. As all birds were provided with food *ad libitum,* we predicted that if hormones associated with ovarian growth and long-day conditions are sufficient to slow the rate of feather growth, then birds kept on long days should grow an induced rectrix with narrower growth bars than birds kept on short days. However, if daily feather growth is related to nutrition and not hormones, then birds on long days should grow an induced rectrix with equal or wider growth bars than birds kept on short days.

METHODS

American Tree Sparrows were captured in mist nets near Manhattan, KS, on 5 and 9 February 1991. Birds were housed in cages and held on 8L:16D (08:30–16:30 CST) at about 21°C; water and food (a vitamin- and mineral-enriched 20% protein crumble, formulated and prepared in the Department of Grain Science and Industry, Kansas State University) were provided *ad libitum.* After being held 8–10 days, birds were sexed by laparotomy under lidocaine-induced local anesthesia (Wilson 1989), and 25 females were maintained, two birds per cage (23 × 25 × 41 cm), on short days (8L:16D). On 21 Feb. 1991, we plucked the right outer rectrix from 20 females, measured the wing chord of each bird to the nearest mm, moved 10 randomly-selected birds to 20L:4D (08:30–04:30 CST), and retained the other 10 birds on 8L:16D. Ambient illumination was provided by fluorescent (cool white) lamps. We narcotized the five remaining females (initial controls) with a lethal dose of Nembutal and removed their ovaries. After 42 days (4 April 1991), we plucked the induced feathers, narcotized the 20 birds and removed their ovaries to verify ovarian response to photostimulation. After removal, ovaries were fixed in AFA (glacial acetic acid, formalin, 95% ethanol, and distilled water [1:1:3:5]) for five days, stored in 70% ethanol for 7–9 days, cleaned of extraneous tissue, and weighed to the nearest 0.01 mg.

We examined original and induced tail feathers for overall length, mass, and growth bar width (Wood 1950, Grubb 1989). Average growth bar width was calculated for the 10 growth bars surrounding the "distal two-thirds" point on each feather using the technique of Grubb (1989). Lengths were measured to the nearest 0.05 mm using calipers. Masses were recorded to the nearest 0.01 mg.

Significant correlation between length of the wing chord and length of the original R6 rectrix ($r = 0.60$, df = 18, $P < 0.01$) indicated that strong individual differences existed in feather lengths. To control for such variability in treatment comparisons of induced feathers, we used analysis of covariance (ANCOVA) with values for original feathers serving as covariates.

RESULTS

As expected, ovary mass for females exposed to 20L:4D was about 12 times greater than that for females maintained on 8L:16D (48.07 ± 12.09 vs. 4.05 ± 1.28 mg; $t = 16.20$, df = 18, $P < 0.001$). Ovary mass did not differ significantly between birds sacrificed on day zero (3.14 ± 1.10 mg) and birds kept on 8L:16D during the 42-day experiment ($t = 1.91$, df = 13, $P > 0.05$). These results conform to the pattern of photostimulated ovarian growth found for American Tree Sparrows by Morrison and Wilson (1972) and Wilson and Follett (1974).

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TABLE 1. Characteristics of original and induced R6 rectrices of American Tree Sparrows on *ad libitum* food and held on either short (8L:16D) or long (20L:4D) days.

Rectrix	Length (mm)	Mass (mg)	Growth bar width (mm)	Number of growth bars
Original	68.48 ± 2.82 (20)[a]	10.27 ± 0.62 (20)	2.83 ± 0.32 (20)	18.4 ± 1.7 (20)
Induced 8L:16D	66.49 ± 1.73 (10)	9.39 ± 0.70 (10)	2.52 ± 0.15 (10)	20.3 ± 1.9 (10)
Induced 20L:4D	55.71 ± 6.06 (9)	6.99 ± 1.39 (9)	2.48 ± 0.18 (9)	17.4 ± 1.0 (9)
F^b	56.61***	29.75***	0.53 ns	15.09**

[a] Values are $\bar{x} \pm$ SD (n).
[b] ANCOVA comparisons of values for induced rectrices among birds on short and long days; values of original feathers are used as covariates. *** = $P < 0.001$; ** = $P < 0.005$; ns = $P > 0.05$.

All birds grew a complete replacement tail feather except one bird in the long-day group for which no replacement feather was found. Induced rectrices of photostimulated females were significantly shorter and less massive than rectrices grown by short-day controls (Table 1). Mean growth bar width, however, did not differ significantly between treatments; accordingly, fewer growth bars were present in rectrices from long-day birds than in rectrices from controls (Table 1).

That feather growth may vary seasonally even between nonreproductive periods was supported by data collected from control birds. Induced rectrices grown under short days were significantly shorter (ANOVA, $F_{1,9} = 6.55$, $P < 0.05$), less massive ($F_{1,9} = 34.39$, $P < 0.001$), and had narrower growth bars ($F_{1,9} = 7.07$, $P < 0.05$) than original rectrices likely produced during the fall molt (Table 1). Growth bars on induced feathers averaged 88% of the width of bars on original feathers. No significant difference existed in the number of growth bars per feather ($F_{1,9} = 3.12$, $P > 0.10$) between original rectrices and rectrices induced under short days.

DISCUSSION

Neither of our hypotheses fully anticipated the differences in rectrix regrowth which we observed between control females and females that experienced photostimulated ovary expansion. An inhibitory hormonal influence on feather growth in American Tree Sparrows was supported by our observation that induced feathers from photostimulated birds were, on average, 84% of the length and 74% of the mass of induced feathers from control birds. Nutritional regulation of daily feather growth increments as suggested in Grubb's (1989) ptilochronology model could not be rejected, however, because growth bar widths did not differ significantly between treatments.

Feather growth is unlikely to be affected directly by the length of the light cycle above some undefined minimum. Chilgren (1978) found no difference in growth rates of primary remiges during postnuptial molt in White-crowned Sparrows (*Zonotrichia leucophrys*) kept on 4L:20D and 8L:16D. Likewise, Murphy and King (1986) found that growth rates of primary remiges in molting White-crowned Sparrows did not differ among birds kept on 12L:12D, 16L:8D and 20L:4D. Furthermore, Murphy and King (1990) found that mean daily *ad libitum* food intake by molting White-crowned Sparrows did not differ significantly among those three photocycles.

Alterations in photoperiod may affect feather growth indirectly by triggering shifts in hormonal or physiological status. Honda et al. (1982) studied regrowth of contour feathers in Japanese Quail (*Coturnix coturnix japonica*) in experiments where shortened daily photoperiods may have stimulated hormonal conditions characteristic of the period of fall molt. Just as in the present study, they found that the period of growth, but not the rate of growth, of induced feathers was greater under short than long photoperiods. They found that feather growth was extended under short days, and here we found that feather growth was abbreviated when ovary expansion was stimulated by long days. These results suggest that seasonal patterns in feather growth, such as found by Grubb et al. (1991) in Northern Cardinals (*Cardinalis cardinalis*), may be hormonally mediated, and that comparisons of induced feather growth among asynchronous treatment groups should be corrected for seasonal effects, especially if indices of overall feather size are used instead of growth bar width.

Based on our results, we suggest that the duration of rectrix growth, measured in days, is controlled hormonally while the rate of growth, measured by growth bar width, is controlled nutritionally.

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FLIGHT DISTANCES OF BLACK-BILLED MAGPIES IN DIFFERENT REGIMES OF HUMAN DENSITY AND PERSECUTION[1]

SUE P. KENNEY AND RICHARD L. KNIGHT[2]
Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

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Vertebrate responses to human beings have both a learned and genetic component. The learned component is apparently influenced by both the number and outcome of individual human–bird interactions that occur within the animal's lifetime (e.g., Buitron 1983, Knight and Temple 1986). Some bird species have adjusted to high human density and have become "urbanized" (e.g., Cooke 1980). The ability of birds to coexist with humans is largely attributed to the absence of active persecution (e.g., shooting) (Knight et al. 1987). Outside of urban or protected areas, however, active persecution occurs, whether legally (e.g., hunting seasons) or illegally. In the presence of persecution it would be maladaptive to habituate to humans, and birds show avoidance behavior (Knight 1984, Knight et al. 1989).

Terrestrial vertebrates may show variation to human intruders by altering flushing response and flight distance (Altmann 1958). Both are important behavioral attributes of organisms in that they affect survival and essential daily routines (e.g., foraging, social behavior). The Black-billed Magpie (*Pica pica*) is a common species in Europe and western North America and has made the transition to an urban environment (Birkhead 1991). We examined two hypotheses pertaining to flushing response and flight distance in magpie populations in northeastern Colorado. First, in the absence of active persecution, we predicted that the flushing response and flight distance of magpies would correlate negatively with human density. Second, magpie flushing response and flight distance would be greater in areas with human persecution than in areas without persecution.

METHODS AND STUDY AREA

To examine the effects of human density and persecution on magpie flushing response and flight distance, we studied magpies in: (1) an urban, nonpersecuted population; (2) rural, nonpersecuted populations; and (3) rural, persecuted populations. We visited 11 sites in northeastern Colorado between 12 December 1989 and 13 April 1990. Three urban, nonpersecuted locations were in the city of Fort Collins (approximately 90,000 people); four rural, nonpersecuted sites (hereafter called state parks) in Larimer and Jefferson counties; and four rural, persecuted sites in Larimer County. The rural areas were predominately shrub and grassland, whereas the urban sites were residential neighborhoods and parks. Because the discharge of firearms is prohibited in both the urban and state park sites, we assumed that magpies in these areas were not subject to active persecution.

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[2] Corresponding author.