ULTRAVIOLET DEGRADATION IN CAROTENOID PATCHES: LIVE VERSUS MUSEUM SPECIMENS OF WOOD WARBLERS (PARULIDAE)

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Magnolia Warbler (*D. magnolia*), Yellow-rumped

across the color spectrum (UV vs. human-visible) with respect to source.

We were also interested in assessing degradation related to age. Specifically, we were interested in whether newer museum specimens di ered significantly from live individuals. If they did not, new museum specimens could provide a reliable means of using museum specimens to represent natural color. Ideally, we would like to have a model of how a variable like UV brightness varies with age. However, because museum specimens of intermediate ages were not available ("old" specimens = 1878–1934 and "new" specimens = 1983–2001) and data points for new specimens consisted of only nine individuals, a predictive regression model of the data seemed tenuous at best. Therefore, we calculated relative di erence scores for old and new specimens for both species in which new specimens were available (*D. c. coronata* and *G. t. trichas*) for both the UV and human-visible regions. Those scores represent the percentage of decrease in brightness of museum specimens as compared with live individuals. Di erence scores were then calculated as follows: (species average for live measurement – species average museum measurement)/species average for live measurement × 100). Those means were then used to assess degradation in the old and new museum specimens compared with the live individuals.

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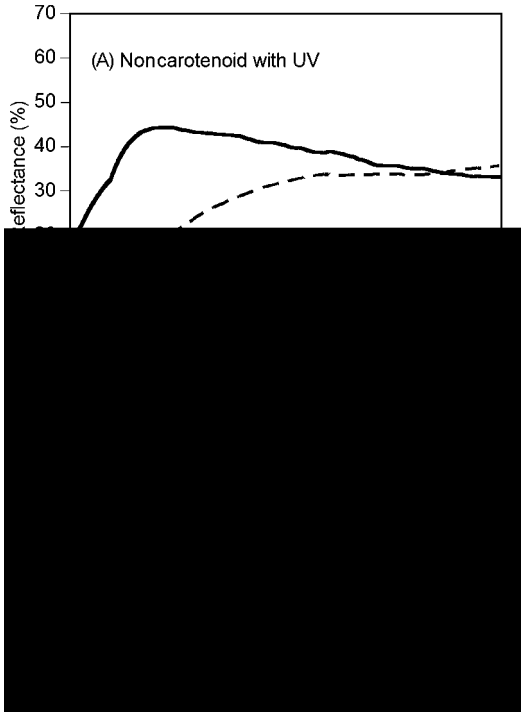
C C

Significant di erences according to species occur with all three parameters: brightness, chroma, and hue (Table 1). That is not surprising, given that di erent colors were measured (e.g. yellow and orange). However, we note that in most cases, the source variable explained more of the variation than species (Table 1). Our primary question is whether live and museum specimens di er. Mean brightness of carotenoid patches di ered between live and museum specimens (F = 105.78, df = 1 and 118, P < 0.001; Fig. 1 and Table 1). Mean chroma and hue also di ered significantly between live and museum specimens (chroma, F = 181.40, df = 1 and 118, P < 0.001; hue, F = 204.46, df = 1 and 118, P < 0.001). With brightness, there was also a significant species ∗ source interaction, indicating that each species did not exhibit the same pa ern of an increase or decrease in brightness 612 ca3< w (.17D 0.09 l24755555 l24752cie8be ciepecim)Tf 0.0bTD 09555559 23 al.8p22-11.3

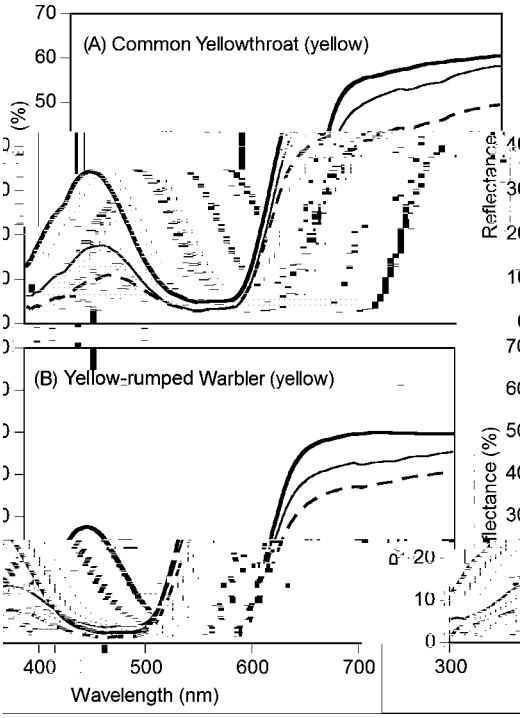
df = 12, $P = 0.097$). Again, degradation in the UV seems to contribute to di erences, because the peak is significantly di erent between live specimens and new museum specimens (Common Yellowthroat, *t*-test: $t = 3.68$, df = 12, $P = 0.003$; Yellow-rumped Warbler, *t*-test: $t = 3.50$, df = 12, $P = 0.003$), whereas the human-visible peak is not (Common Yellowthroat, *t*-test: $t = 1.103$, df = 12, $P = 0.29$; Yellow-rumped Warbler, *t*-test: $t = 2.00$, df = 12, $P = 0.68$).

D

Although color measurements from museum specimens have frequently been used in studies of color variation (e.g. Burkhardt 1989, Andersson and Amundsen 1997, Brumfield et al. 2001, Bleiweiss 2004), we report here that museum specimens of wood-warblers may be unrepresentative of natural color. More importantly, the uniqueness of the current study is its demonstration that UV plays a unique role in



F . 2. Degradation from live (solid) and museum (dashed) spectra from (A) noncarotenoid patches that contain UV (white on the eyestripe of the Black-and-white Warbler; live n = 8, museum n = 10) and (B) noncarotenoid patches that do not reflect in the UV (brownish-orange crown stripe from the Ovenbird; live n = 10, museum n = 10).



F . 3. Age-related differences between live (solid bold line), old-museum (1878–1934; dashed line), and new-museum (1983–2001; solid thin line) spectra in carotenoid-based plumage. (A) Common Yellowthroat (live n = 10, museum n = 10, new n = 4). (B) Yellow-rumped Warbler (live n = 9, museum n = 10, new n = 5).

Increased UV degradation associated with museum age is demonstrated, but the mechanisms responsible for that degradation are not entirely clear. Although we measured only specimens that appeared to be in the best condition, physical damage is one possible mechanism, given that it may accumulate with increasing age, perhaps through repeated handling of specimens. Physical degradation has been described in the orange-red and white colors of museum specimens of the Cock-of-the-rock (*Rupicola rupicola*; Endler and Théry 1996) and in the short-wavelength, structurally based color of live Blue Tits (*Parus caeruleus*; Örnborg 2002). Another possibility, as yet untested, is the isomerization of the pigment itself. Carotenoid pigments produce the UV peak in carotenoid-based plumage by minimally absorbing UV wavelengths and absorbing wavelengths outside the UV range to a greater extent, allowing the underlying color of the feather to be reflected. Carotenoids are sensitive to environmental perturbation. In carotenoid-containing foods, for example, trans- to cis-isomerization may result from exposure to light, heat, or oxygen (Chen et al. 1994, Tang and Chen 2000). Cis-isomers characteristically absorb more UV light (i.e. less reflectance) than the more naturally occurring all-trans form (figure 2 in Negro et al. 2001). Whether such isomerization occurs in bird feathers of museum specimens remains to be tested, but that would be consistent with the greater decrease of UV described here.

Geographic and seasonal variation also may contribute to di erences in color, and e orts were made to avoid those influences. All our live specimens were measured in the spring in New York; similarly, all museum specimens were collected in spring in the New York

metropolitan area. Geographic variation in UV
refl

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