How birds use color to stay warm: Pigment driven thermal properties in the plumage of birds on the highest mountains in the world.

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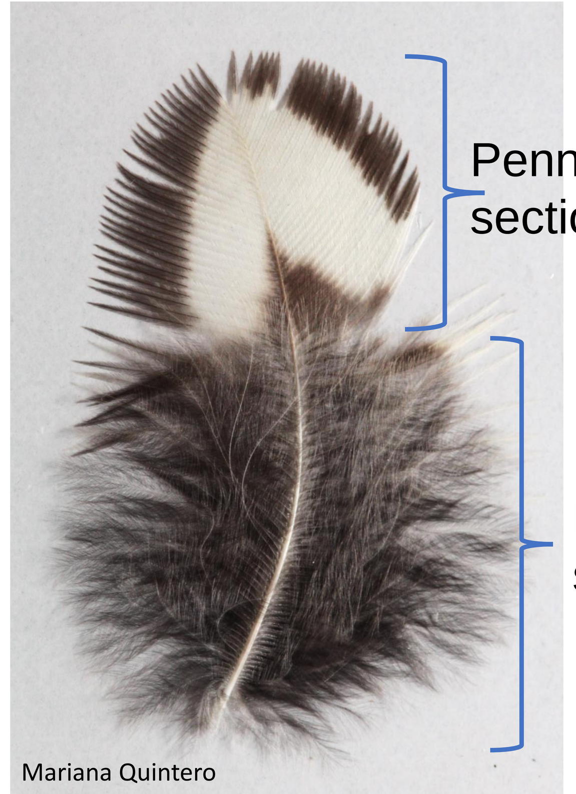
Introduction

Feathers are the defining characteristic of birds.

Bird body feathers can be divided in two sections. A proximal downy section that aids thermal insulation and a distal pennaceous section that can have multiple functions such as camouflage and courtship. Recent evidence[1] has shown that the color of the pennaceous section in some passerine birds may be important in absorbing heat from sunlight.



Contour Feather
Chamaeza turdina

The downy section also varies in brightness from white to dark gray.

Hypothesis

Building on previous research, we tested whether Himalayan birds show a pattern of increased absorbance of light (and thus heat) through pennaceous and/or downy sections of feathers to aid the bird in thermoregulation in cold environments.

Methods

Reflectance was measured across most of the solar spectrum (UV-Visible: 350 to 700 nm and (Near Infrared (NIR): 700 to 2500 nm)[2,3] , on the breast patch of 412 specimens (161 species) of Himalayan passerines using an ASD FieldSpec spectrophotometer® and light source (London, UK). The system was calibrated against a white reference. All statistical analyses were conducted in R using the packages *nlme*[4] and *phytools*[5].

For each specimen we assembled a dataset of 1) the brightness of the downy region, 2) the visible color of the pennaceous section, 3) elevation of specimen collection, 4) the relative length of feathers (controlled for body size)[6].

We used Phylogenetic Generalized Least Squares (PGLS) regressions to evaluate if the reflectance of breast patches varied with pennaceous color, down brightness, feather structure, body size and elevation.

Results

The PGLS analyses show that, irrespective of the color of the pennaceous section, in the UV-Visible spectrum,

- Small birds (that have longer feathers) typically show lower reflectance (Figure 1.A).
- Birds with dark pennaceous sections have light downy section and vice versa. (Figure 1.B).

Effect of feather length and down color on the mean reflectance across the UV-Visible (350-700 nm) range of the solar spectrum.

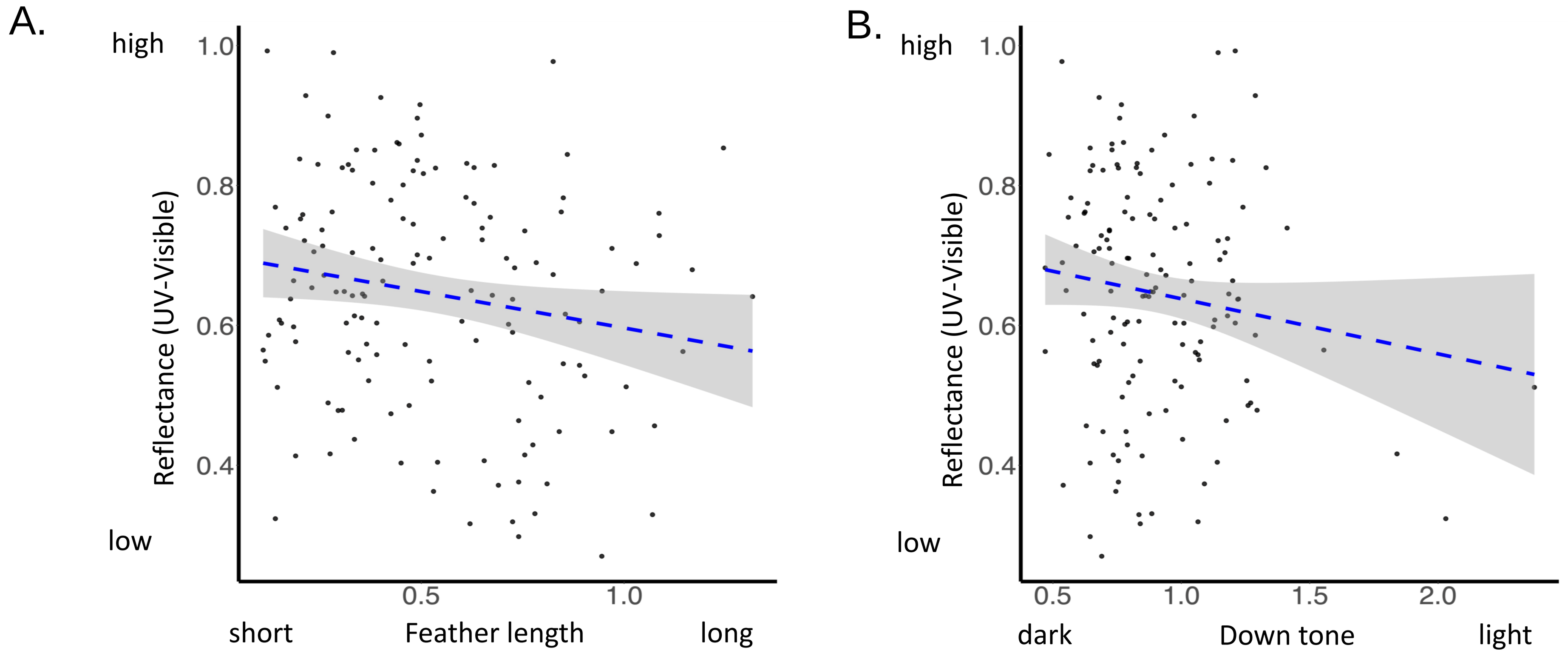


Figure 1. Drivers of reflectance in the UV-Visible spectrum. **A.** There is a negative relationship between mean reflectance and the relative feather length. **B.** Mean reflectance shows a negative relationship with the tone of the downy section.

In the NIR spectrum,

- Small birds (that have longer feathers) typically show lower reflectance (Figure 2.A).
- Birds with large downy sections (more insulative feathers) have higher reflectance (Figure 2.B).

Effect of feather length and proportion of down on the mean reflectance across the Near Infrared (700-2500 nm) range of the solar spectrum.

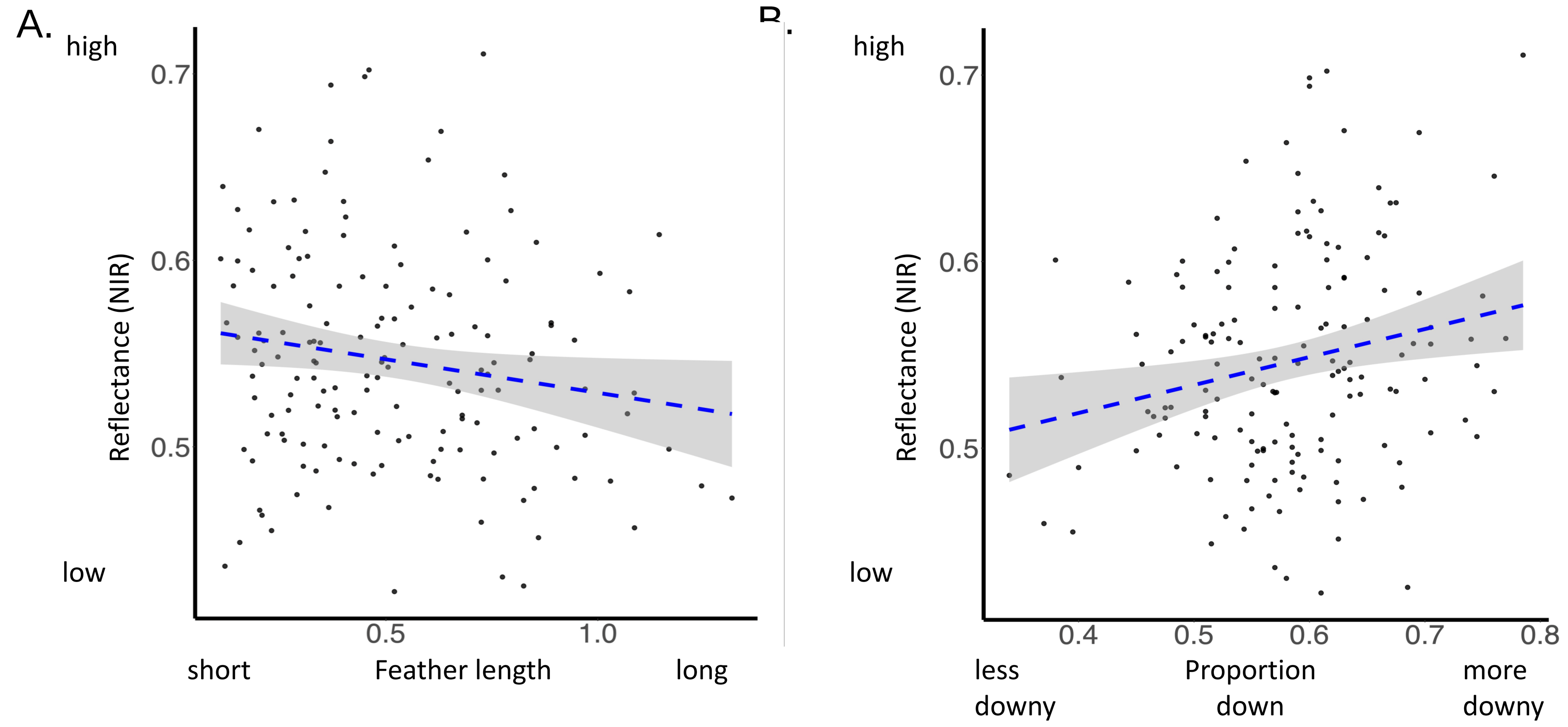


Figure 2. Drivers of reflectance in the Near Infra-red spectrum **A.** Mean reflectance shows a negative relationship with feather length. **B.** Mean reflectance shows a positive relationship with the proportion of down in the feather.

Discussion

Small birds that are more sensitive to cold temperatures absorb more light energy from incident solar radiation across the entire light spectrum.

Passerines may have repeatedly evolved light down under dark pennaceous sections and vice versa to modulate the amount of heat gained due to pigmentation.

Himalayan birds show a tradeoff between having enhanced downy structure and amount of energy absorbed from solar radiation in the near infrared spectrum.

Future studies should explore the generality of these patterns through research on other montane taxa (e.g., Andean birds) and across latitudinal temperature gradients.

Museum specimens showing diversity of color in Himalayan passerine birds.

References

1. Rogalla, S., Patil, A., Dhinojwala, A., Shawkey, M. D. & D'Alba, L. Enhanced photothermal absorption in iridescent feathers. *J. R. Soc. Interface* **18**, (2021).
2. Shawkey, M. D. *et al.* Beyond colour: consistent variation in near infrared and solar reflectivity in sunbirds (Nectariniidae). *Naturwissenschaften* **104**, 78 (2017).
3. Smith, K. R. *et al.* Colour change on different body regions provides thermal and signaling advantages in bearded dragon lizards. *Proc. R. Soc. B Biol. Sci.* **283**, 1–9 (2016).
4. Pinheiro J, Bates D, DebRoy S, Sarkar D, R Core Team (2022). _nlme: Linear and Nonlinear Mixed Effects Models_. R package version 3.1-155, <URL: https://CRAN.R-project.org/package=nlme>.
5. Revell, L. J. (2012) phytools: An R package for phylogenetic comparative biology (and other things). Methods Ecol. Evol. 3217-223. doi:10.1111/j.2041-210X.2011.00169.x
6. Barve, S., Ramesh, V., Dotterer, T. M. & Dove, C. J. Elevation and body size drive convergent variation in thermo-insulative feather structure of Himalayan birds. *Ecography (Cop.).* **44**, 680–689 (2021).

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