

Reflection of near-infrared light confers thermal protection in birds

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Overview

- ✓ INTRODUCTION AND STUDY SETUP
- ✓ VARIATION OF NIR REFLECTIVITY AMONG BIRDS' SPECIES
- ✓ ASSOCIATION WITH THERMAL ENVIRONMENT
- ✓ ADAPTIVE BENEFITS
- ✓ CONCLUSIONS AND IMPORTANCE OF THE RESULTS

Introduction

55% of sunlight energy falls within near-infrared (NIR) wavelengths (700-2500 nm) that are not visually perceived by most terrestrial animals

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HYPOTESIS: capacity to **reflect NIR radiation** may be **selected for thermoregulation** and enable birds to remain within their critical thermal limits.

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FINDINGS

- Species in arid, hot environment have higher NIR reflectivity of patches exposed to direct sunlight
- Association and benefits are stronger for smaller species.

Study setup

→ **90 species of Australian birds**, from **all the major habitat types** (sea and shore birds, waterbirds, forest or arid specialists, habitat generalists), representing 12% of the avian biodiversity of the continent.

→ Use of reflectance measurements, phylogenetic comparative methods, principal component analysis and biophysical modelling.

Observations

- 70% of Australian continent is characterized by hot and dry environment
- Fitness rapidly drops at T above the optimum
- Birds are vulnerable to heat stress: small body size, high internal temperatures, diurnal habitus

NIR reflectivity among species

- **Reflectance measurements** from the four primary patches of feathers on the bird skin (crown, mantle, breast and belly) were taken with dual-spectrometer system
- **Reflectivity** = proportion of solar energy reflected by feathers → Calculated as function of reflectance and solar Irradiance for UV, visible and NIR spectrum.

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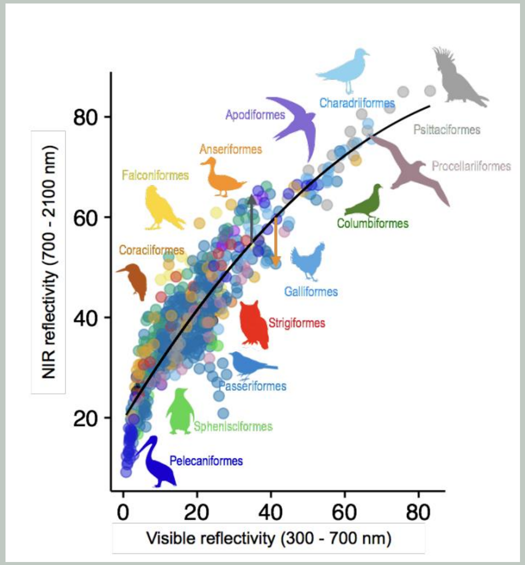
Found an association between UV-visible and NIR reflectivity →

Definition of the parameter "**relative NIR**" as the residual from the quadratic regression between UV-visible and NIR reflectivity

High relative NIR = observed value > expected value

Low relative NIR = observed value < expected value



NIR reflectivity among species

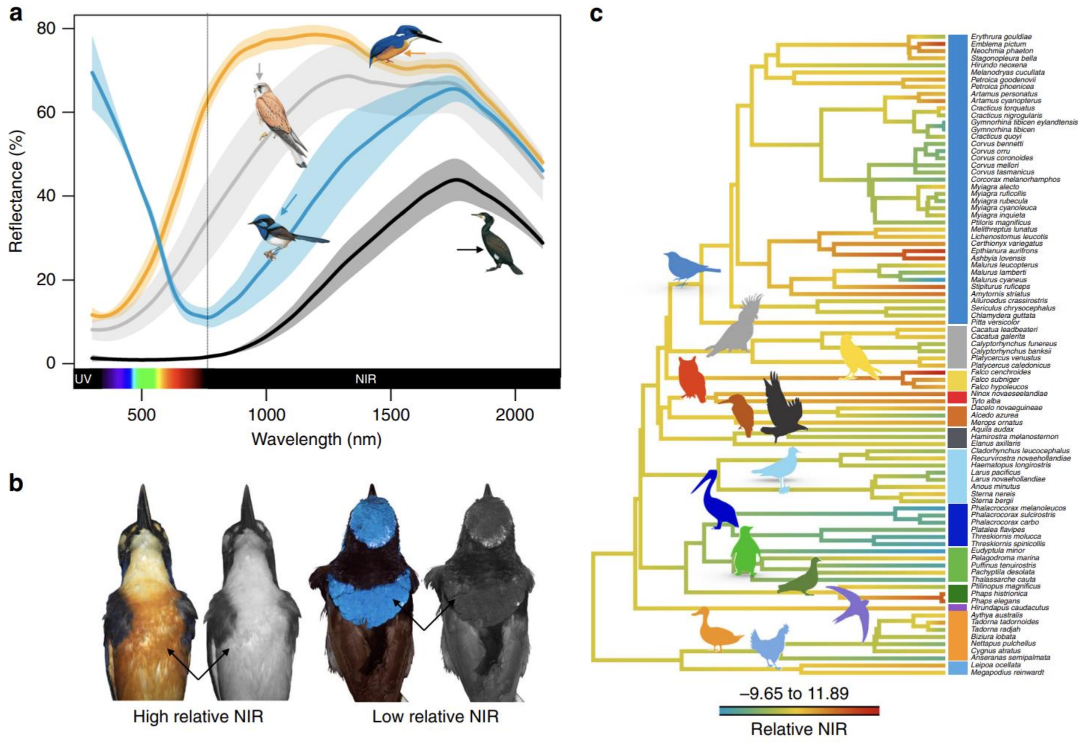


Fig. 1 Near-infrared (NIR) reflectance variation in Australian birds. **a** Reflectance spectra for representative species with relatively high (light grey and orange) and low (blue and black) NIR reflectivity. Grey: Nankeen kestrel (*Falco cenchroides*, crown); orange: azure kingfisher (*Alcedo azurea*, belly); blue: superb fairy-wren male (*Malurus cyaneus*, mantle); and black: great cormorant (*Phalacrocorax carbo*, belly). Species drawings taken with permission from ref. [31]. **b** Visible (left) and NIR (right) photographs of specimens with high (azure kingfisher) and low (superb fairy-wren) relative NIR. **c** Average relative NIR per species (across dorsal patches) mapped onto a phylogenetic tree (random example from the 1000 trees used in analysis), branch colours represent the value of relative NIR for each species. Vertical bars represent avian order, and correspond to the colour silhouettes on top of the branches

Findings from relative NIR evaluation:

a) High variation of NIR reflectance between species

b) Difference between dorsal and ventral patches

c) NIR reflectivity **varies within and between avian orders** (phylogenetic tree)

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Association with thermal environment?

NIR reflectivity and environment

Climate data were summarized using **principal component analysis**. Variables used:

- Average maximum summer temperatures
- Average number of days with T > 35°C
- Average summer and winter solar irradiation
- Average yearly vapour pressure

PC2 index represents **hot and dry environments** with high irradiation, extreme temperatures and low annual vapour pressure.

NIR reflectivity and environment

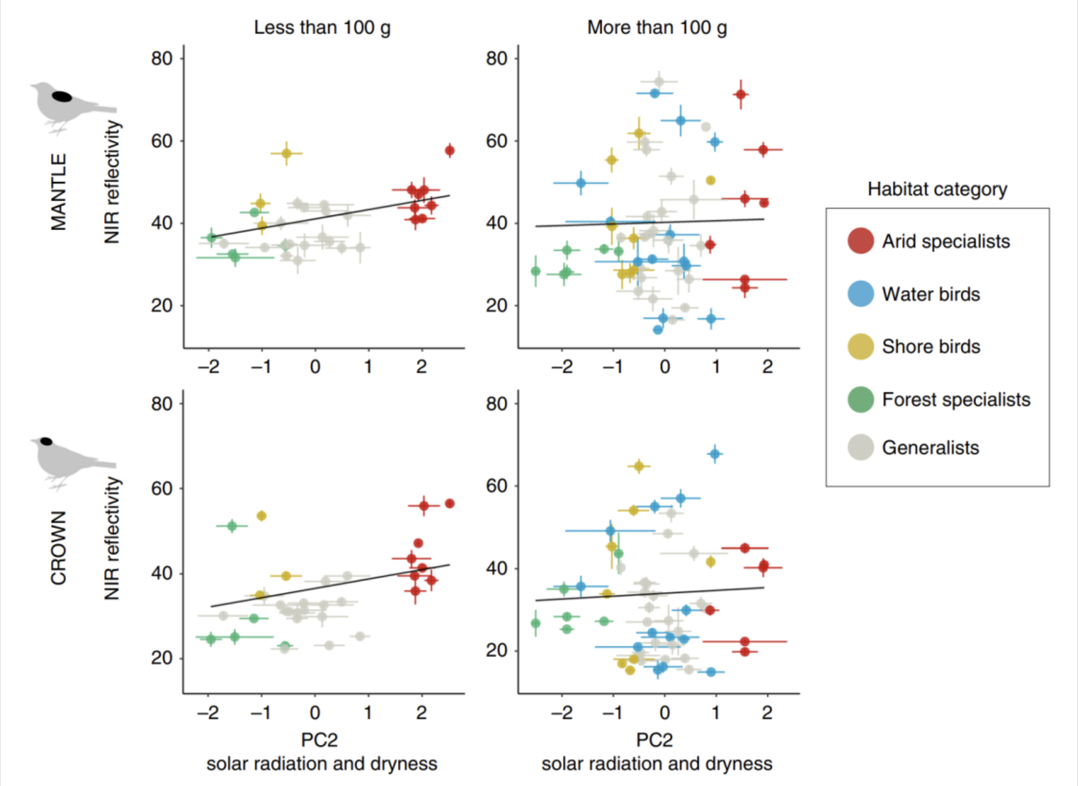
Plotting NIR reflectivity against PC2 index and habitat categories it has been found that:

→ **Mantle and crown** (dorsal patches) have **higher NIR reflectivity** in **hot and arid** environments.

→ Same association also for total reflectance (UV + visible + NIR)

→ Maximum values for arid specialists' species

→ Association is **stronger for smaller species** (less than 100g)



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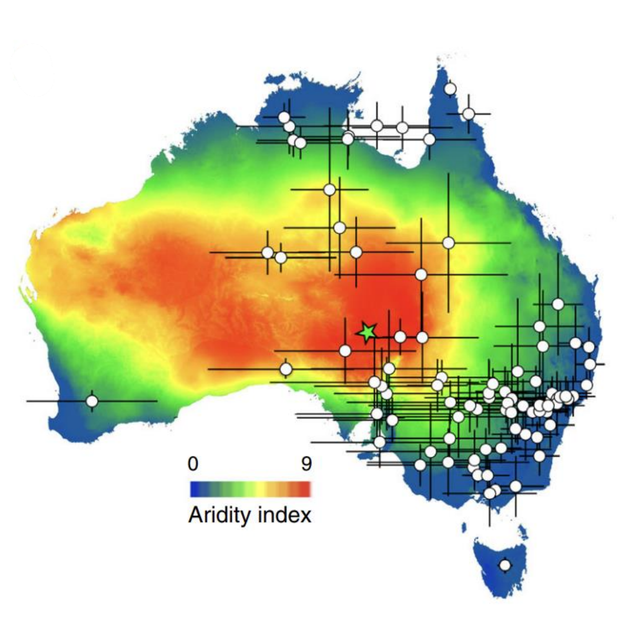
All this results sustain the hypothesis that plumage reflectance properties have been selected (directly or indirectly) for thermal protection.

Adaptive benefit

To evaluate how plumage reflectivity affects fitness it has been used a **biophysical model** of an endotherm, forced by a specific microclimate model reflecting **extreme environmental conditions** (reference to Simpson Desert)



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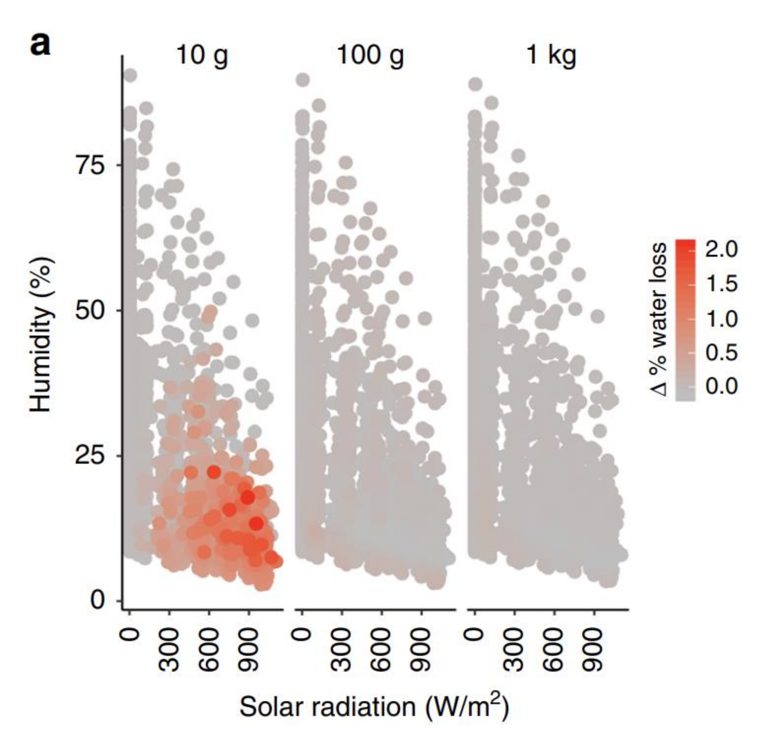
Taking into account climate variables, biophysical attributes of the organism and its physiological and behavioural responses, the model computes a **heat and water budget** and calculates **metabolic and evaporative water loss (EWL) rate.**

Model has been run for three different body masses: 10 g, 100 g and 1 kg.

Adaptive benefit



Results:

- High NIR reflectivity results in a maximum **reduction in evaporative water loss** that allow birds to avoid overheating and reduce mortality.
- Maximum benefit for birds <10g with a **saving of EWL of 2,12% of body mass per hour.**
- Less saving for medium (100g) and large (1 kg) birds: respectively 0,24% and 0,11% of body mass per hour.

Adaptive benefit

During extreme heat and drought stress, the **EWL for cooling is very expensive** for small birds, that can reach the lethal threshold in just a couple of hours. This happens because small birds have:

1) Thinner insulating feather layer
2) Higher surface area to volume ratio
3) Less possibility to maintain water reservoirs
4) Lower survival rate during heat waves
5) Frequent exposure to higher temperatures, due to boundary layer effect, when foraging on the ground

Conclusions

→ Birds' species from hot and arid environments have a higher NIR reflectivity

→ Smaller species gain a greater advantage from this characteristic reducing compensatory evaporative water loss up to 2,12% body mass per hour.

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The problem of thermoregulation in birds has been partially solved by modulating visible and NIR reflectivity

Importance of the results

- Half of the Australian continent reaches "extreme conditions" during summer
- Arid and hyper-arid zones will expand, heat waves incidence will increase due to climate change
- The link between NIR reflectivity, environment and thermal benefit could be global

Thank you for attention

Credits: Medina, I., Newton, E., Kearney, M.R. et al. Reflection of near-infrared light confers thermal protection in birds. Nat Commun 9, 3610 (2018). https://doi.org/10.1038/s41467-018-05898-8