Species-, habitat-, and body mass-associated changes in plasma metabolites during the avian stress response

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Introduction

Stress and energy are linked: Responding to stress requires energy and fluctuations in energetic state can alter the stress response. The acute stress response which results in glucocorticoid production raises plasma glucose partly via triglyceride and protein catabolism. Much research has been done on this subject in captive rodents but not in birds. Birds differ from mammals in having higher metabolic rates and blood glucose concentrations, various lipid storage mechanisms, and in primarily using fatty acids to power muscles during flight. Combined, these factors make birds highly susceptible to short-term changes in body mass. This allows us to test predictions concerning how current energetic state impacts the capacity to respond to stress, which may be especially important when comparing habitats that differ in both in energy availability and in the likelihood of encountering stressors.

Hypothesis & Questions

Hypothesis: The higher the lipid stores, the greater the capacity to respond to acute stress via increased reliance on lipolytic pathways.

1. *Do changes in body mass alter corticosterone secretion and plasma metabolites during stress?*
2. *Can plasma metabolite profiles be used to assess differences between species and populations that may differ in putative resource abundance?*

Methods

Stress response: Blood collected within < 3mins and after 30 mins of capture assayed for corticosterone (avian glucocorticoid) *via* commercial enzyme-linked immunoassay (Assay Designs).

Free glycerol and **Triglycerides**: Measured sequentially *via* an endpoint assay following Guglielmo *et al.* (2002, 2005).

Glucose, and **β-hydroxybutyrate (β -HB)**: Measured using commercial kinetic endpoint assays (Cayman Chemical).

Study 1

The daily food intake (DFI) of 28 adult male captive Curve-billed Thrashers (*Toxostoma curvirostre*) was measured. Birds were then placed either in a "Loss-Gain" (LG) or a "Gain-Loss" (GL) food treatment group (n=14 each).

GL: 90% DFI (10 d), *ad libitum* (5 d), 60% DFI (5 d)

LG: DFI (10 d), 60% DFI (5 d), a*d libitum* (5 d).

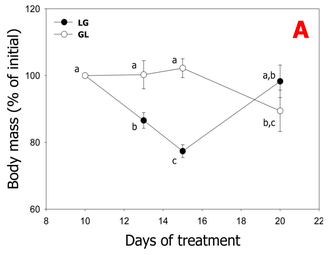


Fig A: Proportional changes in body mass for two treatments manipulating food availability in thrashers. Plotted as % body mass of the original pre-treatment weight (i.e. 100%). Shared letters indicate no significant differences at $P > 0.05$.

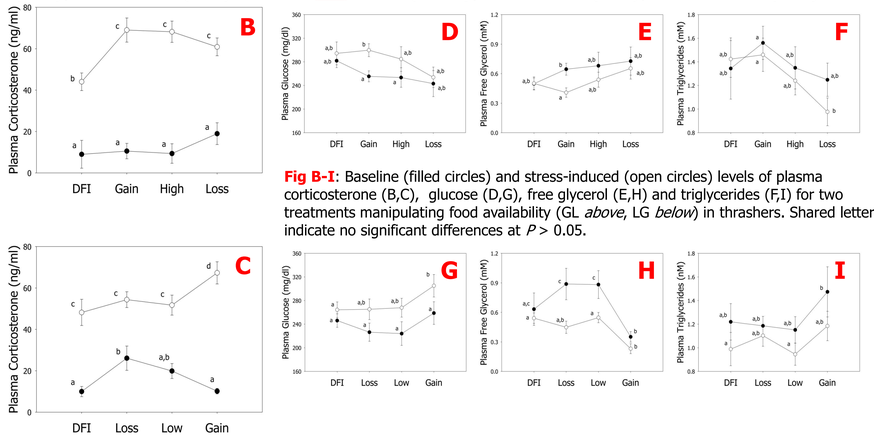


Fig B-I: Baseline (filled circles) and stress-induced (open circles) levels of plasma corticosterone (B,C), glucose (D,G), free glycerol (E,H) and triglycerides (F,I) for two treatments manipulating food availability (GL *above*, LG *below*) in thrashers. Shared letters indicate no significant differences at $P > 0.05$.

Decreases in body mass (**A**) elevated baseline corticosterone levels without altering stress levels (**C**). However, body mass did not change in the GL group (**B**), but stress corticosterone levels were elevated (**B**). Glucose generally increased with stress (**D**,**G**). The effect was most prominent when food was available (**D**: i.e. "gain") but this was not associated with body mass changes. Free glycerol, but not triglyceride (**F**,**I**) levels declined with stress (**E**,**H**) and the former was more prominent during mass loss (**H**).

Study 2

Previous research proposed urban and farm birds maintain higher body condition and stress responses than desert conspecifics. We sampled blood (< 3 and 30 mins post-capture) from 5 bird species (adult males) within the urban area of Phoenix, desert, or agriculture areas (marked gray bars). Plasma was assayed for metabolites associated with glucose mobilization (glucose, free glycerol), lipid deposition (triglycerides) or oxidation (β-HB).

Fig J-N: Changes in plasma metabolites during 30 mins of acute capture and handling stress in five bird species across habitats that differ in putative food abundance (urban = white bars, desert = gray bars, farmland = gray with pattern). Previous research suggested higher food availability in urban and farmland localities than in native desert. * indicates significant differences between sites at $P \leq 0.05$. **X** indicates no effect of stress on metabolites ($P > 0.05$).

Stress elevated plasma glucose in thrashers (**K**) and mockingbirds (**L**), but no effect of site was observed in any species. Stress decreased plasma free glycerol (**K**-**N**), except in farm sparrows (**J**), and the relative decrease for urban sparrows (**J**) and desert thrashers (**K**), was greater than for farm or urban birds, respectively. Stress decreased plasma triglycerides in all species, but most prominently in desert thrashers (**K**) and mockingbirds (**L**). Site differences in plasma β–HB were seen in 4 species (**K**-**N**), but urban thrashers (**K**) and canyon towhees (**M**), elevated plasma β–HB more than desert ones. However, urban mockingbirds (**L**) and Abert's towhees (**N**) decreased plasma β–HB during stress.

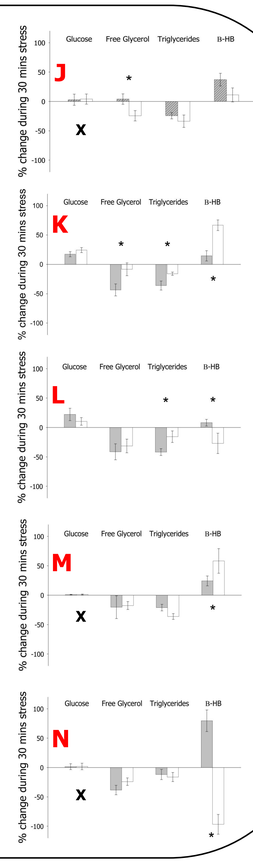
House Sparrow
Passer domesticus

Curved-billed Thrasher
Toxostoma curvirostre

Northern Mockingbird
Mimus polyglottos

Canyon Towhee
Pipilo fuscus

Abert's Towhee
Pipilo aberti



Summary & Conclusions

Loosing body mass elevates baseline corticosterone with little effect on stress-induced corticosterone levels. By contrast, gaining mass increases the magnitude of the stress response, thus resulting in higher stress-induced plasma corticosterone.

Stress-induced increases in plasma glucose are inconsistent across bird species or body mass changes. However free glycerol, which can be metabolized to produce glucose, decreases with stress, especially during mass loss. Triglycerides also decline with stress, but are not associated with mass changes.

Stress-induced changes in lipid mobilization appear to be responsive to environmental variation, such as differences in habitat (i.e. urban vs. desert). Stress may stimulate the release of fatty acid substrates that provide energy to avian muscle. This hypothesis is supported by changes in plasma β–HB during stress**.** These changes suggest more fatty acid oxidation in certain populations than others depending on the species.