USE OF INFRARED THERMOGRAPHY TO MEASURE BODY-SURFACE HEAT DISSIPATION IN FREE-LIVING HUMMINGBIRDS

Kathleen M. Langland[1], Donald R. Powers[1], and Susan M. Wethington[2]

[1]Biology Department, George Fox University, Newberg, OR 97132, USA; [2]The Hummingbird Monitoring Network, Patagonia, AZ 85624, USA.

INTRODUCTION

Global climate change is increasing temperature around the world impacting a number of habitats and species (Traill et al., 2010). This includes habitats where many of the world's hummingbird species are found. As temperatures rise hummingbird populations will experience habitat and physiological changes that could result in range shifts or threaten survival. Hummingbirds are linked to nectar plants and insects, and the availability of these resources could be profoundly changed as temperatures increase (Sommer et al., 2010). Warmer temperatures also pose the risk of higher thermal loads, which could make body-temperature regulation more difficult.

The effects of climate change on hummingbird thermoregulation have not been addressed. Hummingbirds have high metabolic rates (Weathers & Stiles 1989; Powers & Conley 1994) and thus must dissipate large amounts of heat (Evangelista et al., 2012). Heat dissipation occurs via conduction, convection, and radiation across body surfaces all of which require a favorable thermal gradient. However, coming climate change could narrow or in some instances invert the thermal gradient resulting in a higher thermal load impacting environmental toleratance driving shifts in hummingbird geographical distribution (Buermann et al., 2011).

The purpose of this study was two fold: 1) to determine if higher environmental temperatures resulted in detectable increased in thermal load for hummingbirds, and 2) to assess the effectiveness of body-surface heat dissipation over a range of environmental temperatures.

METHODS

Study site & species. We studied 3 hummingbird species at 2 locations in SE Arizona. Broad-tailed hummingbirds (*Selasphorus platycercus;* ~3.0 g; ,BTLH) were studied on Mt. Lemmon (~3,000 m; high-elevation site), and Broad-billed hummingbirds (*Cynanthus latirostris*; ~3.0 g; BBLH) and Black-chinned hummingbirds (*Archilochus alexandri*; ~3.0 g; BCHU) along Harshaw Creek in the Patagonia Mts. (~1,300 m; mid-elevation site) (Figure 1).

Infrared thermography. We measured the surface temperature (T_s) of hummingbirds by infrared (IR) thermography using a FLIR SC6700 infrared video camera. T_s and size of the "hotspot" (HS) around the eye, a key region of heat dissipation, were measured (Figure 2).

Figure 1. Male broad-tailed (left) and broad-billed (center), and black-chinned (right) hummingbirds.

Figure 2. IR thermographic image of a BBLH. The eye HS is visible, exhibiting elevated T_s relative to the general body surfaces.

Operative temperature. IR thermography data were correlated with operative temperature (T_e). T_e was measured using sphere thermometers (Walsberg & Weathers, 1986), that were approximately the same volume as the hummingbirds.

RESULTS

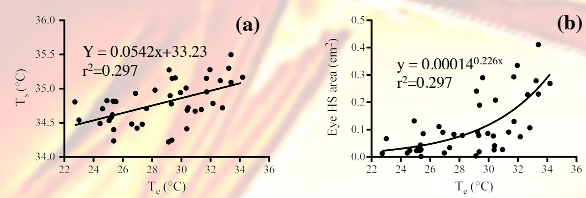

Figure 3. Mean eye HS T_s and size as a function of T_e for BTLH. (a) T_s significantly correlates with T_e ($P < 0.001$). (b) Eye HS size increases exponentially with T_e. Note how size increases rapidly above 30 °C perhaps to dampen increases in T_s. Estimated heat dissipation ranges from 4.1-5.2 mW (calculations from Ward et al., 1999).

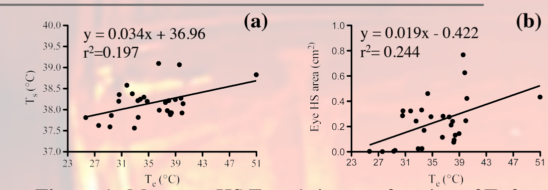

Figure 4. Mean eye HS T_s and size as a function of T_e for BBLH. (a) T_s significantly correlates with T_e ($P = 0.018$). (b) Unlike BTLH Eye HS size exhibits linear correlation with T_e ($P = 0.008$). This may be due to the limited range of T_e measurements. Heat was dissipated at low T_e (8.8 mW @ 27 °C), but heat was gained at high T_e (108 mW gained @ 51 °C).

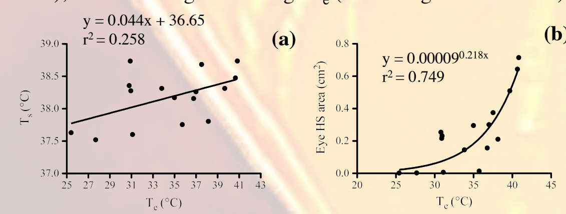

Figure 5. T_s and eye hotspot (HS) size as a function of T_e for BCHU. (a) T_s significantly correlates with T_e ($P = 0.044$). Mean T_s is higher in the BBLH and BCHU compared to BTLH. (b) Eye HS size increases exponentially with T_e. HS size increases rapidly above 32 °C, 2°C higher than in BTLH. Like BBLH heat is dissipated at low T_e (~4.4 mW @ 25 °C), but absorbed at higher T_e (0.8 mW @ 41 °C).

CONCLUSIONS

- The linear relationship of T_s to T_e, observed in all 3 species indicates that environmental temperature might have some influence on thermal load.
- Eye HS size likely an exponential function of T_e. May serve to increase the area of heat dissipation rather than increase T_s.
- HS size is similar for two of three species at corresponding T_e values. While the pattern of change in HS area is similar between a mid- and high elevation species, a higher HS T_s is seen in the mid-elevation hummingbirds.

ACKNOWLEDGEMENTS

Funding was provided by NASA (10-BIOCLIM10-0094) and the Richter Scholar Program at George Fox University. We thank Luke Andrew for his assistance in the field.