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Water and energy economy of an omnivorous bird: Population differences in the Rufous-collared Sparrow (*Zonotrichia capensis*)

Pablo Sabat [a b], Grisel Cavieres [a], Claudio Veloso, Mauricio Canals [a]

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Abstract

We investigated the intraspecific variation in basal metabolic rate (BMR) and total evaporative water loss (TEWL) in the omnivorous passerine *Zonotrichia capensis* from two populations inhabiting regions with different precipitation regimes and aridity indices. Values of TEWL in birds from the semi-arid region were significantly lower than those found in sparrows from the mesic region. TEWL in birds from the semi-arid site was 74% of the expectation based on body mass for passerines from mesic areas and similar to the allometric expectation for passerines from arid environments. In sparrows from the mesic area, TEWL was higher than predicted by their body mass for passerines from arid environments (133%), but very close (97%) to the expectation for passerines from mesic areas. BMR values were 25% lower in sparrows from the semi-arid region. The lower TEWL and BMR of birds from the semi-arid region may be a physiological adjustment that allows them to cope with fewer resources and/or water. We propose that the lower endogenous heat production in birds from the semi-arid environment may decrease their water requirements.

Introduction

Organisms can survive and colonize xeric environments through mechanisms acting at cellular, physiological, ecological and/or behavioural levels (Cade et al., 1965, Casotti and Richardson, 1992, Tieleman et al., 1999, Haugen et al., 2003, Bozinovic and Gallardo, 2006, Bozinovic et al., 2003).

Because of their diurnal habits, high mass-specific metabolisms, and high body temperatures, passerines tend to have proportionately high rates of water flux. For xeric-adapted birds, one trait may be possessing low total evaporative water loss (TEWL) rates. Such physiological traits would allow birds to conserve water by reducing insensible water losses (Williams, 1996, McNab, 2002, Tieleman et al., 2003, Vikelski et al., 2003). Some authors have proposed that the low productivity of desert and semi-desert environments selectively favours animals with lower energy requirements. This hypothesis predicts that animals with a low basal metabolic rate (BMR) are more likely to inhabit xeric environments (Dawson and Bennett, 1973, Schleucher et al., 1991). The scarcity of water in these environments may also be a selective pressure favouring lower BMRs as lower endogenous heat production may decrease water requirements for evaporative cooling (Dawson, 1984).

Recent evidence has shown that energy and water requirements not only vary among species from desert and non desert habitats (see Withers and Williams, 1990, Hinsley et al., 1993, Williams and Tieleman, 2000), but also along an aridity gradient (Tieleman et al., 2004). This suggests that physiology is responsive to and reflects small differences in water availability and temperature. Several studies have examined water conservation in birds at the interspecific level (see also Tieleman et al., 2002, Tieleman et al., 2003); however, relatively few have sought to understand water conservation at either the intraspecific level (Arieli et al., 2002, Williams and Tieleman, 2000) or between populations of the same

species that inhabit both mesic and arid environments (Macmillen and Hinds, 1998). However, inter-populational differences in the energy and water economy among birds may be widespread but it is not universal. For example, Macmillen and Hinds (1998) compared the water economy of coastal and desert populations of house finches (*Carpodacus mexicanus*) and reported that birds from the Mojave Desert are more economical in water use (ca. 40% lower TEWL) rather than California coastal forms. By the other hand, Thomas et al. (2001) found no evidence of local adaptation in resting metabolic rates of blue tits (*Parus caeruleus*), in response to hot climates. Intraspecific differences in the physiology of geographically separated populations can provide insight into the evolutionary processes that permit species to cope with environmental variability. These studies are, therefore, important for understanding the origin of physiological diversity and the evolution of physiological tolerance (Garland and Adolph, 1991, Spicer and Gaston, 1999).

To investigate intraspecific variability in energy and water budgets, we measured BMR, TEWL, in the passerine bird, Rufous-collared Sparrow (*Zonotrichia capensis*, Emberizidae). We made these measurements in birds from two localities that varied in both annual precipitation and temperature. We also assessed how the nasal passages affected the capacity to recovery water from expelled air. *Zonotrichia capensis* is an omnivore distributed throughout the neotropics (from southeast México to Cabo de Hornos; Goodall et al., 1951). In Chile, it is nearly ubiquitous, inhabiting areas as different as deserts and rain forests from 0to

more than 3600 m.a.s.l. (Araya, 1996). We predicted that animals from the southern and wet area would have higher levels of energy production (BMR) and water flux (TEWL), than those from the northern xeric area.

Section snippets

Animals and capture

Sparrows were collected during the austral winter of 2005 from two localities in Chile: (1) La Serena (29° 54′S, 71° 15′W, n=6), and (2) Quebrada de la Plata (33° 31′S, 70° 50′W, n=9). Our study sites varied in mean annual rainfall: La Serena is semi-arid, and receives 100 mm per year, whereas Quebrada de la Plata is mesic and receives 367 mm per year, and their aridity scores using the index of de Martone, (Martone index=P/(T+10), where P is annual precipitation in mm, and T is mean annual …

Results

Values of TEWL in birds from the semi-arid region of La Serena were significantly lower than those found in sparrows from Quebrada de la Plata, which is the mesic region (locality: $F_{1,10}$=16.60, p=0.002, Fig. 2). We also found that TEWL increased with increasing T_a (T_a: $F_{2,22}$=268.4, p<0.001, Fig. 2). BMR values were 25% lower ($F_{1,20}$=27.08, p<0.001, Table 1) in sparrows from La Serena than those of birds from Quebrada de la Plata. Coupled with the increase in TEWL, body temperature was also…

Discussion

In this paper we tested for intraspecific variability in energy and water budgets, between populations of the passerine bird, Rufous-collared Sparrow. The study of Tieleman et al. (2002) account for interspecific differences in TEWL and BMR in an aridity gradient. In this study, we confirm the effect of climate on the water and energy economy of an granivorous bird at an inter population level. Rufous-collared sparrows from both populations maintain low TEWL when exposed to 25 and 30°C.…

Acknowledgements

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Evaporative water loss in Kuhl's pipistrelles declines along an environmental gradient, from mesic to hyperarid

2020, Comparative Biochemistry and Physiology -Part A : Molecular and Integrative Physiology

> *Citation Excerpt :*
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> ...For measurements on bats wearing a mask, our values were higher, but within 1 S.D. of the mean of those measured by Muñoz-Garcia et al. (2012b). Our finding, that groups differ in their water loss depending on the aridity of the location of the group's origin are similar to those of other studies (Herreid and Schmidt-Nielsen, 1966; Williams, 1996; MacMillen and Hinds, 1998; Tracy and Walsberg, 2001; Tieleman and Williams, 2002; Sabat et al., 2006; Dunbar and Brigham, 2010; Klüg-Baerwald and Brigham, 2017). Herreid and Schmidt-Nielsen (1966), for example, reported that the Brazilian free-tailed bat (Tadarida brasiliensis), a species that tends to inhabit arid regions, has lower water loss per

milliliter of O2 consumed than the big brown bat (Eptesicus fuscus), a species of more mesic habitats.…

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Reaction norms for heat tolerance and evaporative cooling capacity do not vary across a climatic gradient in a passerine bird

2019, Comparative Biochemistry and Physiology -Part A : Molecular and Integrative Physiology

Citation Excerpt :

…The lack of variation of any thermoregulatory variables (EWL, RMR, EHL/MHP or Tb) among sparrow-weaver populations following acclimation suggests the shapes of reaction norms for heat tolerance and evaporative cooling capacities are similar across this species' range. Previous studies have reported lower EWL and RMR at thermoneutrality in arid-zone species compared to mesic counterparts (Tieleman et al., 2002, 2003b; Williams, 1996), and some studies suggest these patterns also exist at the intraspecific level (MacMillen and Hinds, 1998; Noakes et al., 2016; Sabat et al., 2006). The absence of interpopulation variation in RMR and EWL of sparrow-weavers after acclimation highlights that these patterns can arise from phenotypic flexibility, although common-garden experiments have demonstrated a genotypic basis for metabolic differences among populations of Saxicola torquata (Wikelski et al., 2003) and great tits Parus major (Broggi et al., 2005).…

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The interplay between ambient temperature and salt intake affects oxidative status and immune responses in a ubiquitous Neotropical passerine, the rufous-collared sparrow

2019, Comparative Biochemistry and Physiology -Part A : Molecular and Integrative Physiology

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> ...These two temperatures are comparable to the mean of daily maximum temperatures experienced by wild birds in winter and summer, respectively. We were confident that these two temperatures represent contrasting thermoregulatory demands because we previously observed a 60% increase in oxygen consumption relative to BMR at 17 °C in Z. capensis from Central Chile (Sabat et al., 2006). Thus, our experiment included four total treatments: SW-27 (n = 8), SW-17 (n = 9), TW-17 (n = 7) and TW-27 (n = 7)....

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Osmoregulatory and metabolic costs of salt excretion in the Rufous-collared sparrow Zonotrichia capensis

2013, Comparative Biochemistry and Physiology - A Molecular and Integrative Physiology

> *Citation Excerpt :*
>
> ...Water treatments were available to birds for 24 h. Fluid intake rates were determined using graduated inverted plastic tubes of 100 mL and corrected for evaporation by using control tubes located outside the experimental cage. After habituating birds to captive conditions for 31 days, we measured the basal metabolic rate (BMR) at 30 °C, which is

within the thermoneutral zone for this species (Sabat et al., 2006). Then, each bird was assigned to one of two treatments: one group was housed in an aviary with mealworms, bird seed and tap water (FW acclimated group, n = 10) and the other with mealworms, bird seed and salt water (SW acclimated group, n = 10)....

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