Appendix S1

Evolution of avian heat tolerance: The role of atmospheric humidity

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Ecology

Section S1: Materials and Methods

Study species

We quantified HTL, $T_b$max and associated thermoregulatory variables at high T_{air} for both dry and humid conditions among 408 individuals representing 29 species (*Pycnonotus tricolor* and *Lanius collaris* occurred at multiple sites) in this study. All measurements from our arid (n = 9 species), montane (n = 9 species) and lowland (n = 13 species) sites took place during the austral spring/summer of 2021 - 2022 (see Appendix S1: Table S1 and S2).

We include published data collected under dry conditions for both montane (n= 9 species, n = 100 individuals) and lowland species (n = 11 species, n = 109 individuals). Data for lowland species were obtained from Freeman *et al*. (2022), collected near our study site (28°460S, 32°20E) following identical protocols to this study (Appendix S1: Table S1). All data for Rudd's apalis (*Apalis ruddii* – this study) and pink-throated twinspot (*Hypargos margaritatus* – this study) were collected during this study (Appendix S1: Table S7) while data for blue waxbills (*Uraeginthus angolensis*) were obtained from Liddle *et al.* (unpublished data) at the same study site. Dry air data for montane species were also obtained from Freeman *et al*. (2022) and collected at the same site as in the present study (Appendix S1: Table S1). Overall, our analysis includes data from 626 individuals (humid, n = 307; dry, n = 320) from 30 species, 15 families and three orders - Passeriformes, Piciformes and Coraciiformes.

Air and body temperature measurements

Temperature-sensitive passive integrated transponders (PIT) tags (Biotherm 13, Biomark, Boise, ID, USA) were injected into the peritoneal cavity of each bird prior to the commencement of experimentation to measure body temperature. PIT tags were calibrated before use in a circulating water bath (model F34, Julabo, Seelbach BW, DE) from temperatures ranging between 30 and 50 °C against a thermocouple meter (TC-1000, Sable Systems, Las Vegas, NV, USA), which was verified against a mercury-in-glass thermometer with NIST-traceable accuracy before and after the PIT tag calibration. Measured temperatures from pit tags deviated by 0.13 ± 0.05 °C (n = 30) from actual values and we corrected for measured body temperature values accordingly. A reader and transceiver system (HPR +, Biomark, Boise ID, USA) was used to record data from PIT tags. During experimentation T_{air} within the metabolic chamber was measured using a thermistor probe (TC-100, Sable Systems, Las Vegas, NV, USA) which was inserted through a small hole in the side of the chamber sealed by a rubber grommet.

Gas exchange measurements

Evaporative water loss (EWL) and carbon dioxide production ($\dot{V}_{CO_2}$) were measured using an open flow-through respirometry system, with our set up identical to that described by Freeman *et al.* (2020, 2022). Birds were placed individually into 3-L (200 mm high × 150 mm wide × 100 mm deep) plastic metabolic chambers known to not absorb water vapour (Whitfield *et al*. 2015), fitted with a raised mesh platform ∼10 cm above a ~1-cm mineral oil layer into which excreta fell to prevent evaporation affecting measured rates of evaporative water loss. Metabolic chambers were then placed inside a modified ∼100-L cooler box in which T_{air} was regulated by a Peltier device (AC-162 Thermoelectric Air Cooler, TE Technology, Traverse City MI, USA) and adjusted using a digital controller (TC-36–25-RS485 Temperature Controller, TE Technology, Traverse City MI, USA).

For all measurements under dry conditions (hereafter, the dry protocol), methods were identical to those of Freeman *et al.*(Freeman *et al*. 2020, 2022). In brief. atmospheric air supplied by an oil-free compressor and scrubbed of water vapour using a membrane dryer

(Atlas Copco SD1N air dryer and filter, Atlas Copco, Stockholm, Sweden). Dried air was then split into an experimental, additional dry line and a dry air baseline channel using Bev-A-Line IV tubing (Thermoplastic Processes Inc., Warren, NJ, USA). A needle valve (Swagelok, Solon, OH, USA) maintained flow rates to the baseline channel ("dry baseline") at ~ 1 L min^{-1}, whereas the experimental line proceeded directly to the metabolic chamber with flow rates being regulated by a mass flow controller (Alicat Scientific Inc., Tuscon AZ, USA) calibrated using a soap-bubble flow meter (Gilibrator 2, Sensidyne, St Petersburg, FL, USA). Flow rates were adjusted to minimise water vapour pressure within the metabolic chamber (mean in chamber humidity across sites = 1.07 ± 0.84 g H_2O m^{-3}), and varied between and 3 L min^{-1} and 24 L min^{-1}. Freeman *et al.*(Freeman *et al*. 2020, 2022)

For measurements at ~19 g H_2O m^{-3} (hereafter, humidity protocol) downstream of the compressor the experimental air stream was split into two channels. In one (humid stream), flow rates were regulated at 1000 – 4000 mL min^{-1} using a mass flow controller (Alicat Scientific Inc., Tuscon AZ, USA) before air was passed through three water-filled bubblers connected in series. Each bubbler was constructed from a 3-L sealable screw-top bottle (diameter =14cm, height=25cm) (Universal Jar, Tupperware, Orlando, FL, USA) with in- and outlet fittings installed in the lid and incurrent air passing through tubing and an aquarium stone positioned ~ 1 cm from the bottom of the water column. The first bubbler was kept at (T_{air} = ~35 °C). The second and third bubblers were placed in a temperature-controlled chamber (PELT-5, Sable Systems, Las Vegas NV, USA) set to a T_{air} slightly higher than the desired chamber dewpoint (~22°C or 19 g H_2O m^{-3}).

The second air stream (dry stream) consisted of dry air and merged with the experimental humid stream downsteam of the bubblers, permitting dry air at flow rates regulated by second mass flow controller (Alicat Scientific Inc., Tuscon AZ, USA) to be mixed with our humidified air upstream of the metabolic chamber. We found that mixing air humidified to values above the desired chamber values with dry air provided more precise control of chamber humidity than using bubblers alone. Regular adjustments of the dry stream flow rates permitted chamber humidity levels to be regulated precisely (mean chamber humidity across sites = 19.21 ± 1.20 g H_2O m^{-3}) despite evaporative water loss from the bird increasing with T_{air}. Downstream of the experimental humid stream and dry stream merge, the channel was split into a humid baseline channel with flow rate regulated using a needle valve (~ 1 L min^{-1}) allowing for the precise humidity of the air entering the metabolic chamber to be monitored and recorded. Downstream of this final split, incurrent flow rates were measured upstream of the chamber inlet using a 0-10 L min^{-1} mass flow controller (Alicat Scientific Inc., Tuscon AZ, USA), set to its maximum flow rate, thereby functioning as a mass flow meter at flow rates < 10 L min^{-1}, also calibrated using a Gilibrator 2 flow meter. Incurrent flow rates varied between 240 - 4000 mL min^{-1} for the humidity protocol. Adjustments of flow rates and/or in current humid air took place during transitional periods ~10-15 minutes before measurements at a set point T_{air} where possible, maximizing the likelihood that equilibrium conditions within the metabolic chamber were reached (Lasiewski *et al*. 1966). Should humidity values or T_{air} within the chamber have been unstable or still transitioning to the desired set point, additional time was permitted to ensure data were collected from stable O_2, CO_2 and H_2O traces at the desired humidity level.

By periodically adjusting T_{air} in the temperature-controlled chamber housing the second and third bubblers and flow rates of the humid and dry air streams, we were able to maintain approximately constant values of absolute humidity in the metabolic chamber (i.e., the humidity experienced by a bird). Across study sites, absolute humidity within the metabolic chambers averaged 19.48 ± 1.19 g H_2O m^{-3} (n =1873), comparable with that used in previous studies of the effects of humidity on avian thermoregulation (Powers 1992, Gerson *et al*. 2014, van Dyk *et al*. 2019) and similar to the highest monthly

(January/February) humidity values experienced by birds at our lowland site (mean maximum absolute humidity ~ 18.2 g H_2O m^{-3} at 30 °C) (Fick and Hijmans 2017). Site-specific mean chamber humidities varied by < 1.5 g H_2O m^{-3}: arid (19.56 ± 1.26 g H_2O m^{-3}, n = 446), montane (18.96 ± 1.05 g H_2O m^{-3}, n =499) and lowland sites (20.37 ± 1.33 g H_2O m^{-3}, n = 928). As chamber humidities were equivalent to dewpoints of ~22-23 °C, we set up all equipment in a controlled climate with T_{air} = ~35 °C to avoid condensation in analysers and tubing. For the dry protocol, incurrent humidity was ~0 g H_2O m^{-3}, whereas excurrent humidity (i.e., the humidity experienced by birds in chamber once evaporative water loss is taken into account) was maintained ~1 g H_2O m^{-3}. For dry runs, mean absolute humidity within the metabolic chamber was 1.07 ± 0.84 g H_2O m^{-3} (n =715).

For both dry and humid protocols, air from baselines or chamber channels was sequentially subsampled using a respirometry multiplexer (model MUX3-1101-18M, Sable Systems) in manual mode, at a flow rate of ~ 160 mL min^{-1} regulated by a subsampling pump (model SS4, Sable Systems, Las Vegas NV, USA) and pulled through a CO_2/H_2O analyser (LI-840A, LI-COR, Lincoln NE, USA) followed by an O_2 analyser (FC-10A, Sable Systems, Las Vegas NV, USA). The CO_2/H_2O analyser was regularly zeroed using pure nitrogen (AFROX, Johannesburg, South Africa) and spanned using a 2000 ppm CO_2 in N_2 gas mix (AFROX) or humidified air with a dewpoint 5 - 6 °C below ambient T_{air} generated using a dew point generator (DG-4, Sable Systems, Las Vegas NV, USA). The O_2 analyser was periodically spanned to 20.95% using dry, CO_2-free air scrubbed of CO_2.

Data were acquired every 5 s from analysers using an analog–digital converter (model UI-3, Sable Systems, Las Vegas NV, USA) which converted the voltage inputs to digital values. We then recorded these values using a computer using Expedata software (Sable Systems, Las Vegas NV, USA).

Experimental protocol

We measured T_b, evaporative water loss and metabolic rate using both the dry and humidity protocols. Measurements typically lasted 2 – 4 h and began with a bird placed in a chamber at T_{air} = 28 °C, and given at least 1 h to habituate to conditions in the metabolic chamber for both the dry and humid assessments. For the dry protocol, T_{air} setpoints beginning from T_{air} = 28 °C were increased incrementally by 4 °C until T_{air} = 40 °C and then increased incrementally by 2 °C until birds reached their thermal endpoint(Freeman *et al*. 2022). For the humid protocol, T_{air} setpoints started at 34 °C and were increased incrementally by 2 °C until birds reached their thermal endpoint. Transitions between successive T_{air} setpoints took 10–15 min. At each setpoint T_{air}, birds were exposed to stable T_{air} and humidity for a minimum of 15-20 minutes until traces of O_2, CO_2 and H_2O were stable for at least 5 min. The stepped respirometry protocol involving brief (15-20 min) exposure to each T_{air} setpoint used in this study has been shown to yield patterns of evaporative water loss, metabolic rate and T_b as functions of T_{air} similar to those using a steady state protocol where birds experience each T_{air} setpoint for several hours (Short *et al*. 2022).

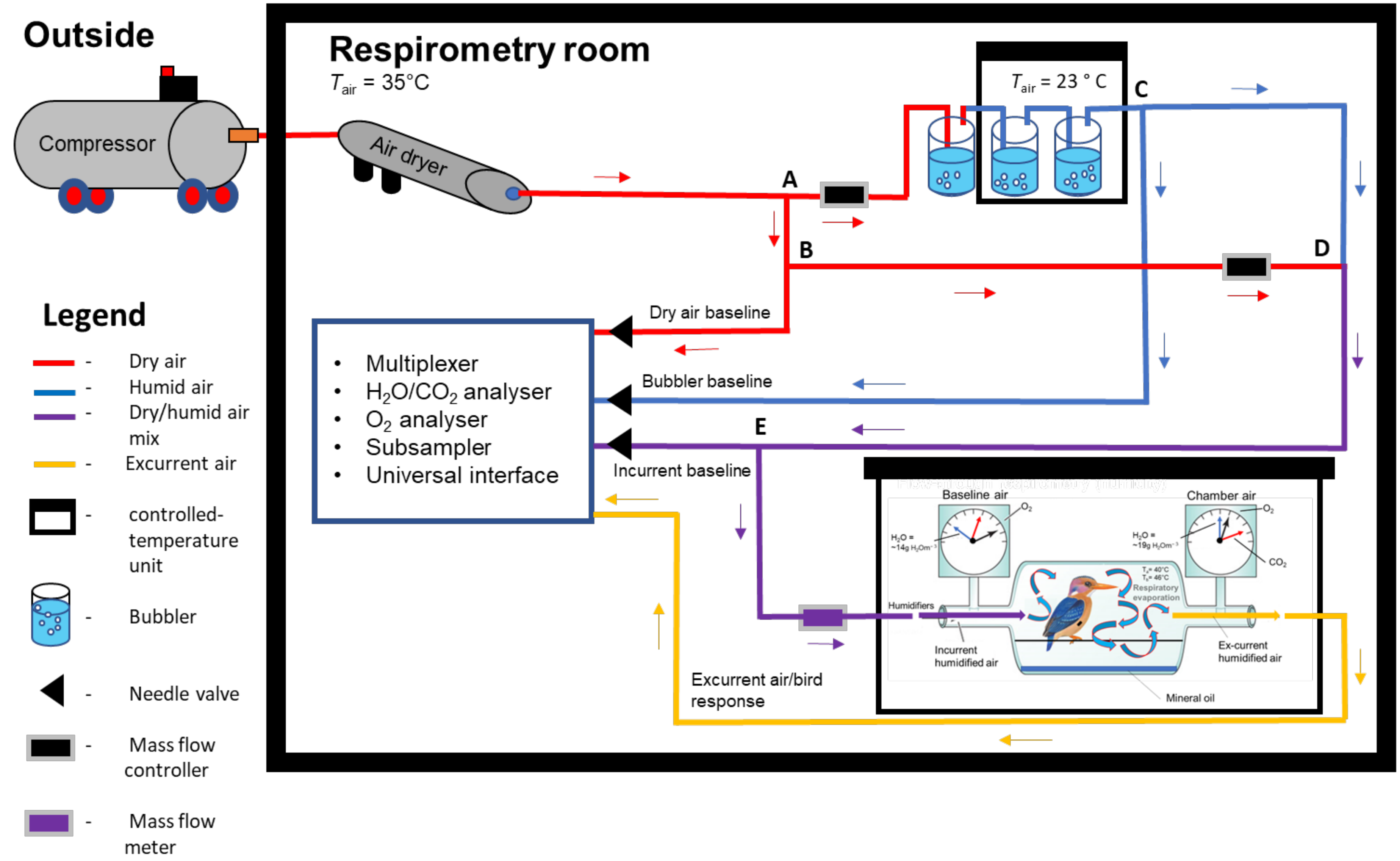
Outside
Compressor
Respirometry room
T_{air} = 35°C
Air dryer
T_{air} = 23 ° C
A
B
C
D
E
Dry air baseline
Bubbler baseline
Incurrent baseline
Multiplexer
H_2O/CO_2 analyser
O_2 analyser
Subsampler
Universal interface
Baseline air
Chamber air
O_2
H_2O = ~14g H_2Om^{-3}
H_2O = ~19g H_2Om^{-3}
CO_2
T_a= 40°C
T_b= 46°C
Respiratory evaporation
Humidifiers
Incurrent humidified air
Ex-current humidified air
Mineral oil
Excurrent air/bird response
Legend
Dry air
Humid air
Dry/humid air mix
Excurrent air
controlled-temperature unit
Bubbler
Needle valve
Mass flow controller
Mass flow meter

Figure S1

Figure S1 – Humidity setup; Visual representation of the flow through respirometry setup used in this study to manipulate and regulate levels of absolute humidity within the metabolic chamber and subsequently measure avian thermoregulatory response variables pertaining to evaporative water loss (EWL), resting metabolic rate (RMR), body temperature (T_b) at incrementally increasing air temperatures until birds displayed signs associated with severe hyperthermia. At point A, our dry air line was split into an experimental channel line and dry air baseline. The dry air baseline and regulatory dry air line are subsequently split at point B. At point C experimental line air has now been humidified by our bubblers (dew point = 22-23 °C) and was split again into a bubbler baseline (which travels to our analysers to determine current absolute humidity) and a continuing experimental "humidified" line. If required at point D, dry air from our regulatory dry air line was mixed with our experimental "humidified" line air to down regulate to the desired absolute humidity. The humidified air is split one last time at point E into our main humidity baseline (provides a value for incurrent absolute humidity) and our incurrent chamber line which passes through a mass flow meter to measure the exact flow rate of humidified air entering the chamber.

Section S2: Additional figures and tables

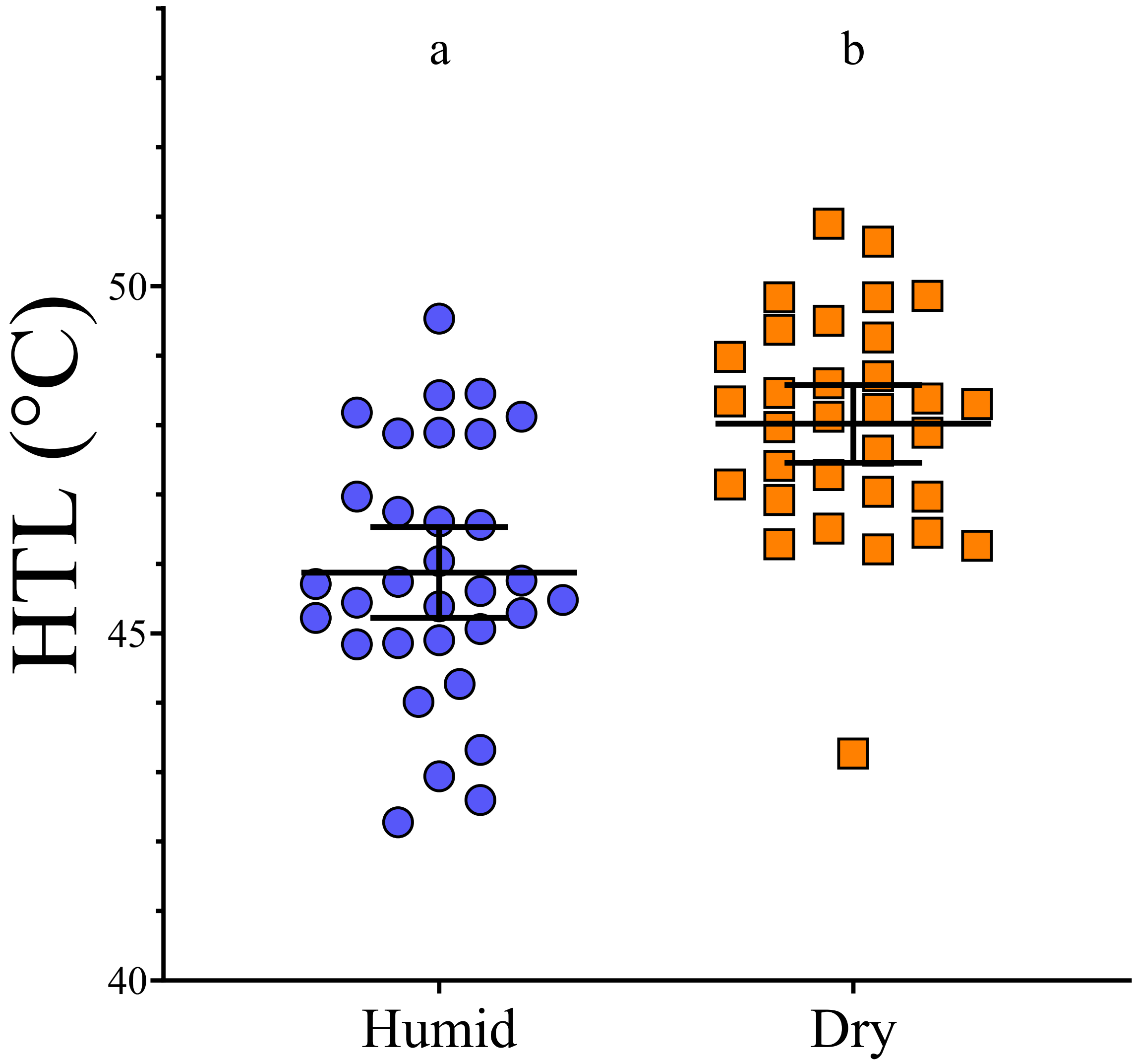

Figure S2 Overall heat tolerance limits (HTL; i.e., maximum air temperature tolerated) among 30 South African bird species (two species were assessed at multiple sites) subjected to a stepped respirometry protocol under dry (~1 g H_2O m^{-3}) or humid (~19 g H_2O m^{-3}) conditions. Horizontal lines represent mean values and vertical lines 95% confidence intervals. Letters above plots denote significant differences ($\alpha = 0.05$) as derived from phylogenetic analysis (PhylANOVA) of variance post hoc multiple comparison assessments. Categories include humid (blue circles, n=32) and dry (orange squares, n=32). HTLs were significantly higher for species under dry conditions.

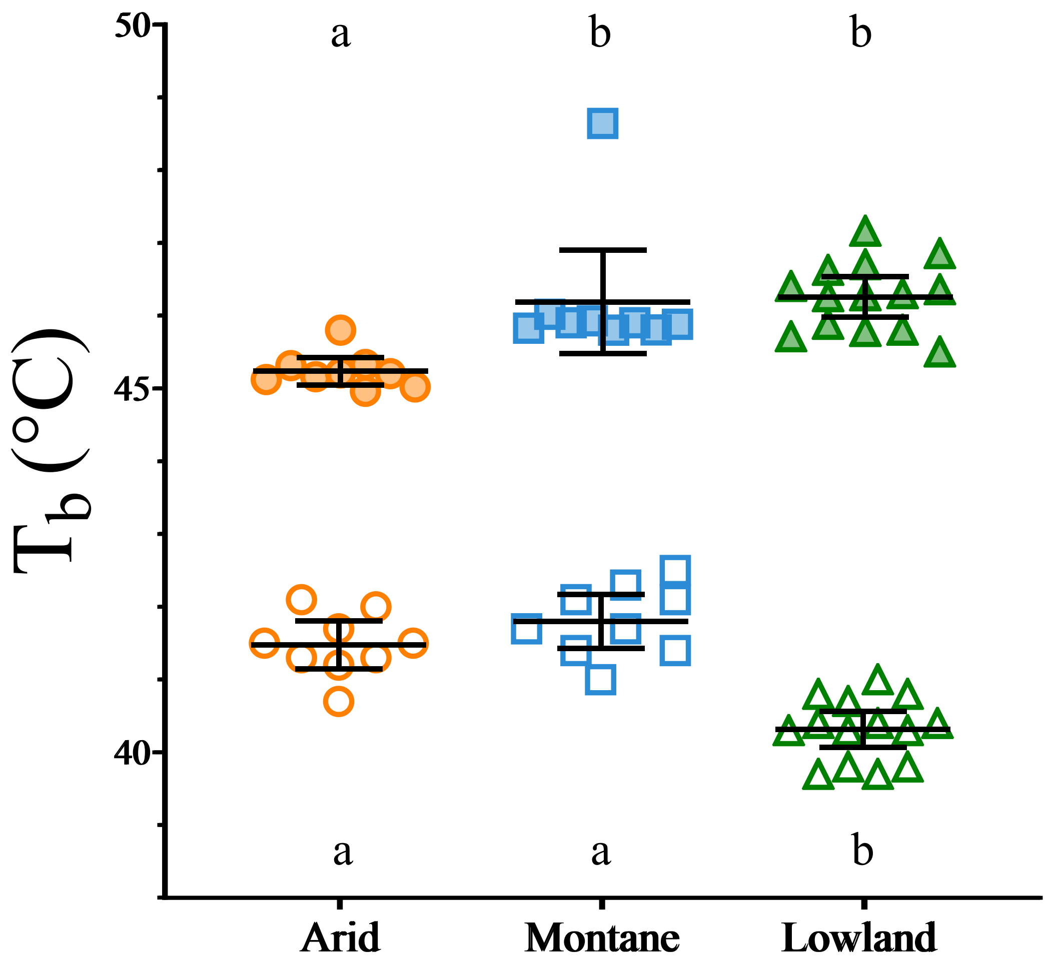

Figure S3 Maximum body temperature ($T_b max$; filled symbols) and normothermic body temperature ($T_b norm$; white filled symbols] varied significantly among 30 South African bird species across multiple climatic study sites with differing maximum air temperatures and humidity. Horizontal lines represent mean values and vertical lines represent 95% confidence intervals. Letters above plots denote significant differences ($\alpha < 0.05$) in $T_b max$ values between sampling localities; letters at the bottom denote significant differences ($\alpha = 0.05$) in $T_b norm$ values. Significant differences are derived from phylogenetic analysis of variance post-hoc multiple comparison assessments (PhylANOVA) and conventional Tukey multiple comparison assessments regressions. Climate categories are hot arid (orange circles, *n*=9), mesic montane (blue squares, *n*=9) and humid lowland (green triangles, *n*=14).

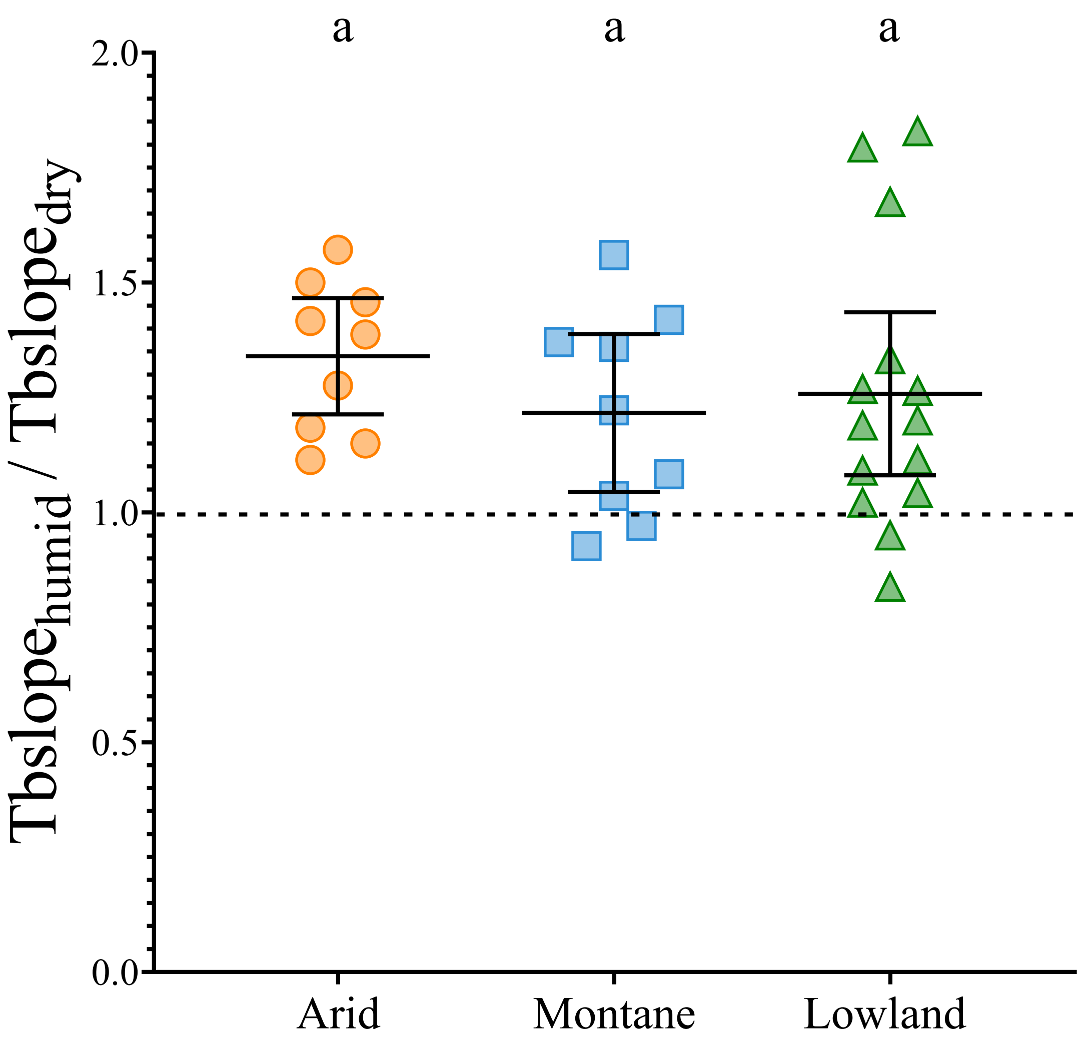

Figure S4 Proportional difference in $T_b$slope (humid/dry) for birds subjected to a stepped respirometry protocol under dry (~1 g H_2O m^{-3}) or humid (~19 g H_2O m^{-3}) conditions did not differ significantly between our three climatic study areas. Climate categories are hot arid (orange circles, *n*=9), mesic montane (blue squares, *n*=9) and humid lowland (green triangles, *n*=14). Horizontal lines represent mean values and vertical lines 95% confidence intervals. Letters above plots denote significant differences ($\alpha < 0.05$) in $T_b$slope values between sampling localities. Significant differences are derived from phylogenetic analysis of variance post-hoc multiple comparison assessments (PhylANOVA) and conventional Tukey multiple comparison assessments regressions.

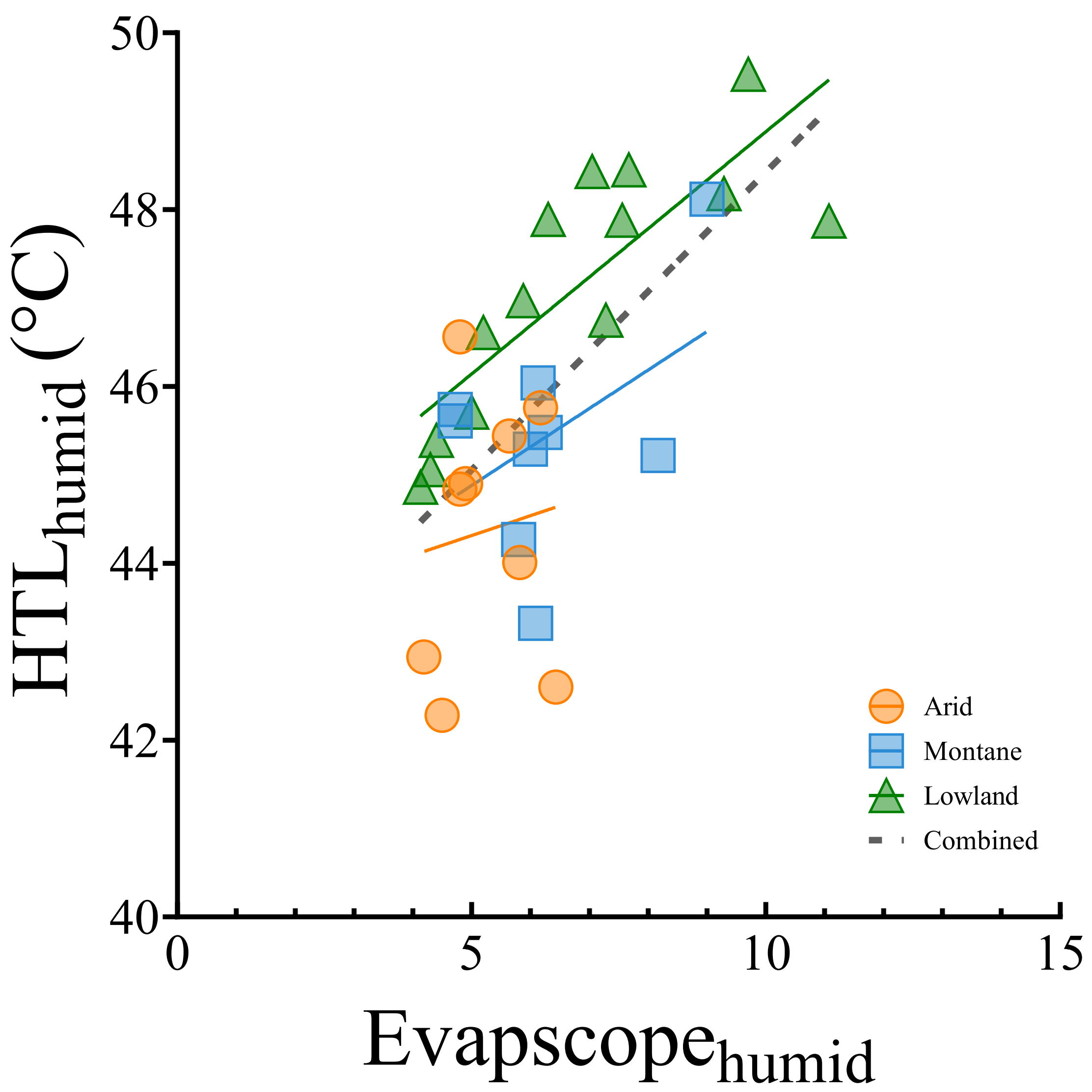

Figure S5 The relationship between Evapscope (maximum evaporative water loss (EWL)/minimum evaporative water loss) and heat tolerance limits (HTL - i.e., maximum air temperature tolerated) under our humid protocol (19 g H_2O m^{-3}) for birds at our hot arid (orange circles, *n*=9), mesic montane (blue squares, *n*=9) and humid lowland (green triangles, *n*=14) study sites. A combined slope is indicated by the black dotted line to represent overall response of evapscope and HTL across all sites. The increasing relationship of HTL in response to increasing Evapscope was mostly driven by lowland species which had lowered minimum EWL, however, support for this pattern was weak among montane and arid species. The increasing relationship within the montane species was driven primarily by *Quelea quelea* (as indicated by the highest blue square), the positive relationship among the other montane species was weak.

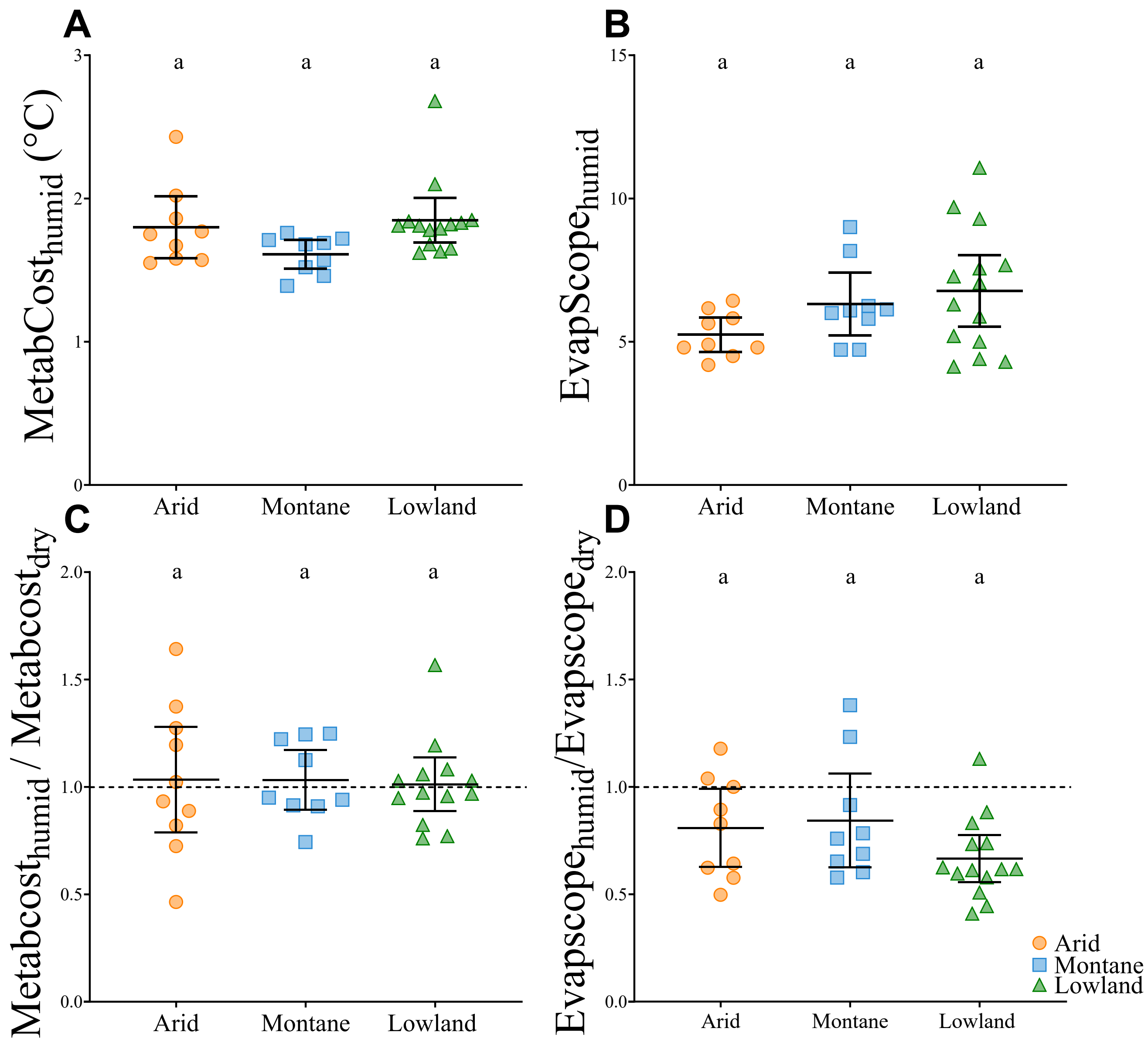

Figure S6 (A–D) Variation in ratio of minimum RMR and Maximum RMR under humid conditions [Metabcost; (A)], the ratio of maximum to minimum thermoneutral evaporative water loss [EvapScope (B)], variation in MetabCost between humid and dry conditions [Metabcost$_{humid}$/Metabcost$_{dry}$; (C)], and variation in EvapScope between humid and dry conditions [EvapScope$_{humid}$/EvapScope$_{dry}$; (D)] among 30 South African bird species inhabiting hot arid (orange circles, *n*=9), mesic montane (blue squares, *n*=9), or humid lowland (green triangles, *n*=14) climates. Horizontal dotted lines (C-D) represent ratio of 1:1 of MetabCost and Evapscope between humid and dry conditions, respectively. Horizontal lines represent mean values, and vertical lines 95% confidence intervals. Letters above plots denote significant differences (α = 0.05) as identified using phylogenetic ANOVA post hoc multiple (PhylANOVA) comparison assessments. Significant differences were not detected among assemblages from the climatic areas for (A-D).

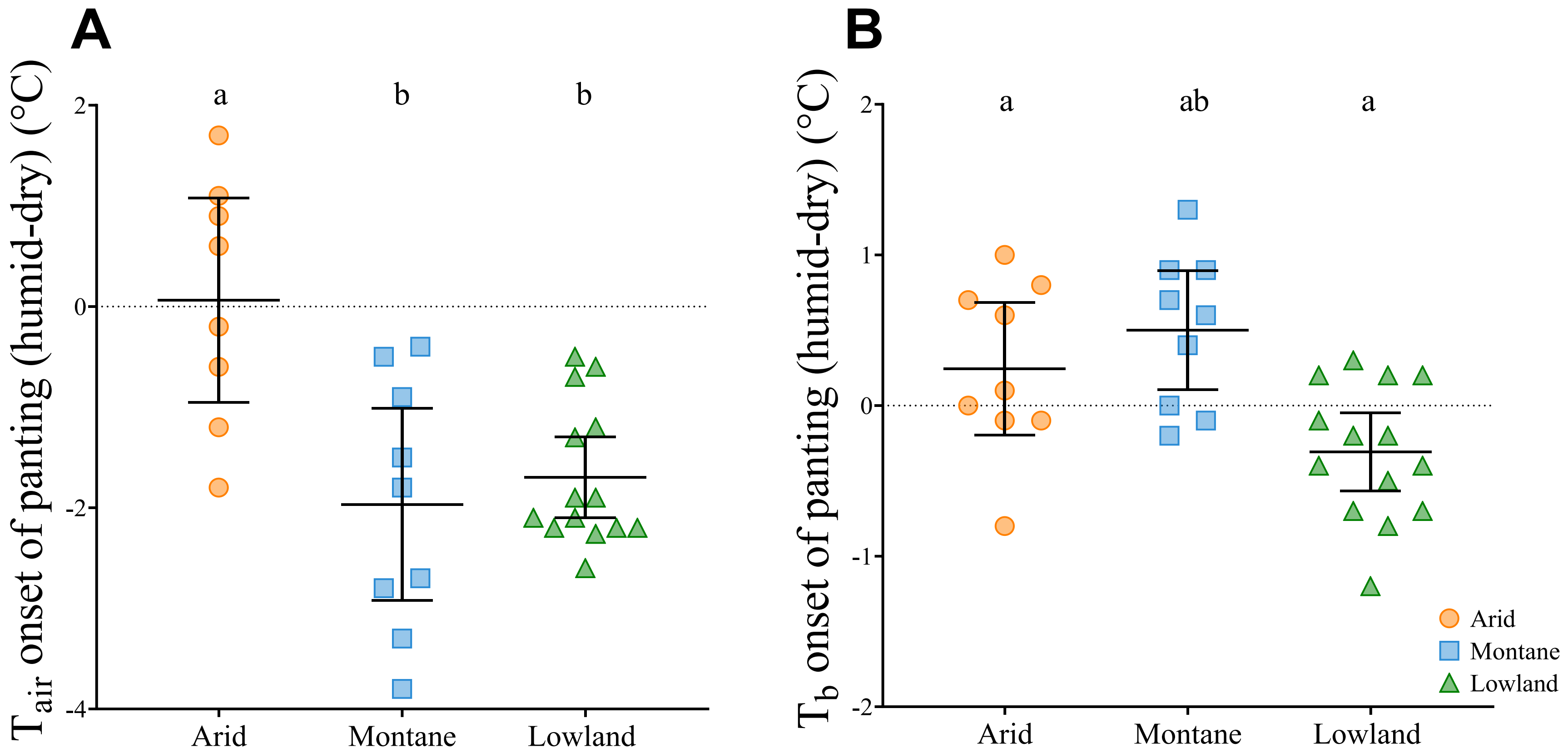

Figure S7 Onset of panting as a function of (A) air temperature (T_{air}) and (B) body temperature (T_b) for birds at the hot arid (orange circles, n=9), mesic montane (blue squares, n=9) and humid lowland (green triangles, n=14) site. Horizontal dotted lines represent zero-change between humid and dry conditions. Horizontal lines represent mean values and vertical lines 95% confidence intervals. Letters above plots denote significant differences ($\alpha < 0.05$) among climatic areas values between sampling localities. Significant differences are derived from phylogenetic analysis of variance post-hoc multiple comparison assessments (PhylANOVA) and conventional Tukey multiple comparison assessments regressions.

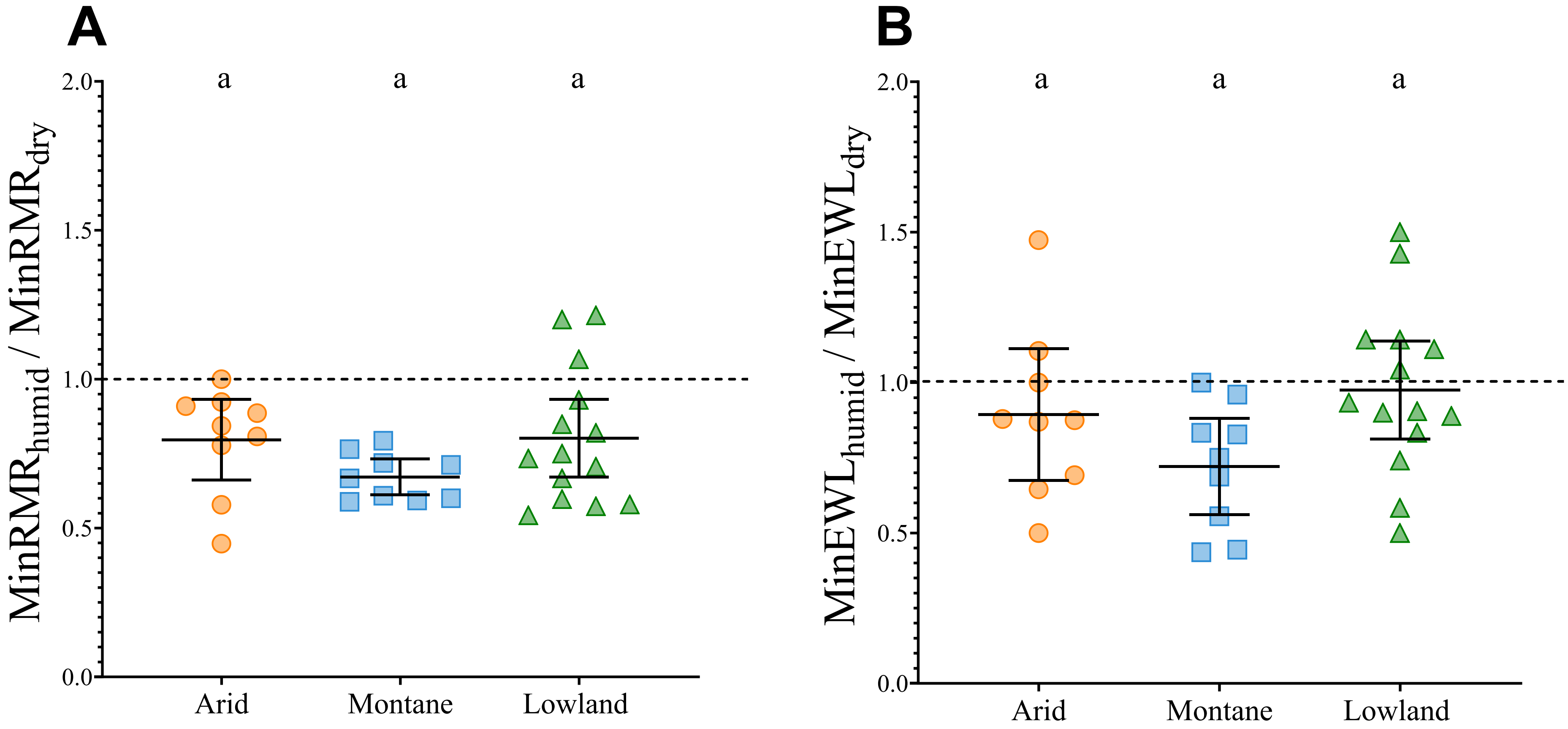

Figure S8 Minimum values recorded for (A) resting metabolic rate (RMR) and (B) evaporative water loss *(EWL)* for birds at the hot arid (orange circles, *n*=9), mesic montane (blue squares, *n*=9) and humid lowland (green triangles, *n*=14) site. Horizontal dotted lines represent zero-change between humid and dry conditions. Horizontal lines represent mean values and vertical lines 95% confidence intervals. Letters above plots denote significant differences ($\alpha < 0.05$) among climatic areas values between sampling localities. Significant differences are derived from phylogenetic analysis of variance post-hoc multiple comparison assessments (PhylANOVA) and conventional Tukey multiple comparison assessments regressions.

Tables

Table S1 All 30 species' avian families, orders and sample sizes across the study sites (mesic montane, humid lowland and hot arid) under dry (~1 g H_2O m^{-3}) and humid (~19 g H_2O m^{-3}) conditions. Also included is the source of the data if individuals were not collected as part of the main study.

Common Name	Species	Family	Order	Study area (sample size)	Source
Dry Assessments (~1 g H_2O m^{-3})	n = 30	n = 15	n = 3	Lowland (n = 139) Montane (n = 100) Arid (n = 81)	
African Pygmy Kingfisher	*Ceyx pictus*	Alcedinidae	Coraciiformes	Lowland (n = 10)	Freeman *et al.* 2022
Black-headed Canary	*Serinus alario*	Fringillidae	Passeriformes	Arid (n = 5)	This study
Blue Waxbills	*Uraeginthus angolensis*	Estrelidae	Passeriformes	Lowland (n = 10)	Liddle *et al.* unpublished
Brown-hooded Kingfisher	*Halcyon albiventris*	Alcedinidae	Coraciiformes	Lowland (n = 10)	Freeman *et al.* 2022
Cape Bulbul	*Pycnonotus capensis*	Pycnonotidae	Passeriformes	Arid (n = 10)	Freeman *et al.* 2022
Cape Bunting	*Emberiza capensis*	Emberizidae	Passeriformes	Arid (n = 10)	This study
Cape White-eye	*Zosterops virens*	Zosteropidae	Passeriformes	Montane (n = 10)	Freeman *et al.* 2022
Collared Sunbird	*Anthreptes collaris*	Nectariniidae	Passeriformes	Lowland (n = 10)	Freeman *et al.* 2022
Dark-capped Bulbul	*Pycnonotus tricolor*	Pycnonotidae	Passeriformes	Montane (n = 10) Lowland (n = 10)	Freeman *et al.* 2022
Drakensberg Prinia	*Prinia hypoxantha*	Cisticolidae	Passeriformes	Montane (n = 10)	Freeman *et al.* 2022
Green-backed Camaroptera	*Camaroptera brachyura*	Cisticolidae	Passeriformes	Lowland (n = 10)	Freeman *et al.* 2022
Karoo Lark	*Certhilauda albescens*	Alaudidae	Passeriformes	Arid (n = 10)	This study
Karoo Prinia	*Prinia maculosa*	Cisticolidae	Passeriformes	Arid (n = 10)	This study
Lark-like Bunting	*Emberiza impetuani*	Emberizidae	Passeriformes	Arid (n = 6)	This study
Orange River White-eye	*Zosterops pallidus*	Zosteropidae	Passeriformes	Arid (n = 10)	This study
Pink-throated Twinspot	*Hypargos margaritatus*	Estreldidae	Passeriformes	Lowland (n = 10)	This study
Red-billed Quelea	*Quelea quelea*	Ploceidae	Passeriformes	Montane (n = 20)	Freeman *et al.* 2020

Table S1 Cont.

Common Name	Species	Family	Order	Study area (sample size)	Source
Red-capped Lark	*Calandrella cinerea*	Alaudidae	Passeriformes	Montane (n = 10)	Freeman *et al.* 2022
Red-capped Robin Chat	*Cossypha natalensis*	Muscicapidae	Passeriformes	Lowland (n = 10)	Freeman *et al.* 2022
Rudd's Apalis	*Apalis ruddi*	Cisticolidae	Passeriformes	Lowland (n = 10)	This study
Sombre Greenbul	*Andropadus importunus*	Pycnonotidae	Passeriformes	Lowland (n = 10)	Freeman *et al.* 2022
South African cliff swallow	*Hirundo spilodera*	Hirundinidae	Passeriformes	Montane (n = 10)	Freeman *et al.* 2022
Southern Fiscal	*Lanius collaris*	Laniidae	Passeriformes	Lowland (n = 10) Montane (n = 10)	Freeman *et al.* 2022
Southern Masked Weaver	*Ploceus velatus*	Ploceidae	Passeriformes	Montane (n = 10)	Freeman *et al.* 2022
Spectacled Weaver	*Ploceus ocularis*	Ploceidae	Passeriformes	Lowland (n = 10)	Freeman *et al.* 2022
Spike-heeled Lark	*Chersomanes albofasciata*	Alaudidae	Passeriformes	Montane (n = 10)	Freeman *et al.* 2022
White-throated Canary	*Serinus albogularis*	Carduelinae	Passeriformes	Arid (n = 10)	This study
Yellow Bishop	*Euplectes capensis*	Ploceidae	Passeriformes	Arid (n = 9)	This study
Yellow Weaver	*Ploceus subaureus*	Ploceidae	Passeriformes	Lowland (n = 9)	Freeman *et al.* 2022
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	Lybiidae	Piciformes	Lowland (n = 10)	Freeman *et al.* 2022
Humidity Assessments (~19 g H_2O m^{-3})	n = 30	n = 15	n = 3	Lowland (n = 132) Montane (n = 90) Arid (n = 85)	
African Pygmy Kingfisher	*Ceyx pictus*	Alcedinidae	Coraciiformes	Lowland (n = 10)	This study
Black-headed Canary	*Serinus alario*	Fringillidae	Passeriformes	Arid (n = 5)	This study
Blue Waxbills	*Uraeginthus angolensis*	Estrelidae	Passeriformes	Lowland (n = 10)	This study
Brown-hooded Kingfisher	*Halcyon albiventris*	Alcedinidae	Coraciiformes	Lowland (n = 10)	This study
Cape Bulbul	*Pycnonotus capensis*	Pycnonotidae	Passeriformes	Arid (n = 10)	This study
Cape Bunting	*Emberiza capensis*	Emberizidae	Passeriformes	Arid (n = 10)	This study
Cape White-eye	*Zosterops virens*	Zosteropidae	Passeriformes	Montane (n = 10)	This study
Collared Sunbird	*Anthreptes collaris*	Nectariniidae	Passeriformes	Lowland (n = 8)	This study
Dark-capped Bulbul	*Pycnonotus tricolor*	Pycnonotidae	Passeriformes	Montane (n = 10) Lowland (n = 10)	This study
Drakensberg Prinia	*Prinia hypoxantha*	Cisticolidae	Passeriformes	Montane (n = 10)	This study

Table S1 Cont.

Common Name	Species	Family	Order	Study area (sample size)	Source
Green-backed Camaroptera	*Camaroptera brachyura*	Cisticolidae	Passeriformes	Lowland (n = 10)	This study
Karoo Lark	*Certhilauda albescens*	Alaudidae	Passeriformes	Arid (n = 10)	This study
Karoo Prinia	*Prinia maculosa*	Cisticolidae	Passeriformes	Arid (n = 10)	This study
Lark-like Bunting	*Emberiza impetuani*	Emberizidae	Passeriformes	Arid (n = 10)	This study
Orange River White-eye	*Zosterops pallidus*	Zosteropidae	Passeriformes	Arid (n = 10)	This study
Pink-throated Twinspot	*Hypargos margaritatus*	Estreldidae	Passeriformes	Lowland (n = 10)	This study
Red-billed Quelea	*Quelea quelea*	Ploceidae	Passeriformes	Lowland (n = 10) Montane (n = 10)	This study
Red-capped Lark	*Calandrella cinerea*	Alaudidae	Passeriformes	Montane (n = 10)	This study
Red-capped Robin Chat	*Cossypha natalensis*	Muscicapidae	Passeriformes	Lowland (n = 10)	This study
Rudd's Apalis	*Apalis ruddi*	Cisticolidae	Passeriformes	Lowland (n = 10)	This study
Sombre Greenbul	*Andropadus importunus*	Pycnonotidae	Passeriformes	Lowland (n = 10)	This study
South African Cliff Swallow	*Hirundo spilodera*	Hirundinidae	Passeriformes	Montane (n = 10)	This study
Southern Fiscal	*Lanius collaris*	Laniidae	Passeriformes	Lowland (n = 10) Montane (n = 10)	This study
Southern Masked Weaver	*Ploceus velatus*	Ploceidae	Passeriformes	Montane (n = 10)	This study
Spectacled Weaver	*Ploceus ocularis*	Ploceidae	Passeriformes	Lowland (n = 5)	This study
Spike-heeled Lark	*Chersomanes albofasciata*	Alaudidae	Passeriformes	Montane (n = 10)	This study
White-throated Canary	*Serinus albogularis*	Carduelinae	Passeriformes	Arid (n = 10)	This study
Yellow Bishop	*Euplectes capensis*	Ploceidae	Passeriformes	Arid (n = 10)	This study
Yellow Weaver	*Ploceus subaureus*	Ploceidae	Passeriformes	Lowland (n = 10)	This study
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	Lybiidae	Piciformes	Lowland (n = 9)	This study

Table S2 Summary of the number of individuals and species for this study across study sites (Namaqualand, Harrismith and Hluhluwe) under dry (~1 g H_2O m^{-3}) and humid (~ 19 g H_2O m^{-3}) conditions and the corresponding ranges of flow-rates (ml min−1) and body mass (grams) across the sites.

Variable	Hot Arid (Namaqualand)	Mesic Montane* (Harrismith)	Humid Lowland* (Hluhluwe)	All sites
No. individuals (dry 0mg^{-3})	81	-	20	101
No. species (dry 0mg^{-3})	9	-	2	11
No. individuals (humid 19mg^{-3})	85	90	132	307
No. species (humid 19mg^{-3})	9	9	13	30
Mb Range Dry (min: max)	7.4: 32.8	-	9.6: 12.5	7.4: 32.8
Mb Range Humid (min: max)	6.9: 32.8	9.3: 42.8	7: 61.7	6.9: 61.7
Flow rate Range Dry (min: max)	600: 17 000	-	3 000: 16 000	3 000: 20 000
Flow rate Range Humid (min: max)	650: 4 000	500: 1 980	840: 2 900	500: 4 000

*Dry assessments for the mesic montane site and several lowland species were not performed for this study, see Freeman *et al.* (Freeman *et al*. 2022).

Table S3 Summary of thermoregulatory performance as a function of chamber air temperature (T_{air}) at humidity of ~ 19g H_2O m^{-3} in nine bird species from the arid study site (Namaqualand). T_b = body temperature, T_{air} = ambient temperature, RMR = resting metabolic rate, EWL = evaporative water loss, EHL= evaporative heat loss, MHP = metabolic heat production. Means ± SD and (n) are reported.

Variable	Black-headed Canary	Cape Bulbul	Cape Bunting	Karoo Lark	Karoo Prinia	Lark-like Bunting
Body mass (g)	**11.2±0.2 (5)**	**32.8±2.1 (10)**	**19.3±1.3 (10)**	**27.6±2.2 (10)**	**6.9±0.6 (10)**	**13.5±0.9 (10)**
Body temperature						
Min. T_b (°C)	41.5±0.6 (5)	42.1±0.4 (10)	42.0±0.7 (10)	41.3±0.8 (10)	40.7±0.4 (10)	41.7±0.5 (10)
Inflection T_{air} (°C)	N/A	40.9	N/A	N/A	N/A	N/A
T_b versus T_{air} slope (per °C)	0.41	0.39	0.43	0.39	0.53	0.37
Max T_b (°C)	45.2±0.3 (5)	45.0±0.8 (10)	45.3±0.8 (10)	45.2±0.5 (10)	45.3±0.7 (10)	45.1±0.2 (10)
Max T_{air} (°C)	42.5±1.6 (5)	45.8±2.2 (10)	42.3±1.9 (10)	46.6±1.4 (10)	44.8±1.1 (10)	45.4±0.9 (10)
T_b at onset of panting (°C)	43.6±0.4 (5)	42.4±0.5 (10)	43.9±0.6 (8)	42.1±1.1 (10)	44.2±0.7 (10)	43.08±0.7 (10)
T_{air} at onset of panting (°C)	38.3±0.8 (4)	37.6±2.1 (10)	39.1±1.1 (8)	38.8±1.8 (10)	41.8±0.7 (10)	40.3±1.7 (10)
Metabolic rate						
Min. RMR (W)	0.20±0.01 (5)	0.37±0.14 (10)	0.30±0.07 (10)	0.31±0.03 (10)	0.14±0.03 (10)	0.24±0.06 (10)
T_{uc} (°C)	N/A	N/A	N/A	N/A	N/A	N/A
RMR slope (mW $°C^{-1}$)	16.64	35.39	31.45	19.2	7.82	24.95
Max. RMR (W)	0.35±0.07 (3)	0.90±0.18 (5)	0.53±0.21 (4)	0.48±0.12 (8)	0.22±0.01 (3)	0.40±0.06 (3)
Max. RMR/min. RMR	1.75	2.43	1.77	1.55	1.57	1.67
Evaporative water loss					2.34	
Min. EWL (g h^{-1})	0.07±0.04 (5)	0.29±0.11 (10)	0.20±0.09 (10)	0.20±0.07 (10)	0.09±0.03 (10)	0.14±0.08 (10)
Inflection T_{air} (°C)	N/A	40.01	N/A	40.13	39.3	38.29
EWL slope (g h^{-1} $°C^{-1}$)	0.06	0.21	0.09	0.11	0.05	0.09
Max. EWL (g h^{-1})	0.45±0.13 (3)	1.79±0.38 (5)	0.90±0.43 (4)	0.96±0.30 (8)	0.46±0.70 (3)	0.79±0.15 (3)
		2.20 (1)				
Max. EWL/min. EWL	6.43	6.17	4.5	4.80	5.11	5.64
Min. EHL/MHP	0.23±0.13 (5)	0.53±0.14 (10)	0.44±0.10 (10)	0.44±0.15 (10)	0.40±0.13 (10)	0.39±0.20 (10)
EHL/MHP inflection T_{air} - T_b	-6.0	N/A	N/A	N/A	N/A	N/A
EHL/MHP slope	0.19	0.11	0.14	0.14	0.16	0.16
Max. EHL/MHP	0.85±0.12 (3)	1.32±0.18 (5)	1.14±0.13 (4)	1.34±0.18 (8)	1.39±0.20 (3)	1.32±0.05 (3)
		1.75 (1)		1.63 (1)		

Table S3 Cont.

Variable	Orange-river White-eye	White-throated Canary	Yellow Bishop
Body mass (g)	**9.5±0.5 (10)**	**22.6±1.4 (10)**	**29.5±4.9(10)**
Body temperature			
Min. T_b (°C)	41.2±2.0 (10)	41.5±0.6 (10)	41.3±0.7 (10)
Inflection T_{air} (°C)	38.5	N/A	37.0
T_b versus T_{air} slope (per °C)	0.54	0.51	0.45
Max T_b (°C)	45.2±0.2 (10)	45.0±0.9 (10)	45.8±0.4 (10)
Max T_{air} (°C)	44.0±1.1 (10)	42.9±1.9 (10)	44.9±1.3 (10)
T_b at onset of panting (°C)	43.2±0.8 (9)	42.2±2.3 (10)	43.0±1.2 (10)
T_{air} at onset of panting (°C)	38.8±1.2 (9)	39.6±1.0 (10)	40.6±1.1 (10)
Metabolic rate			
Min. RMR (W)	0.21±0.03 (10)	0.36±0.06 (10)	0.43±0.11 (10)
T_{uc} (°C)	N/A	38.77	37.0
RMR slope (mW °C^{-1})	21.03	33.73	45.95
Max. RMR (W)	0.39±0.07 (8)	0.57±0.10 (5) 0.64 (1)	0.87±0.16 (3)
Max. RMR/min. RMR	1.86	1.58	2.02
Evaporative water loss			
Min. EWL (g h^{-1})	0.11±0.04 (10)	0.21±0.10 (10)	0.28±0.08 (10)
Inflection T_{air} (°C)	38.0	39.1	38.5
EWL slope (g h^{-1} °C^{-1})	0.07	0.10	0.13
Max. EWL (g h^{-1})	0.64±0.14 (8)	0.88±0.18 (5) 1.12 (1)	1.38±0.20 (3)
Max. EWL/min. EWL	5.82	4.19	4.9
Min. EHL/MHP	0.37±0.12 (10)	0.38±0.15 (10)	0.45±0.14 (10)
EHL/MHP inflection T_{air} - T_b	N/A	N/A	N/A
EHL/MHP slope	0.11	0.42	0.12
Max. EHL/MHP	1.10±0.11 (8)	1.04±0.17(5) 1.17 (1)	1.06±0.09 (3)

Table S4 Summary of thermoregulatory performance as a function of chamber air temperature (T_{air}) at humidity of ~1 g H_2O m^{-3} (dry air) in nine bird species from the arid study site (Namaqualand). T_b = body temperature, T_{air} = ambient temperature, RMR = resting metabolic rate, EWL = evaporative water loss, EHL= evaporative heat loss, MHP = metabolic heat production. Means ± SD and (n) are reported.

Variable	Black-headed Canary	Cape Bulbul	Cape Bunting	Karoo Lark	Karoo Prinia	Lark-like Bunting	Orange-river White-eye
Body mass (g)	**10.4±0.6 (5)**	**32.8±2.1 (10)**	**19.7±1.8 (10)**	**28.2±3.2 (10)**	**7.4±0.5 (10)**	**13.5±0.8 (6)**	**9.6±0.5 (10)**
Body temperature							
Min. T_b (°C)	41.3±0.9 (5)	41.4±0.6 (10)	40.60±0.8 (10)	40.5±0.8 (10)	40.5±1.5 (10)	40.1±0.7 (6)	40.66±0.95(10)
Inflection T_{air} (°C)	32.5	38.9	32.5	37.3	34.0	33.9	32.9
T_b versus T_{air} slope (per °C)	0.26	0.26	0.31	0.36	0.47	0.38	0.36
Max T_b (°C)	44.8±0.4 (4)	45.2±0.3 (9)	45.2±0.3 (9)	45.0±0.7 (10)	45.3±0.5 (10)	45.2±0.2 (6)	45.3±0.3 (10)
Max T_{air} (°C)	46.5±0.5 (4)	49.8±1.4 (9)	47.0±1.5 (9)	48.3±1.3 (10)	46.2±1.1 (10)	48.3±1.0 (6)	46.3±1.1 (10)
T_b at onset of panting (°C)	44.2±0.4 (4)	42.3±0.9 (10)	43.2±1.5 (10)	42.9±0.8 (10)	44.3±0.9 (9)	42.3±0.8 (5)	43.3±1.1 (10)
T_{air} at onset of panting (°C)	40.4±1.1 (4)	36.7±3.3 (10)	38.9±2.1 (10)	40.6±2.1 (10)	41.7 ±1.1 (9)	38.6±2.1 (5)	40.0±1.7 (10)
Metabolic rate							
Min. RMR (W)	0.33±0.07 (4)	0.64±0.14 (10)	0.67±0.12 (10)	0.35±0.05 (10)	0.18±0.02 (10)	0.24±0.03 (6)	0.26±0.04 (10)
T_{uc} (°C)	32.5	38.50	33.94	37.71	35.17	37.2	38.0
RMR slope (mW °C^{-1})	27.7	27.96	35.02	19.13	11.5	14.6	16.37
Max. RMR (W)	0.65±0.16 (4) 0.84 (2)	0.95±0.15 (9)	1.16±0.25 (6)	0.66±0.09 (4)	0.27±0.03 (10)	0.43±0.10 (4)	0.38±0.04 (9)
Max. RMR/min. RMR	1.97	1.48	1.73	1.89	3.38	1.79	1.46
Evaporative water loss							
Min. EWL (g h^{-1})	0.14±0.07 (4)	0.33±0.11 (10)	0.31±0.11 (10)	0.23±0.07 (10)	0.13±0.05 (10)	0.16±0.06 (6)	0.11±0.03 (10)
Inflection T_{air} (°C)	36.45	39.25	34.96	38.25	39.03	39.15	37.5
EWL slope (g h^{-1} °C^{-1})	0.09	0.16	0.14	0.11	0.07	0.09	0.06
Max. EWL (g h^{-1})	0.79±0.18 (4) 0.87 (2)	2.45±0.60 (5) 2.55 (1)	2.17±0.41 (6) 2.36 (2)	1.77±0.22 (4)	0.61±0.12 (7)	1.01±0.15 (4)	0.64±0.13 (9) 0.70 (1)
Max. EWL/min. EWL	5.64	7.42	7	7.70	4.62	6.31	5.82
Min. EHL/MHP	0.25±0.14 (4)	0.35±0.09 (10)	0.29±0.10 (10)	0.41±0.13 (10)	0.45±0.18 (10)	0.42±0.13 (6)	0.31±0.09 (10)
EHL/MHP inflection T_{air} - T_b	-4.07	-7.46	-7.80	-5.96	-4.07	-5.46	-6.44
EHL/MHP slope	0.05	0.13	0.10	0.12	0.17	0.15	0.12
Max. EHL/MHP	0.89±0.34 (4) 0.94 (1)	1.96±0.25 (5) 2.20 (1)	1.29±0.30 (6) 1.63 (2)	1.80±0.30 (4)	1.24±0.70 (7) 1.81 (1)	1.61±0.29 (4)	1.35±0.17 (7)

Table S4 Cont.

Variable	White-throated Canary	Yellow Bishop
Body mass (g)	**22.1±1.5 (10)**	**30.6±4.4 (9)**
Body temperature		
Min. T_b (°C)	40.19±0.6 (10)	40.6±0.7 (9)
Inflection T_{air} (°C)	37.0	38.2
T_b versus T_{air} slope (per °C)	0.45	0.38
Max T_b (°C)	45.3±0.3 (10)	45.4±0.3 (9)
Max T_{air} (°C)	46.5±1.5 (10)	48.7±1.2 (9)
T_b at onset of panting (°C)	42.2±1.2 (10)	42.0±0.7 (9)
T_{air} at onset of panting (°C)	39.0±2.0 (10)	39.5±0.6 (10)
Metabolic rate		
Min. RMR (W)	0.39±0.06 (10)	0.51±0.11 (9)
T_{uc} (°C)	39.12	41.77
RMR slope (mW °C^{-1})	48.56	62.32
Max. RMR (W)	0.85±0.05 (4)	0.86±0.27 (6)
Max. RMR/min. RMR	2.18	1.69
Evaporative water loss		
Min. EWL (g h^{-1})	0.19±0.05 (10)	0.19±0.05 (9)
Inflection T_{air} (°C)	38.0	37.8
EWL slope (g h^{-1} °C^{-1})	0.14	0.13
Max. EWL (g h^{-1})	1.60±0.22 (4)	1.62±0.42 (6)
Max. EWL/min. EWL	8.42	8.52
Min. EHL/MHP	0.31±0.09 (10)	0.24±0.11 (9)
EHL/MHP inflection T_{air} - T_b	-4.60	-6.21
EHL/MHP slope	0.13	0.11
Max. EHL/MHP	1.35±0.17 (7)	1.28±0.10 (6) 1.36 (2)

Table S5a Mass-specific resting metabolic rate (RMR) and evaporative water loss (EWL) rate at high T_{air} in ten bird species thermoregulatory performance as a function of chamber air temperature (T_{air}) coupled with humidity of ~ 19g H_2O m^{-3} within a southern African arid region (Namaqualand). Means, SD and (n) are reported.

Variable	Black-headed Canary	Cape Bulbul	Cape Bunting	Karoo Lark	Karoo Prinia
Min. RMR (mW g^{-1})	17.78±2.35 (5)	11.30±3.75 (10)	15.23±3.84 (10)	10.52±2.53 (10)	20.59±3.86 (10)
RMR slope (mW g^{-1} °C^{-1})	1.22		1.55		1.13
Max. RMR (mW g^{-1})	31.49±6.04 (3)	26.66±5.39 (5)	26.89±11.22 (4)	16.70±3.63 (8) 17.58 (1)	32.32±6.84 (3)
Min. EWL (mg h^{-1} g^{-1})	6.21±3.45 (5)	8.75±3.06 (10)	10.03±4.07 (10)	7.06±2.44 (10)	12.63±5.36 (10)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	0.96		4.59		4.49
Max. EWL (mg h^{-1} g^{-1})	40.36±11.07 (3)	52.53±10.27 (5) 62.44 (1)	45.64±20.97 (4)	33.79±9.45 (8) 42.89 (1)	66.35±8.17 (3)

Variable	Lark-like Bunting	Orange-river White-eye	White-throated Canary	Yellow Bishop
Min. RMR (mW g^{-1})	17.54±4.21 (11)	21.20±1.81 (10)	15.69±2.46 (10)	14.64±4.64 (10)
RMR slope (mW g^{-1} °C^{-1})	1.84	1.54	1.16	0.53
Max. RMR (mW g^{-1})	32.78±10.27 (11)	40.14±6.08 (8)	24.25±3.40 (5) 29.88(1)	29.11±10.78 (3)
Min. EWL (mg h^{-1} g^{-1})	10.27±5.32 (11)	11.82±4.0 (10)	9.05±3.90 (10)	9.41±2.70 (10)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	5.65	4.96	3.98	2.15
Max. EWL (mg h^{-1} g^{-1})	58.91±14.85 (3)	66.21±14.07 (8)	37.51±6.69 (5) 52.11 (1)	46.01±16.50 (3)

Table S5b Mass-specific resting metabolic rate (RMR) and evaporative water loss (EWL) rate at high T_{air} in nine bird species thermoregulatory performance as a function of chamber air temperature (T_{air}) coupled with humidity of ~1 g H_2O m^{-3} (dry air) within a southern African arid region (Namaqualand). Means, SD and (n) are reported.

Variable	Black-headed Canary	Cape Bulbul	Cape Bunting	Karoo Lark	Karoo Prinia
Min. RMR (mW g^{-1})	30.43±9.07 (5)	18.27±2.34 (10)	34.87±6.22 (10)	12.30±2.24 (10)	14.66±66.6 (7)
RMR slope (mW g^{-1} °C^{-1})	2.51	0.91	1.68	0.69	1.59
Max. RMR (mW g^{-1})	61.02±19.9 (4) 43.46 (2)	29.1±4.31 (9)	55.69±11.39 (6)	22.22±5.34 (4)	37.61±5.63 (10)
Min. EWL (mg h^{-1} g^{-1})	12.73±9.77 (5)	10.19±3.30 (10)	15.31±5.38 (10)	7.95±1.48 (10)	17.86±6.98 (10)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	1.06	5.08	7.21	4.01	9.13
Max. EWL (mg h^{-1} g^{-1})	73.05±18.00 (4) 87.62 (2)	78.42±22.21 (5) 82.17 (1)	104.55±17.88 (6) 114.21 (2)	59.31±14.99 (4)	83.67±23.07 (7)

Variable	Lark-like Bunting	Orange-river White-eye	White-throated Canary	Yellow Bishop
Min. RMR (mW g^{-1})	17.69±2.33 (6)	27.20±4.33 (10)	17.40±2.70 (10)	16.79±3.75 (9)
RMR slope (mW g^{-1} °C^{-1})	1.44	1.70	2.43	0.19
Max. RMR (mW g^{-1})	31.02±8.06 (4)	39.65±3.78 (9)	36.27±4.46 (4)	27.60±6.21 (6)
Min. EWL (mg h^{-1} g^{-1})	11.94±4.39 (6)	11.62±3.31 (10)	8.21±2.08 (10)	6.41±2.21 (9)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	5.76	6.12	6.21	1.92
Max. EWL (mg h^{-1} g^{-1})	73.10±10.30 (4)	65.76±11.81 (9) 74.21 (1)	67.88±15.10 (4)	54.64 (2) 52.46±10.08 (6)

Table S6 Summary of thermoregulatory performance as a function of chamber air temperature (T_{air}) at humidity of ~ 19g H_2O m^{-3} in 13 bird species from the lowland study site (Hluhluwe). T_b = body temperature, T_{air} = ambient temperature, RMR = resting metabolic rate, EWL = evaporative water loss, EHL= evaporative heat loss, MHP = metabolic heat production. Means ± SD and (n) are reported.

Variable	African Pygmy Kingfisher	Brown-hooded Kingfisher	Collared Sunbird	Southern Fiscal	Dark-capped Bulbul	Green-backed Camaroptera
Body mass (g)	**13.4 ± 1.1(10)**	**61.7 ± 3.3 (10)**	**7.0 ± 0.6 (8)**	**40.9 ± 1.8 (10)**	**36.4 ± 2.8 (10)**	**11.7 ± 0.4 (10)**
Body temperature						
Min. T_b (°C)	40.8 ± 0.7 (10)	40.4 ± 0.7 (10)	39.8 ± 0.7(8)	40.8 ± 0.7 (10)	39.8 ± 1.1(9)	40.4 ± 0.5 (10)
Inflection T_{air} (°C)	N/A	N/A	N/A	NA	N/A	N/A
T_b versus T_{air} slope (per °C)	0.44	0.39	0.49	0.43	0.36	0.39
Max T_b (°C)	45.7 ± 0.5 (10)	46.3 ± 0.4 (10)	45.9 ± 0.6 (7)	46.9 ± 0.3 (10)	45.8 ± 0.5 (10)	46.3 ± 0.5 (10)
Max T_{air} (°C)	44.9 ± 0.7 (10)	48.2 ± 1.1 (10)	45.4 ± 1.7 (8)	47.9 ± 1.0 (10)	49.5 ± 1.6 (10)	48.5 ± 0.7 (10)
T_b at onset of panting (°C)	42.1 ± 0.8 (10)	41.7 ± 0.6 (10)	41.8 ± 1.3 (8)	42.4 ± 0.8 (10)	40.8 ± 1.6 (10)	41.2 ± 0.8 (10)
T_{air} at onset of panting (°C)	38.2 ± 0.6 (10)	38.2 ± 0.6 (10)	38.7 ± 0.9 (8)	38.4 ± 1.0 (10)	36.7 ± 1.3 (10)	36.4 ± 1.3 (10)
Metabolic rate						
Min. RMR (W)	0.22 ± 0.01 (10)	0.47 ± 0.04 (10)	0.14 ± 0.01 (8)	0.50 ± 0.07 (10)	0.44 ± 0.05 (10)	0.24 ± 0.02 (10)
T_{uc} (°C)	N/A	N/A	34.34	38.83	41.34	N/A
RMR slope (mW $°C^{-1}$)	14.6	61.26	10.89	49.49	36.05	11.27
Max. RMR (W)	0.37 ± 0.03 (10)	1.26 ± 0.22 (8) 1.85 (1)	0.26 ± 0.03 (4)	0.92 ± 0.22 (10)	0.79 ± 0.20 (9) 0.83 (1)	0.39 ± 0.03 (8)
Max. RMR/min. RMR	1.68	3.93	1.85	1.84	1.79	1.62
Evaporative water loss						
Min. EWL (g h^{-1})	0.16 ± 0.03 (10)	0.21 ± 0.07 (10)	0.10 ± 0.04 (8)	0.14 ± 0.03 (10)	0.20 ± 0.05 (10)	0.09 ± 0.03 (10)
Inflection T_{air} (°C)	36.3	37.215	34.61	38.93	39.231	37.42
EWL slope (g h^{-1} $°C^{-1}$)	0.06	0.17	0.03	0.14	0.13	0.04
Max. EWL (g h^{-1})	0.66 ± 0.14 (10)	1.95 ± 0.59 (8) 3.18 (1)	0.44 ± 0.09 (4)	1.55 ± 0.48 (5)	1.94 ± 0.22 (3) 2.40 (1)	0.64 ± 0.13 (8) 0.69 (1)
Max. EWL/min. EWL	4.13	9.29	4.4	11.07	9.7	7.67
Min. EHL/MHP	0.49 ± 0.07 (10)	0.31 ± 0.12 (10)	0.42 ± 0.18 (8)	0.19 ± 0.06 (10)	0.30 ± 0.10 (10)	0.26 ± 0.08 (10)
EHL/MHP inflection T_{air} - T_b	-5.51	-5.579	N/A	-4.13	N/A	N/A
EHL/MHP slope	0.16	0.107	0.15	0.14	0.12	0.11
Max. EHL/MHP	1.30 ± 0.27 (10)	1.11 ± 0.26 (10) 1.14 (1)	1.18 ± 0.19 (6)	1.15 ± 0.34 (5)	1.98 ± 0.08 (3)	1.08 ± 0.24 (8) 1.18 (1)

Table S6 Cont.

Variable	Pink-throated Twinspot	Red-capped Robin Chat	Rudd's Apalis	Sombre Greenbul	Spectacled Weaver
Body mass (g)	**12.5 ± 1.2 (10)**	**27.8 ± 2.4 (10)**	**9.5 ± 0.4 (10)**	**27.3 ± 1.8 (10)**	**26.7 ± 1.3 (5)**
Body temperature					
Min. T_b (°C)	40.3 ± 1.1 (10)	40.3 ± 0.7 (10)	39.7 ± 1.1 (10)	40.3 ± 0.9 (10)	40.4 ± 0.9 (5)
Inflection T_{air} (°C)	N/A	43.0	N/A	N/A	40.84
T_b versus T_{air} slope (per °C)	0.48	0.61	0.48	0.38	0.75
Max T_b (°C)	46.4 ± 0.4 (10)	46.4 ± 0.4 (10)	46.3 ± 1.2 (10)	45.9 ± 0.6 (10)	46.7 ± 0.9 (4)
Max T_{air} (°C)	46.9 ± 0.8 (10)	48.4 ± 1.1 (10)	46.6 ± 2.1 (10)	47.9 ± 2.1 (10)	46.8 ± 1.8 (4)
T_b at onset of panting (°C)	41.3 ± 0.9 (10)	41.0 ± 1.2 (10)	41.8 ± 1.0 (10)	40.6 ± 1.1 (10)	40.6 ± 0.6 (5)
T_{air} at onset of panting (°C)	37.7 ± 0.9 (10)	36.8 ± 1.5 (10)	38.7 ± 1.1 (10)	35.3 ± 1.4 (10)	35.6 ± 0.7 (5)
Metabolic rate					
Min. RMR (W)	0.18 ± 0.01 (10)	0.36 ± 0.03 (10)	0.16 ± 0.02 (10)	0.38 ± 0.03 (10)	0.40 ± 0.03 (5)
T_{uc} (°C)	40.74	N/A	N/A	41.56	40.735
RMR slope (mW °C^{-1})	24.43	16.94	10.03	28.76	63.39
Max. RMR (W)	0.33 ± 0.04 (9)	0.59 ± 0.04 (3)	0.29 ± 0.07 (7)	0.68 ± 0.01 (4)	0.81 ± 0.01 (3) 0.84 (1)
Max. RMR/min. RMR	1.83	1.63	1.81	1.78	2.10
Evaporative water loss					
Min. EWL (g h^{-1})	0.09 ± 0.04 (10)	0.19 ± 0.06 (10)	0.10 ± 0.03 (10)	0.24 ± 0.09 (10)	0.14 ± 0.03 (5)
Inflection T_{air} (°C)	36.93	35.93	37.14	N/A	37.93
EWL slope (g h^{-1} °C^{-1})	0.04	0.08	0.04	0.08	0.08
Max. EWL (g h^{-1})	0.53 ± 0.09 (9)	1.34 ± 0.13 (3)	0.52 ± 0.17 (7)	1.52 ± 0.11 (4)	1.02 ± 0.29 (3) 1.20 (1)
Max. EWL/min. EWL	5.88	7.05	5.2	6.3	7.28
Min. EHL/MHP	0.35 ± 0.09 (10)	0.36 ± 0.13 (10)	0.41 ± 0.12 (10)	0.41 ± 0.14 (10)	0.24 ± 0.06 (5)
EHL/MHP inflection T_{air} - T_b	-4.95	-5.64	-4.841	N/A	N/A
EHL/MHP slope	0.12	0.14	0.12	0.11	0.08
Max. EHL/MHP	1.06 ± 0.14 (9)	1.50 ± 0.06 (3)	1.19 ± 0.28 (5)	1.61 ± 0.12 (4)	0.84 ± 0.22 (3) 0.95 (1)

Table S6 Cont.

Variable	Yellow-rumped Tinkerbird	Yellow Weaver
Body mass (g)	14.2 ± 1.1 (10)	25.7 ± 2.6 (10)
Body temperature		
Min. T_b (°C)	40.7 ± 0.8 (10)	41.0 ± 0.5 (10)
Inflection T_{air} (°C)	N/A	40.9
T_b versus T_{air} slope (per °C)	0.52	0.6
Max T_b (°C)	46.6 ± 0.2 (10)	46.7 ± 0.5 (10)
Max T_{air} (°C)	45.1 ± 0.8 (10)	47.9 ± 1.1 (10)
T_b at onset of panting (°C)	41.8 ± 0.8 (10)	41.4 ± 0.9 (10)
T_{air} at onset of panting (°C)	38.2 ±3.4 (10)	36.4 ± 1.9 (10)
Metabolic rate		
Min. RMR (W)	0.28 ± 0.05 (10)	0.37 ± 0.04 (10)
T_{uc} (°C)	36.55	39.63
RMR slope (mW °C^{-1})	27.72	35.03
Max. RMR (W)	0.51 ± 0.05 (2)	0.67 ± 0.12 (8)
Max. RMR/min. RMR	1.82	1.81
Evaporative water loss		
Min. EWL (g h^{-1})	0.10 ± 0.02 (10)	0.16 ± 0.04 (10)
Inflection T_{air} (°C)	N/A	37.08
EWL slope (g h^{-1} °C^{-1})	0.02	0.09
Max. EWL (g h^{-1})	0.43 ± 0.03 (2)	1.21 ± 0.38 (8)
Max. EWL/min. EWL	4.3	7.56
Min. EHL/MHP	0.25 ± 0.04 (10)	0.29 ± 0.08 (10)
EHL/MHP inflection T_{air} - T_b	-4.59	-5.65
EHL/MHP slope	0.08	0.12
Max. EHL/MHP	0.56 ± 0.01 (2)	1.21 ± 0.35 (8)

Table S7 Summary of thermoregulatory performance as a function of chamber air temperature (T_{air}) at humidity of ~ 0 g H_2O m^{-3} (dry air) in two bird species from the lowland study site (Hluhluwe). T_b = body temperature, T_{air} = ambient temperature, RMR = resting metabolic rate, EWL = evaporative water loss, EHL= evaporative heat loss, MHP = metabolic heat production. Means ± SD and (n) are reported.

Variable	Pink-throated Twinspot	Rudd's Apalis
Body mass (g)	**12.5 ± 0.6 (10)**	**9.6 ± 0.6 (10)**
Body temperature		
Min. T_b (°C)	39.1 ± 0.8 (10)	38.9 ± 1.0 (10)
Inflection T_{air} (°C)	34.8	34.55
T_b versus T_{air} slope (per °C)	0.47	0.44
Max T_b (°C)	46.6 ± 0.4 (10)	46.4 ± 1.2 (10)
Max T_{air} (°C)	48.2 ± 0.6 (10)	50.6 ± 1.7 (10)
T_b at onset of panting (°C)	42.0 ± 1.6 (10)	42.0 ± 1.4 (9)
T_{air} at onset of panting (°C)	39.9 ± 1.8 (10)	39.2 ± 2.4 (9)
95^{th} percentile T_b>T_{air} (°C)		
Metabolic rate		
Min. RMR (W)	0.15 ± 0.01 (10)	0.15 ± 0.02 (10)
T_{uc} (°C)	36.55	33.577
RMR slope (mW $°C^{-1}$)	12.52	8.24
Max. RMR (W)	0.29 ± 0.03 (10)	0.28 ± 0.05 (10)
Max. RMR/min. RMR	1.93	1.86
Evaporative water loss		
Min. EWL (g h^{-1})	0.06 ± 0.01 (10)	0.07 ± 0.02 (10)
Inflection T_{air} (°C)	37.56	37.93
EWL slope (g h^{-1} $°C^{-1}$)	0.05	0.06
Max. EWL (g h^{-1})	0.61 ± 0.09 (9)	0.82 ± 0.15 (6)
Max. EWL/min. EWL	10.16	11.7
Min. EHL/MHP	0.23 ± 0.03 (10)	0.30 ± 0.05 (10)
EHL/MHP inflection T_{air} - T_b	-4.57	-3.492
EHL/MHP slope	0.16	0.21
Max. EHL/MHP	1.40 ± 0.19 (9)	2.07 ± 0.18 (6)

Table S8 Mass-specific metabolic rate (RMR) and evaporative water loss (EWL) rate at high T_{air} in 13 bird species thermoregulatory performance as a function of chamber air temperature (T_{air}) coupled with humidity of ~ 19g H_2O m^{-3} within a southern African lowland region (Hluhluwe). Means, SD and (n) are reported.

Variable	African Pygmy Kingfisher	Brown-hooded Kingfisher	Collared Sunbird	Common Fiscal	Dark-capped Bulbul	Green-backed Camaroptera	Pink-throated Twinspot
Min. RMR (mW g^{-1})	16.81 ± 1.7 (10)	7.65 ± 0.5 (10)	20.38 ± 2.7 (8)	12.36 ± 2.0(10)	12.17 ± 1.6 (10)	21.30 ± 2.0 (10)	14.84 ± 1.8 (10)
RMR slope (mW g^{-1} °C^{-1})	1.09	1.12	1.39	1.21	0.95	0.96	1.99
Max. RMR (mW g^{-1})	27.64 ± 1.9 (10)	20.34 ± 3.4 (8) 30.99 (1)	36.68 ± 4.7 (4)	21.96 ± 3.3 (10)	22.10 ± 6.3 (9) 22.76 (1)	33.91 ± 3.4 (8) 35.64 (1)	27.08 ± 3.0 (9)
Min. EWL (mg h^{-1} g^{-1})	12.44 ± 2.3 (10)	3.54 ± 1.3 (10)	12.82 ± 4.7 (8)	3.50 ± 0.8 (10)	5.52 ± 1.7 (10)	8.36 ± 2.8 (10)	7.89 ± 2.69 (10)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	4.14	2.84	5.36	3.58	3.58	4.13	3.71
Max. EWL (mg h^{-1} g^{-1})	50.04 ± 12.2 (10)	31.44 ± 9.5 (8) 53.22 (1)	61.74 ± 8.4 (4)	37.53 ± 12.1 (5)	51.98 ± 7.8 (3) 65.91 (1)	54.98 ± 12.4 (8) 63.12 (1)	42.82 ± 5.5 (9)

Variable	Red-capped Robin Chat	Rudd's Apalis	Sombre Greenbul	Spectacled Weaver	Yellow-rumped Tinkerbird	Yellow Weaver
Min. RMR (mW g^{-1})	13.18 ± 1.5 (10)	17.50 ± 2.2 (10)	14.13 ± 1.3 (10)	15.23 ± 0.76 (5)	20.02 ± 3.45 (10)	14.75 ± 1.96 (10)
RMR slope (mW g^{-1} °C^{-1})	0.60	1.04	1.05	2.15	1.95	1.31
Max. RMR (mW g^{-1})	20.74 ± 1.3 (3)	30.06 ± 7.8 (7)	25.59 ± 1.7 (4)	29.68 ± 0.82 (3) 29.93 (1)	37.27 ± 1.10 (2)	25.49 ± 2.18 (8)
Min. EWL (mg h^{-1} g^{-1})	7.15 ± 2.8 (10)	10.83 ± 3.5 (10)	0.24 ± 0.1 (10)	5.45 ± 1.34 (5)	7.53 ± 1.83 (10)	6.44 ± 1.73 (10)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	3.12	4.219	3.25	3.54	2.07	3.63
Max. EWL (mg h^{-1} g^{-1})	46.82 ± 4.8 (3)	54.32 ± 19.1 (5)	1.52 ± 0.1 (4)	37.39 ± 9.89 (3) 42.58 (1)	31.36 ± 0.05 (2)	46.06 ± 13.5 (8)

Table S9 Summary of thermoregulatory performance as a function of chamber air temperature (T_{air}) at water vapour pressures of ~ 19g H_2O m^{-3} in nine bird species from the montane study site (Harrismith). T_b = body temperature, T_{air} = ambient temperature, RMR = metabolic rate, EWL = evaporative water loss, EHL= evaporative heat loss, MHP = metabolic heat production. Means ± SD and (n) are reported.

Variable	Cape White-eye	Dark-capped Bulbul	Drakensberg Prinia	Red-billed Quelea	Red-capped Lark	South African Cliff-swallow
Body mass (g)	**11.9±0.5 (10)**	**42.4±3.6 (10)**	**9.3±0.8 (10)**	**17.1±0.8 (10)**	**26.7±1.5 (10)**	**19.1 ± 1.2 (10)**
Body temperature						
Min. T_b (°C)	41.7±0.8 (10)	42.1±0.5 (10)	41.4±1.0 (10)	41.0±0.7 (10)	42.3±0.5 (9)	41.7±0.6 (7)
Inflection T_{air} (°C)	NA	40.7	N/A	44.8	37.6	N/A
T_b versus T_{air} slope (per °C)	0.44	0.51	0.38	0.88	0.37	0.39
Max T_b (°C)	45.9±0.9 (10)	45.8±0.2 (10)	45.9±0.3 (10)	48.6±0.7 (10)	45.9±0.4 (10)	45.8±0.4 (10)
Max T_{air} (°C)	43.3±1.6 (10)	45.7±1.4 (10)	45.6±1.0 (10)	48.1±1.1 (10)	46.0±0.6 (10)	44.3±0.8 (10)
T_b at onset of panting (°C)	42.9±0.5 (10)	42.4±0.5 (10)	42.9±0.6 (10)	43.1±0.9 (10)	43.0±0.6 (10)	42.6±0.7 (10)
T_{air} at onset of panting (°C)	37.3±0.9 (10)	37.0±1.0 (10)	37.8±0.8 (10)	38.9±1.3 (10)	38.1±2.3 (10)	37.4±1.2 (10)
Metabolic rate						
Min. RMR (W)	0.26±0.05 (10)	0.50±0.09 (10)	0.23±0.06 (10)	0.30±0.04 (10)	0.42±0.11 (10)	0.32±0.07 (7)
T_{uc} (°C)	~34	32.21	36.14	41.90	38.28	41.58
MR slope (mW °C^{-1})	18.24	47.81	9.93	19.92	36.28	45.88
Max. RMR (W)	0.44±0.09 (4)	0.84±0.10 (6)	0.32±0.07 (7)	0.54±0.10 (6)	0.74±0.26 (5)	0.47±0.1 (9)
Max. RMR/min. RMR	1.69	1.68	1.39	1.7	1.76	1.46
Evaporative water loss						
Min. EWL (g h^{-1})	0.11±0.05 (10)	0.37±0.11 (10)	0.10±0.05 (10)	0.1±0.03 (10)	0.24±0.12 (10)	0.15±0.04 (10)
Inflection T_{air} (°C)	NA	N/A	35.27	~35.6	37.70	38.47
EWL slope (g h^{-1} °C^{-1})	0.06	0.11	0.05	0.07	0.11	0.07
Max. EWL (g h^{-1})	0.67±0.13 (4)	1.75±0.21 (6)	0.68±0.15 (7)	0.9±0.20 (10)	1.46±0.52 (5)	0.87±0.23 (9)
Max. EWL/min. EWL	6.09	4.72	6.81	9.0	6.13	5.80
Min. EHL/MHP	0.27±0.08 (10)	0.51±0.16 (10)	0.27±0.10 (10)	0.2±0.10 (10)	0.37±0.16 (9)	0.33±0.15 (7)
EHL/MHP inflection T_{air} - T_b	-7.1	N/A	N/A	-6.2	N/A	N/A
EHL/MHP slope	0.17	0.10	0.16	0.19	0.12	0.15
Max. EHL/MHP	1.04±0.25 (4)	1.40±0.11 (6)	1.44±0.31 (7)	1.3±0.2 (10)	1.32±0.13 (5)	1.25±0.19 (9)

Table S9 Cont.

Variable	Southern Fiscal	Southern Masked Weaver	Spike-heeled Lark
Body mass (g)	**42.8±1.9 (10)**	**28.9±3.4 (10)**	**30.35±3.59 (10)**
Body temperature			
Min. T_b (°C)	42.1±1.0 (8)	41.4±0.9 (10)	42.5±0.4 (8)
Inflection T_{air} (°C)	N/A	N/A	N/A
T_b versus T_{air} slope (per °C)	0.33	0.39	0.29
Max T_b (°C)	46.0±0.6 (10)	45.9±0.2 (10)	45.8±0.4 (10)
Max T_{air} (°C)	45.3±1.4 (10)	45.2±0.9 (10)	45.5±0.9 (10)
T_b at onset of panting (°C)	43.1±0.6 (10)	42.5±0.8 (10)	43.4±0.6 (10)
T_{air} at onset of panting (°C)	37.8±0.5 (10)	37.5±0.7 (10)	37.2±1.4 (10)
Metabolic rate			
Min. RMR (W)	0.46±0.06 (8)	0.42±0.10 (10)	0.36±0.06 (8)
T_{uc} (°C)	N/A	39.78	41.53
RMR slope (mW °C^{-1})	21.14	50.41	36.35
Max. RMR (W)	0.72±0.15 (5)	0.72±0.17 (10)	0.55±0.05 (6)
Max. RMR/min. RMR	1.57	1.71	1.52
Evaporative water loss			
Min. EWL (g h^{-1})	0.24±0.15 (10)	0.17±0.07 (10)	0.16±0.07 (8)
Inflection T_{air} (°C)	N/A	N/A	36.68
EWL slope (g h^{-1} °C^{-1})	0.11	0.12	0.09
Max. EWL (g h^{-1})	1.44±0.16 (5) 1.54±0.36 (2)	1.39±0.05 (3)	1.10±0.27 ()
Max. EWL/min. EWL	6.0	8.17	6.25
Min. EHL/MHP	0.32±0.19 (10)	0.27±0.08 (10)	0.29±0.12 (8)
EHL/MHP inflection T_{air} - T_b	N/A	N/A	N/A
EHL/MHP slope	0.15	0.16	0.13
Max. EHL/MHP	1.36±0.26 (5) 1.50±0.06 (2)	1.35±0.30 (3)	1.36±0.21 (9)

Table S10 Mass-specific metabolic rate (RMR) and evaporative water loss (EWL) rate at high T_{air} in nine bird species as a function of chamber air temperature (T_{air}) coupled with humidity of ~ 19g H_2O m^{-3} within a southern African montane region (Harrismith). Means, SD and (n) are reported.

Variable	Cape White-eye	Dark-capped Bulbul	Drakensberg Prinia	Red-billed Quelea	Red-capped Lark	South African Cliff Swallow
Min. RMR (mW g^{-1})	21.99±4.55 (10)	12.41±2.68 (10)	24.59±5.34 (10)	16.4±2.7 (10)	15.14±4.67 (10)	15.85±2.94 (10)
RMR slope (mW g^{-1} °C^{-1})	1.55	1.21	1.09	1.4	1.25	2.44
Max. RMR (mW g^{-1})	37.58±8.99 (4)	20.68±2.18 (6)	35.14±7.86 (7)	27.2±4.4 (6)	26.00±11.6 (5)	24.47±5.69 (9)
Min. EWL (mg h^{-1} g^{-1})	9.11±3.96 (10)	9.05±2.69 (10)	10.40±5.01 (10)	5.7±2.0 (6)	9.08±4.66 (9)	7.83±1.73 (10)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	5.22	2.93	5.97	4.11	4.26	5.02
Max. EWL (mg h^{-1} g^{-1})	57.21±13.09 (4)	43.16±5.32 (6)	74.04±16.57 (7)	52.4±8.1 (10)	51.20±22.2 (5)	45.91±14.85 (9)

Variable	Southern Fiscal	Southern Masked Weaver	Spike-heeled Lark
Min. RMR (mW g^{-1})	10.92±1.52 (8) 8.71 (1)	15.39±4.37 (10)	12.18±1.70 (8)
RMR slope (mW g^{-1} °C^{-1})	0.49	1.92	1.41
Max. RMR (mW g^{-1})	16.82±3.62 (5)	26.99±8.43 (10)	19.24±2.57 (6) 21.61 (1)
Min. EWL (mg h^{-1} g^{-1})	5.56±3.33 (10)	6.24±2.84 (10)	5.23±1.81 (8)
EWL slope (mg h^{-1} g^{-1} °C^{-1})	2.74	4.74	2.84
Max. EWL (mg h^{-1} g^{-1})	36.02±8.88 (2)	49.76±7.90 (3)	37.80±4.93 (6) 43.49 (1)

Table S11 Phylogenetically informed stepwise multiple comparisons (PhylANOVA post hoc analysis test) and conventional analysis of variance (ANOVA) stepwise multiple comparisons (Tukey HSD post-hoc test) comparing whether body mass, maximum body temperature ($T_b max$) and the thermoregulatory predictors inlcuded in our multivariate additive linear model differed significantly between study localities. Bold values indicate significant differences between climatic localities ($p < 0.05$). Variables described in table include HTL - the maximum T_{air} tolerated before the onset of severe hyperthermia, EvapScope - maximum EWL (evaporative water loss)/minimum thermoneutral EWL, $T_b$slope - the slope of T_b as a function of T_{air} above thermoneutrality, $T_b norm$ **-** normothermic T_b, MaxEHL/MHP **-** maximum evaporative heat loss(EHL)/ metabolic heat production(MHP), MetabCost **-** maximum resting metabolic rate (RMR)/thermoneutral resting metabolic rate, Pant – T_{air} or T_b at which panting began. Degrees of freedom for all comparisons was calculated as the total number of samples – number of groups included in analysis, df = 29.

	PhylANOVA post hoc		Tukey post hoc	
	t-value	p-value	HSD	p-value
HTL (humid-dry)				
Montane - Arid	1.21	0.220	0.69	0.460
Lowland - Arid	3.71	**0.006**	1.90	**0.002**
Lowland - Montane	2.37	**0.036**	1.22	0.061
HTL (humid)				
Montane - Arid	1.72	0.072	1.16	0.212
Lowland - Arid	4.58	**0.003**	2.77	**<0.001**
Lowland - Montane	2.67	**0.012**	1.62	**0.03**
$T_b$max (humid-dry)				
Montane - Arid	3.73	**0.006**	0.72	**0.002**
Lowland - Arid	3.12	**0.020**	0.54	**0.011**
Lowland - Montane	-0.99	0.326	-0.17	0.584
$T_b$max (humid)				
Montane - Arid	3.42	**0.003**	0.97	**0.005**
Lowland - Arid	4.10	**0.003**	1.05	**<0.001**
Lowland - Montane	0.32	0.773	0.08	0.946
$T_b$norm (humid-dry)				
Montane - Arid	1.53	0.106	0.32	0.289
Lowland - Arid	-6.11	**0.003**	-1.16	**<0.001**
Lowland - Montane	-7.81	**0.003**	-1.48	**<0.001**
T_bSlope (humid/dry)				
Montane - Arid	-0.82	1.0	-0.11	0.701
Lowland - Arid	-0.99	1.0	-0.08	0.587
Lowland - Montane	-0.09	1.0	-0.07	0.995

Table S11 Cont.

	PhylANOVA post hoc		Tukey post hoc	
	t-value	p-value	t-value	p-value
MaxEWL (humid/dry)				
Montane - Arid	-1.58	0.249	-0.12	0.270
Lowland - Arid	-1.63	0.342	-0.11	0.251
Lowland - Montane	0.12	0.913	0.01	0.990
MaxRMR (humid/dry)				
Montane - Arid	-0.58	1.000	-0.05	0.832
Lowland - Arid	0.14	1.000	0.01	0.989
Lowland - Montane	0.78	1.000	0.06	0.719
MaxEHL/MHP (humid)				
Montane - Arid	1.16	0.678	0.14	0.49
Lowland - Arid	0.19	0.876	0.02	0.98
Lowland - Montane	-1.09	0.620	-0.12	0.52
MaxEHL/MHP (humid/dry)				
Montane - Arid	-0.13	1.000	-0.01	0.99
Lowland - Arid	-0.31	1.000	-0.02	0.94
Lowland - Montane	-0.16	1.000	-0.012	0.99
EvapScope (humid/dry)				
Montane - Arid	0.32	0.755	0.03	0.946
Lowland - Arid	-1.44	0.516	-0.14	0.332
Lowland - Montane	-1.80	0.222	-0.18	0.188
Metabcost (humid/dry)				
Montane - Arid	0.92	0.876	0.107	0.633
Lowland - Arid	-0.03	0.980	-0.002	0.999
Lowland - Montane	-1.04	0.940	-0.11	0.557
EWLSlope (humid/dry)				
Montane - Arid	-3.50	**0.003**	-0.37	**0.004**
Lowland - Arid	-4.25	**0.004**	-0.41	**<0.001**
Lowland - Montane	-0.39	0.733	-0.04	0.921
RMRSlope (humid/dry)				
Montane - Arid	-0.08	1.000	-0.02	0.996
Lowland - Arid	-0.85	1.000	-0.23	0.673
Lowland - Montane	-0.76	1.000	-0.21	0.728
PantT_{air}				
Montane - Arid	-3.54	**0.003**	-1.79	**<0.01**
Lowland - Arid	-3.32	**0.012**	-1.52	**<0.01**
Lowland - Montane	0.59	0.562	0.27	0.830
PantT_b				
Montane - Arid	0.79	0.408	0.19	0.712
Lowland - Arid	-2.375	0.112	-0.52	0.061
Lowland - Montane	-3.24	**0.003**	-0.71	**0.008**

Table S12 Model selection for phylogenetically informed linear mixed effects model of humid heat tolerance limit as a function of study locality (Clim), maximum body temperature tolerated by a species ($T_b max$), maximum evaporative cooling efficiency - evaporative heat loss/metabolic heat production (MaxEHL/MHP), ratio of maximum evaporative water loss (EWL) to minimum thermoneutral EWL (EvapScope), ratio of maximum resting metabolic rate (RMR) to minimum RMR (MetabCost), the slope of the relationship between T_b and T_{air} above inflection points ($T_b$slope), and interaction terms between study locality and MaxEHL/MHP. A "+" indicates and inclusion of a predictor variable or interaction from a model formula. Best-performing models are highlighted in bold. If two models were within < 2 AIC_c the most parsimonious model was chosen.

Model	Int.	Clim	MaxEHL/MHP	EvapScope	EWLslope	Metabcost	RMRSlope	$T_b$max	$T_b$slope	Clim: EHL/MHP	df	logLIK	AICc	delta	weight
328	**-0.62**	**+**	**6.61**	**0.24**				**0.80**		**+**	**8**	**-33.83**	**89.81**	**0.00**	**0.50**
76	**-10.16**	**+**	**3.19**		**11.23**			**1.10**			**6**	**-38.38**	**92.12**	**2.20**	**0.27**
72	**-0.20**	**+**	**3.47**	**0.21**				**0.87**			**6**	**-38.41**	**92.18**	**2.27**	**0.16**
456	**6.66**	**+**	**7.13**	**0.25**				**0.61**	**1.59**	**+**	**9**	**-33.20**	**92.57**	**2.66**	**0.12**
360	-5.13	+	6.84	0.19			0.01	0.89		+	9	-33.28	92.74	2.82	0.05
100	-13.92	+	4.02				0.03	1.17			6	-38.71	92.78	2.87	0.05
392	32.43	+	7.66	0.29					3.38	+	8	-35.34	92.95	3.04	0.04
336	-3.16	+	6.35	0.19	3.91			0.86		+	9	-33.48	93.15	3.23	0.04
332	-11.75	+	5.82		11.06			1.06		+	8	-35.63	93.53	3.62	0.03
344	-1.80	+	6.60	0.22		0.24		0.81		+	9	-33.77	93.73	3.81	0.03
356	-16.10	+	7.10				0.03	1.13		+	8	-35.77	93.81	3.89	0.03
104	-6.06	+	3.70	0.13			0.02	0.99			7	-37.57	93.81	3.90	0.03
80	-4.52	+	3.24	0.12	6.69			0.97			7	-37.62	93.90	3.98	0.03
84	-12.01	+	4.05			1.52		1.08			6	-39.59	94.54	4.62	0.02
108	-12.05	+	3.50		7.22		0.01	1.13			7	-38.04	94.75	4.84	0.02
88	-3.26	+	3.64	0.16		0.60		0.92			7	-38.14	94.95	5.03	0.02
200	2.43	+	3.54	0.21				0.81	0.56		7	-38.35	95.37	5.45	0.01
92	-10.45	+	3.27		10.25	0.20		1.10			7	-38.36	95.39	5.47	0.01

Table S13 Durbin-Watson test outputs assessing autocorrelation between model variables included in the 'phylogenetic generalised least square' multivariate additive linear model with heat tolerance limit (HTL) as the response variable. The Durbin-Watson test detects autocorrelation based on the independence of residuals of linear regressions output. Values of DW approaching and around two and $p > 0.05$ indicate no significant autocorrelation between variables or within models. Conversely, values of DW approaching zero and $p < 0.05$ indicate significant autocorrelation between variables or within models. Predictor variables described in table include HTL - the maximum T_{air} tolerated before the onset of severe hyperthermia, EvapScope - maximum EWL (evaporative water loss)/minimum thermoneutral EWL, $T_b$slope - the slope of T_b as a function of T_{air} above thermoneutrality, MaxEHL/MHP **-** maximum evaporative heat loss (EHL)/ metabolic heat production (MHP), Climate – dry arid, humid lowland, mesic montane.

Input	DW Value	p-value
Evapscope ~ Mass	1.92	0.41
Metabcost ~ Mass	1.41	**0.04**
$T_b$max ~ Mass	1.43	**0.05**
MaxEHL_MHP ~ Mass	1.85	0.33
$T_b$slope ~ Mass	1.87	0.36
EWLslope ~ Mass	1.21	**<0.001**
RMRslope ~ Mass	1.89	0.38
Evapscope ~ MaxEHL_MHP	1.91	0.41
Evapscope ~ $T_b$slope	2.1	0.61
Evapscope ~ Metabcost	2.04	0.54
$T_b$max ~ Evapscope	1.5	0.07
$T_b$max ~ Metabcost	1.49	0.07
$T_b$slope ~ Metabcost	2.06	0.56
HTLhumid~Climate+Mass+EHL_MHPmax+Evapscope+Tbmax+Climate: EHL_MHPmax	1.94	0.30

Supporting information references

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