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Editorial: Avian behavioral and physiological responses to challenging thermal environments and extreme weather events

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Editorial on the Research Topic

Avian behavioral and physiological responses to challenging thermal environments and extreme weather events

Introduction

Birds occupy habitats ranging from Antarctic ice shelves to tropical deserts and lowland rainforests, so are exposed to the full range of climates on Earth (Dawson and O'Connor, 1996). Cold, hot or spatially and temporally variable thermal conditions can present significant thermoregulatory challenges to birds, which typically must maintain body temperatures (T_b) within narrow physiological limits (McKechnie, 2022). Such challenges may occur throughout the year (Parr et al., 2019) and in all life stages (DuRant et al., 2012; Nord and Giroud, 2020), so adjustments to these conditions are required to maintain fitness and, ultimately, stable populations. Here, we broadly define a challenging thermal environment as one requiring physiological acclimation or behavioral adjustments that modify rates of thermogenesis or heat loss to maintain long-term ecological function.

Avian abilities to respond physiologically to extreme temperatures are defined by capacities for heat production or dissipation (Swanson, 2010; McKechnie et al., 2021a). Behavioral responses to environmental temperature reduce the magnitude of physiological adjustments, although potentially with opportunity costs (Cunningham et al., 2021). It is this combination of behavioral and physiological responses at multiple levels of organization that determines the survival probability of birds in thermally challenging situations (e.g., Albright et al., 2017; Petit et al., 2017). Moreover, thermal conditions experienced during reproduction can affect parental investment and nestling development, with potentially long-term consequences (Nord and Giroud, 2020; van de Ven et al., 2020; Broggi et al., 2022). Our knowledge of response mechanisms, their time courses, and their impacts on fitness, however, remains incomplete. Behavioral and physiological responses of birds to extreme and/or seasonally variable climates have been a research focus for decades (Chaffee and Roberts, 1971; Dawson et al., 1983), but recent methodological and analytical advances for studies of physiology and behavior have produced novel findings regarding patterns and mechanisms of avian adjustments to challenging thermal environments (e.g., McCafferty et al., 2015; Cheviron and Swanson, 2017; McKechnie et al., 2021a).

Avian responses to heat and aridity

Physiological and behavioral responses permit the maintenance of sublethal T_b under hot conditions, but water is required for evaporative cooling, so interactions between temperature and water availability are important considerations for thermoregulation in the heat (Conradie et al., 2020). Large birds have greater thermal inertia and lower surface area to volume ratios than small species, so body mass may impact the magnitude of heat tolerance responses (McKechnie et al., 2021a), but this has been little studied. Czenze et al. found that heat tolerance, maximum T_b , and evaporative cooling capacities in three larger-bodied South African non-passerines approximated those in other non-passerines and exceeded capacities in passerines (McKechnie et al., 2021a). Sabat et al. tested a new method to estimate metabolic and pre-formed water contributions to the body water pool and detected isotopic differences under cold temperatures and between species using freshwater and saltwater resources, thereby validating the method for future studies of water balance. Navarette et al. experimentally manipulated water availability in rufous-collared sparrows (*Zonotrichia capensis*) and identified trade-offs involving water restriction-induced increases in basal metabolic rate (BMR) and erythrocyte oxidative enzyme activities at the expense of skeletal muscle oxidative damage. Sharpe et al. documented reduced foraging and increased use of thermally buffered microhabitats by Jacky Winters (*Microeca fascians*)

during hot weather; nevertheless, 29% of the study population died when air temperature reached 49°C, demonstrating limits to physiological and behavioral capacities for responding to extreme heat events.

Avian responses to heat during reproduction

The heat dissipation limits hypothesis (HDLH) posits that the capacity to dissipate heat loads acquired during sustained activities, such as breeding, limits performance and may negatively affect reproductive output and fitness (Speakman and Król, 2010). Several studies of free-living birds support the HDLH, even in comparatively cool habitats (Andreasson et al., 2020). Zagkle et al. found support for the HDLH by manipulating heat loss while increasing foraging costs in zebra finches (*Taeniopygia guttata*), documenting negative effects on reproduction under warm temperatures that were buffered by experimentally increased heat loss. Increasing temperatures over an 11-year study period were strongly negatively correlated with reproductive output in southern yellow-billed hornbills (*Tockus leucomelas*) (Pattinson et al.), suggesting that, if current warming trends continue, reproductive capacity will be sufficiently compromised to result in imminent nesting failure for this population. Pipoly et al. demonstrated that negative effects of high temperatures on nestling growth and survival were stronger in forest than urban populations of great tits (*Parus major*), suggesting that urban nestlings are less vulnerable to heat. Udino and Mariette experimentally documented that parental heat calls during the late *in ovo* period resulted in panting at lower temperatures, reduced panting at high temperatures, and higher activity at warm temperatures when the offspring had reached adulthood, highlighting the priming effects of early life conditions on later thermoregulatory patterns.

Avian responses to cold

Metabolic flexibility allows birds to match metabolic rates to environmental conditions (Swanson, 2010). Underlying mechanisms of metabolic flexibility include adjustments in muscle size (Swanson and Vézina, 2015; Swanson et al., 2022) and cellular aerobic and fat catabolism capacities (Swanson, 2010), but the contribution of other metabolic pathways to this flexibility is poorly known (Stager et al., 2015; Cheviron and Swanson, 2017). Wone and Swanson used integrated metabolomics/transcriptomics analyses to document seasonal changes in amino acid, lipid- and cellular metabolism pathways in two passerine birds and identified a potential role for nicotinamide-adenine-nucleotide derivatives in regulating cellular metabolism. In addition to heat production mechanisms, energy conservation strategies, including torpor

(Ruf and Geiser, 2015; Geiser, 2021) and ventilatory/respiratory adjustments (Arens and Cooper, 2005), can contribute to avian cold tolerance. Bech and Mariussen detected winter increases in BMR and the respiratory frequency/tidal volume ratio in great tits, allowing energy savings by reducing respiratory energetic costs and evaporative water losses. Aharon-Rotman et al. showed that winter-acclimatized eastern yellow robins (*Eopsaltria australis*) regularly entered torpor, expanding documentation of torpor use in the comparatively poorly studied passerine taxon.

Conclusions

As demonstrated by the studies in this Research Topic, behavioral and physiological flexibility can buffer temperature impacts on birds. In addition to changes in average temperatures, however, global change is predicted to increase climate variability, with more frequent extreme events for many locations (Jentsch et al., 2007; Wallace et al., 2014; Cohen et al., 2018). Increasing extreme summer maximum temperatures and more variable winter temperatures can have negative consequences for birds, including mass mortality events (McKechnie and Wolf, 2010; McKechnie et al., 2021b), phenotype-environment mismatches (Boyles et al., 2011; Jimenez et al., 2020; Vézina et al., 2020; Ruuskanen et al., 2021), reduced reproductive capacities (Carroll et al., 2018; Nord and Nilsson, 2019; van de Ven et al., 2020), and altered offspring physiology and behavior (Mariette and Buchanan, 2016; Mariette, 2020). Future research incorporating not only behavior and physiology, but also flexibility in these traits and their thermal reaction norms, into population and distribution models will be critical to understand impacts of climate change on avian biodiversity.

References

- Albright, T. P., Mutiibwa, D., Gerson, A. R., Smith, E. K., Talbot, W. A., O'Neill, J. J., et al. (2017). Mapping evaporative water loss in desert passerines reveals and expanding threat of lethal dehydration. *Proc. Natl. Acad. Sci. USA*. 114, 2283–2288. doi: 10.1073/pnas.1613625114
- Andreasson, F., Nilsson, J. -, Å., and Nord, A. (2020). Avian reproduction in a warming world. *Front. Ecol. Evol.* 8, 576331. doi: 10.3389/fevo.2020.576331
- Arens, J. R., and Cooper, S. J. (2005). Seasonal and diurnal variation in metabolism and ventilation in house sparrows. *Condor* 107, 433–444. doi: 10.1093/condor/107.2.433
- Boyles, J. G., Seebacher, F., Smit, B., and McKechnie, A. E. (2011). Adaptive thermoregulation in endotherms may alter responses to climate change. *Integr. Comp. Biol.* 51, 676–690. doi: 10.1093/icb/ict053
- Broggi, J., Hohtola, E., Koivula, K., Rutkönen, S., and Nilsson, J. -, Å. (2022). Prehatching temperatures drive inter-annual cohort differences in great tit metabolism. *Oecologia* 198, 619–627. doi: 10.1007/s00442-022-05126-7
- Carroll, R. L., Davis, C. A., Fuhlendorf, S. D., Elmore, R. D., DuRant, S. E., and Carroll, J. M. (2018). Avian parental behavior and nest success influenced by temperature fluctuations. *J. Therm. Biol.* 74, 140–148. doi: 10.1016/j.jtherbio.2018.03.020
- Chaffee, R. R., and Roberts, J. C. (1971). Temperature acclimation in birds and mammals. *Ann. Rev. Physiol.* 33, 155–202. doi: 10.1146/annurev.ph.33.030171.001103
- Cheviron, Z. A., and Swanson, D. L. (2017). Comparative transcriptomics of seasonal phenotypic flexibility in two species of North American songbirds. *Integr. Comp. Biol.* 57, 1040–1054. doi: 10.1093/icb/ict118
- Cohen, J., Zhang, X., Francis, J., Jung, T., Kwok, R., Overland, J., et al. (2018). *Arctic Change and Possible Influence on Mid-Latitude Climate and Weather: A US CLIVAR White Paper*. US CLIVAR reports.
- Conradie, S. R., Woodborne, S. M., Wolf, B. O., Pessato, A., Mariette, M. M., and McKechnie, A. E. (2020). Avian mortality risk during heat waves will increase greatly in arid Australia during the 21st century. *Conserv. Physiol.* 8, coaa048. doi: 10.1093/conphys/coaa048
- Cunningham, S. J., Gardner, J. L., and Martin, R. O. (2021). Opportunity costs and the response of birds and mammals to climate warming. *Front. Ecol. Environ.* 19, 300–307. doi: 10.1002/fee.2324
- Dawson, W. R., Marsh, R. L., and Yacoe, M. E. (1983). Metabolic adjustments of small passerine birds for migration and cold. *Am. J. Physiol.* 245, R755–R767. doi: 10.1152/ajpregu.1983.245.6.R755

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Conflict of interest

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- Dawson, W. R., and O'Connor, T. P. (1996). "Energetic features of avian thermoregulatory responses," in *Avian Energetics and Nutritional Ecology*, ed. C. Carey (New York, NY: Chapman and Hall), 85–124.
- DuRant, S. E., Hopkins, W. A., Wilson, A. F., and Hepp, G. R. (2012). Incubation temperature affects the metabolic cost of thermoregulation in a young precocial bird. *Funct. Ecol.* 26, 416–422. doi: 10.1111/j.1365-2435.2011.01945.x
- Geiser, F. (2021). "Patterns and expression of torpor," in *Ecological Physiology of Daily Torpor and Hibernation. Fascinating Life Sciences* (Cham: Springer).
- Jentsch, A., Kreyling, J., and Beierkuhnlein, C. (2007). A new generation of climate-change experiments: events, not trends. *Front. Ecol. Environ.* 5, 365–374. doi: 10.1890/1540-9295(2007)5[365:ANGOCE]2.0.CO;2
- Jimenez, A. G., Ruhs, E. C., Tobin, K. J., Anderson, K. N., Le Pogam, A., Régimbald, L., et al. (2020). Consequences of being phenotypically mismatched with the environment: no evidence of oxidative stress in cold- and warm-acclimated birds facing a cold spell. *J. Exp. Biol.* 223, jeb218826. doi: 10.1242/jeb.218826
- Mariette, M. M. (2020). Acoustic developmental programming: implications for adaptive plasticity and the evolution of sensitive periods. *Curr. Opin. Behav. Sci.* 36, 129–134. doi: 10.1016/j.cobeha.2020.09.010
- Mariette, M. M., and Buchanan, K. L. (2016). Prenatal acoustic communication programs offspring for high posthatching temperatures in a songbird. *Science* 353, 812–814. doi: 10.1126/science.aaf7049
- McCafferty, D. J., Gallon, S., and Nord, A. (2015). Challenges of measuring body temperatures of free-ranging birds and mammals. *Anim. Biotelemetry* 3, 33. doi: 10.1186/s40317-015-0075-2
- McKechnie, A. E. (2022). "Regulation of body temperature: patterns and processes," in *Sturkie's avian physiology*, 7th eds, C. Scanes, S. Dridi (New York, NY: Academic Press), 1231–1264.
- McKechnie, A. E., Gerson, A. R., and Wolf, B. O. (2021a). Thermoregulation in desert birds: scaling and phylogenetic variation in heat tolerance and evaporative cooling. *J. Exp. Biol.* 224, jeb229221. doi: 10.1242/jeb.229211
- McKechnie, A. E., Rushworth, I. A., Myburgh, F. M., and Cunningham, S. J. (2021b). Mortality among birds and bats during an extreme heat event in eastern South Africa. *Austral. Ecol.* 46, 687–691. doi: 10.1111/aec.13025
- McKechnie, A. E., and Wolf, B. O. (2010). Climate change increases the likelihood of catastrophic avian mortality events during extreme heat waves. *Biol. Lett.* 6, 253–256. doi: 10.1098/rsbl.2009.0702
- Nord, A., and Giroud, S. (2020). Lifelong effects of thermal challenges during development in birds and mammals. *Front. Physiol.* 11, 419. doi: 10.3389/fphys.2020.00419
- Nord, A., and Nilsson, J. Å. (2019). Heat dissipation rate constrains reproductive investment in a wild bird. *Funct. Ecol.* 33, 250–259. doi: 10.1111/1365-2435.13243
- Parr, N., Bishop, C. M., Batbayar, N., Butler, P. J., Chua, B., Milsom, W. K., et al. (2019). Tackling the Tibetan Plateau in a down suit: insights into thermoregulation by bar-headed geese during migration. *J. Exp. Biol.* 222, jeb203695. doi: 10.1242/jeb.203695
- Petit, M., Clavijo-Baquet, S., and Vézina, F. (2017). Increasing winter maximal metabolic rate improves intrawinter survival in small birds. *Physiol. Biochem. Zool.* 90, 166–177. doi: 10.1086/689274
- Ruf, T., and Geiser, F. (2015). Daily torpor and hibernation in birds and mammals. *Biol. Rev.* 90, 891–926. doi: 10.1111/brv.12137
- Ruuskanen, S., Hsu, B. -, Y., and Nord, A. (2021). Endocrinology of thermoregulation in birds in a changing climate. *Mol. Cell. Endocrinol.* 519, 111088. doi: 10.1016/j.mce.2020.111088
- Speakman, J. R., and Król, E. (2010). The heat dissipation limit theory and evolution of life histories in endotherms-time to dispose of the disposable soma theory? *Integr. Comp. Biol.* 50, 793–807. doi: 10.1093/icb/icq049
- Stager, M., Swanson, D. L., and Cheviron, Z. (2015). Regulatory mechanisms of metabolic flexibility in the dark-eyed junco (*Junco hyemalis*). *J. Exp. Biol.* 218, 767–777. doi: 10.1242/jeb.113472
- Swanson, D. L. (2010). Seasonal metabolic variation in birds: functional and mechanistic correlates. *Curr. Ornithol.* 17, 75–129. doi: 10.1007/978-1-4419-6421-2_3
- Swanson, D. L., and Vézina, F. (2015). Environmental, ecological and mechanistic drivers of avian seasonal metabolic flexibility in response to cold winters. *J. Ornithol.* 156, S377–S388. doi: 10.1007/s10336-015-1192-7
- Swanson, D. L., Zhang, Y., and Jimenez, A. G. (2022). Skeletal muscle and metabolic flexibility in response to changing energy demands in wild birds. *Front. Physiol.* 13, 961392. doi: 10.3389/fphys.2022.961392
- van de Ven, T. M. F., McKechnie, A. E., and Cunningham, S. J. (2020). High temperatures are associated with substantial reductions in breeding success and offspring quality in an arid-zone bird. *Oecologia* 193, 225–235. doi: 10.1007/s00442-020-04644-6
- Vézina, F., Ruhs, E. C., O'Connor, E. S., Le Pogam, A., Régimbald, L., Love, O. P., et al. (2020). Consequences of being phenotypically mismatched with the environment: rapid muscle ultrastructural changes in cold-shocked black-capped chickadees (*Parus atricapillus*). *Am. J. Physiol. Reg. Integr. Comp. Physiol.* 318, R274–R283. doi: 10.1152/ajpregu.00203.2019
- Wallace, J. M., Held, I. M., Thompson, D. W., Trenberth, K. E., and Walsh, J. E. (2014). Global warming and winter weather. *Science* 343, 729–730. doi: 10.1126/science.1243617