SYMPOSIUM

No Effect of Human Presence at Night on Disease, Body Mass, or Metabolism in Rural and Urban House Finches (*Haemorhous mexicanus*)

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Synopsis Global urban development continues to accelerate and have diverse effects on wildlife. Although most studies of anthropogenic impacts on animals have focused on indirect effects (e.g., environmental modifications like habitat change or pollution), there may also be direct effects of physical human presence and actions on wildlife stress, behavior, and persistence in cities. Most studies on how humans physically interact with wildlife have focused on the active, daytime phase of diurnal animals, rarely considering effects of our night-time activities. We hypothesized that, if night-time human presence is a stressor for wildlife that are not commonly exposed to humans, night-disturbed rural animals would show stronger physiological signs of elevated stress than would urban individuals. Specifically, we experimentally investigated the effects of human presence at night (HPAN) on disease, body mass, and mass-specific metabolic rates in urban- and rural-caught house finches (*Haemorhous mexicanus*) in captivity. Our HPAN treatment consisted of a human entering the housing room of the birds and briefly jostling the home cages of each finch as the person walked around the room for a 3-min period on five randomly selected nights per week. Compared with a control (night-undisturbed) group, we found that HPAN greatly increased the odds finches were awake for ca. 33 min post-disturbance, but that chronic treatment did not alter body mass, parasitic infection by coccidian endoparasites, or mass-specific basal metabolic rates. Additionally, finches caught from urban and rural sites did not differ in their response to the treatment. Overall, our results are consistent with those showing that brief but regular human disturbances can have acute negative effects on wildlife, but carry few if any long-term metabolic or disease-related costs in fast-lived birds. However, these findings contrast with the broad, chronic physiological effects of other anthropogenic changes, such as artificial light at night, and highlight the differential impacts that various human activities (which differ in sensory stimulus type, perceived threat, duration and intensity, etc.) can have on wildlife health and behavior.

Introduction

Global urban development is extensive and rapidly increasing (Grimm et al. 2008). Worldwide human populations are projected to reach over 10 billion around the year 2050 (United Nations, Department of Economic and Social Affairs, Population Division 2017). In 2014, the United Nations estimated, for the first time, that over half of all people lived in cities, and that nearly all population growth through 2100 would occur within cities (United Nations, Department of Economic and Social Affairs, Population Division 2014). A major question now

and into the future is how humans directly and indirectly affect animal populations. Some anthropogenic disturbances serve as stimuli that may drive away or keep out animals from human-inhabited areas (McDonnell and Hahs 2015), whereas other environmental alterations (e.g., resource subsidies like food and water, additional breeding substrates on built structures) may be beneficial to certain species (Murray et al. 2016).

The majority of attention placed on human impacts on wildlife have been on indirect effects (e.g., environmental modifications; Isaksson 2010;

Kunc et al. 2014; Ouyang et al. 2017). However, considerably less research has been conducted on the direct effects of physical human presence and actions in cities on animals (Valcarcel and Fernández-Juricic 2009; Vincze et al. 2016). Human presence can be perceived as a threat, especially when humans are a new stimulus (Vincze et al. 2016) and/or their behavior is unpredictable (Koolhaas et al. 2011). Degree of threat also may vary based on taxon (e.g., body size, home range) or exposure intensity and frequency (e.g., number of humans). There are unique examples of human disturbances of wildlife (e.g., New Year's Eve celebrations causing massive-scale flushing of birds from their roosts; Shamoun-Baranes et al. 2011), but overall we need a more comprehensive understanding of the behavioral, physiological, and fitness effects of human presence on different wildlife species.

In those studies conducted to date, it is clear that physical human disturbance can have strong acute effects, such as heart rate (which strongly predicts metabolic activity, Weimerskirch et al. 2002), in both mammals and birds (Andersen et al. 1996; Weimerskirch et al. 2002; Ellenberg et al. 2013), including for a prolonged period based on a brief encounter. For example, brief human disturbance increased heart rate for ca. 2–3 h in wandering albatross (*Diomedea exulans*) (Weimerskirch et al. 2002). Interestingly, nearly all studies on how human disturbance affects animal behavior and physiology have focused on daytime human activity. However, humans are not strictly diurnal, as they can facultatively stay active overnight for a variety of reasons (e.g., shift work and social events). It is surprising then that there have been so few studies of how human disturbance specifically at night affects animals (Bisson et al. 2009, 2011). Those studies mainly center on the effects after acute exposure to human presence at night (HPAN). Bisson et al. (2011) found that three humans walking and playing music in the territories of wild black-capped vireos (*Vireo atricapilla*), a fast-lived bird, for 1 h at night had found no acute effect on heart rate, energy expenditure, or general activity. In contrast, Bisson et al. (2009) found in white-eyed vireos (*Vireo griseus*) that the same disturbance treatment increased heart rate without a concomitant increase in activity or energy expenditure. However, birds living in urban environments are likely chronically exposed to HPAN, and we therefore need studies of the chronic effects of HPAN.

Night-time wildlife disturbances by humans may carry different costs than daytime disturbances, because they could disrupt a different suite of behavioral and physiological processes. Diurnal animals spend most of the night asleep, and sleep has been shown to improve immune function and conserve energy (Bryant et al. 2004; Hui et al. 2007; Van Cauter et al. 2008). Although studies are limited, physiological stress reactivity also can exhibit day–night variation; for example, studies show that house sparrows (*Passer domesticus*) and European starlings (*Sturnus vulgaris*) had more reactive stress systems at night than during the day (Romero and Remage-Haley 2000; Rich and Romero 2001), possibly due to increased adrenal sensitivity to adrenocorticotropic hormone (Romero and Rich 2007), suggesting that night-time disturbance could have stronger physiological impacts on animals. Additionally, experimentally administered chronic stress protocols (including during the night) are known to decrease body mass (Rich and Romero 2005).

Human proximity and presence may often serve as a benign stimulus to wildlife frequently exposed to humans (e.g., walk-bys and sounds), such as those in cities. Evidence from non-urban contexts include a study that showed Magellanic penguins (*Spheniscus magellanicus*) in frequently tourist-visited areas are less sensitive to capture and handling stress than those from non-tourist areas (Walker et al. 2006). Urban birds, for example, are more tolerant of (Møller 2008; Carrete and Tella 2011) and quickly habituate to daytime human disturbance (Arroyo et al. 2017; Vincze et al. 2017), and can even decouple human response from typical anti-predator responses in learning that humans typically are non-threatening (e.g., in owls; Carrete and Tella 2011). This backdrop of findings generates the prediction that human disturbance may have disproportionate effects on animals residing in typical human-inhabited versus rural landscapes, such that those in cities may acclimate or adapt over time to human exposure and thereby show reduced sensitivity and reactivity toward perceived human presence. However, to our knowledge, no studies have yet tested urban–rural variation in the behavioral and physiological responsiveness of animals to HPAN.

Here, we investigated whether acute night-time human disturbance increases behavioral vigilance and whether chronic treatment alters physiological status (i.e., parasitic infection, metabolism, body mass) in both urban and rural birds. Additionally, we hypothesized that prior association with humans should make urban birds more resilient than rural birds to HPAN. Also, we believe our study is the first to examine urban–rural variation in basal metabolic rates of a non-human animal (Sepp et al. 2018). We tested all of this in house finches (*Haemorhous*

mexicanus), a bird species that has successfully colonized cities in its native desert-southwestern range as well as across most of the rest of the lower-48 USA (Hill 2002). Previous urban–ecological studies of house finches in Phoenix, AZ, USA show that urban birds are more severely and likely to be infected with coccidian intestinal parasites (*Isospora* spp.). Previous studies show that rural house finches might be more sensitive to human disturbance, as human presence during the day was found to decrease problem-solving performance in rural house finches, urban finches were resilient to this effect (Cook et al. 2017). Additionally, rural house finches in CA, USA were shown to display higher degrees of behavioral vigilance than urban finches (Valcarcel and Fernández-Juricic 2009). We captured birds from urban and rural sites in Phoenix, AZ, and under common-garden laboratory conditions subjected them to a brief night-time human disturbance treatment on 21 of 31 consecutive nights. Prior to and following the experiment, we measured body mass, basal metabolic rate, and infection by coccidia, with the prediction that human disturbance would increase parasitism and basal metabolic rate, and reduce body mass.

Methods

Experimental timeline and treatment

In June 2013, we caught 56 hatch-year juvenile house finches (of unknown sex) using basket traps baited with sunflower seeds from four different sites ($n = 14$ birds/site)—two urban and two rural—in and around the Phoenix metropolitan area, AZ, USA. These urban and rural capture sites differ greatly in human population density, land-use and land-cover (Giraudeau et al. 2014). Given that, based on 2010 US Census data (Giraudeau et al. 2014), population densities at our two rural sites (11 people/km^2 at Estrella Mountain Regional Park and 1001 people/km^2 at South Mountain Regional Park) were 1–2 orders of magnitude lower than at our two urban sites (7291 people/km^2 at downtown Phoenix and 10,385 people/km^2 at the Arizona State University-Tempe campus). South Mountain and Estrella Mountain are both open to hikers, and Estrella Mountain hosts a camping site. However, we think that the possible human exposure at night at these sites is limited due to the small size of this camping site relative to finch activity ranges, and because quiet hours are imposed on the campgrounds at night. Therefore, our rural-caught birds were expected to have naturally encountered fewer

humans than those at the urban sites, especially at night.

Captured finches were transported to and housed individually in small wire cages at the Life Sciences indoor vivarium on the Arizona State University-Tempe campus (IACUC protocol 12-1234R). Finches were fed black oil sunflower seeds and given tap water *ad libitum*. Rooms were kept at 25°C, and were only artificially illuminated with fluorescent bulbs (photoperiod of 14 h light:10 h dark). Individuals were split evenly, by site, into either a treatment group (explained below) or a control group. After allowing 2 weeks of acclimation to captivity, we began to administer the experimental HPAN treatment. The treatment consisted of a single person entering the room housing the HPAN birds, gently and briefly (for 2–3 s, roughly the amount of time a passing human might physically disrupt a roosting site) jostling each cage, then exiting the room and closing the door. Previous work has shown that cage jostling can elicit a significant glucocorticoid response, suggesting that birds perceive this as a stressful event (Rich and Romero 2005). We chose to jostle the cage because a person silently entering and walking about the room might not awaken the birds, thereby providing no effective stimulus. The person was in the room for ca. 3 min (enough time to walk around the room and jostle each cage). The human visited the room at a randomly selected time during five randomly selected nights per week for a period of 1 month (i.e., 21 overnight room-visits over 31 nights; see Supplementary Table S1 for exact schedule). We await field studies that might help us better understand how much HPAN roosting urban birds are realistically exposed to, and in lieu of this information we chose to administer at this frequency as a conservative estimate. We chose to administer the treatment chronically for a long duration based on prior studies which administered chronic stress protocols at similar length (Rich and Romero 2005). Visitation time was randomized to reduce the likelihood that finches could anticipate and acclimate to our treatment. To address potential, confounding room effects in this experiment, we swapped treatment and control birds between housing rooms each week.

Toward the end of the experiment (days 24 and 28), in a subset of birds ($n = 6$ per treatment group), we monitored the acute behavioral effects of the treatment with infrared cameras (SWPRO-510CAM, Swann, Port Melbourne, Australia). We scan-sampled (with 3 min scans) the sleep state (either awake or asleep) of each individual beginning 15 min

prior to, and for 45 min following, the HPAN treatment. Sleep state was scored following Rattenborg et al. (2005); briefly, at each scan we monitored both body position (either bill forward or backward) and whether the eyes were open or not. If the eyes were visible and open, we scored the bird as awake; if the eyes were visible and closed, the bird was scored as asleep. The eyes were often not visible while the bird had its bill on its back, but based on Costa (2009), this body position is often associated with deep sleep (i.e., slow-wave sleep and high levels of slow-wave activity), so we scored any bird in this position as asleep. By comparing the sleep state of HPAN birds with control birds from the exact same time period, we found that our HPAN treatment was effective in significantly increasing the likelihood of wakefulness for a ca. 33-min period after human entry into the housing room (see the "Results" section).

Coccidian intestinal parasites

At 1630 h on 19 June and 26 July (just prior to beginning and just after ending our experiment, respectively), we collected a fecal sample from each bird so we could score infection by coccidian intestinal parasites (*Isospora* spp.). We stored feces in a 2.2% potassium dichromate in water solution to preserve oocysts until later analysis. Fecal float and slide preparations were done according to Brawner et al. (2000) and Giraudeau et al. (2014). Slides were viewed via light microscopy (magnification set to 40×), and the number of oocysts were estimated on a logarithmic scale: $0 =$ no oocysts, $1 = 1$–10 oocysts, $2 = 11$–100 oocysts, $3 = 101$–1000 oocysts, $4 = 1001$–10,000 oocysts, and $5 = >10,000$ oocysts.

Resting metabolic rate and body mass

On the same days we collected feces, we also measured body mass using a balance (± 0.1 g), and tarsus length using calipers (± 0.01 mm). We then extracted body condition residuals from a linear model of mass on tarsus length, but found that this model was not significant ($\beta = 0.37 \pm 0.24$, $t = 1.56$, P-value $= 0.12$). We analyzed both body mass and condition and found qualitatively similar results for both analyses.

Near the end of the experiment (on experiment days 24–30), we measured basal metabolic rates (in a subsample of $n = 40$; 9–11 from each treatment group). We placed up to seven finches per overnight trial into individual, sealed respirometry chambers without food or water. The respirometry chambers were kept inside a larger environmental room that maintained the same temperature as the birds' regular housing (25°C). The cylindrical respirometry chambers (volume $= 7.0$ L, height $= 13.5$ cm, diameter $= 20.0$ cm) had enameled steel bottoms and walls and a glass lid with a closed cell foam gasket. Each chamber had two ports, one for influent air and one for effluent air. The birds were provided a perch and plastic grating was placed at the bottom of each chamber to prevent any excrement from getting on the birds.

Supply air was provided simultaneously to all respirometry chambers at approximately 450 mL/min by compressing atmospheric air, passing it through a desiccant chamber containing Drierite (W.A. Hammond Drierite Co. Ltd., Xenia, OH, USA), and then sending it through a manifold system. When oxygen consumption was being measured from a bird, that chamber received the same supply air delivered through a mass flow controller (UNIT Instruments, Yorba Linda, CA, USA) that provided air at a constant 450 mL/min. Effluent air from each chamber flowed into individual spill tubes. A peristaltic pump and a group of solenoids were set up and programmed so that effluent air was sub-sampled from the spill tube associated with the respiratory chamber receiving the air from the mass flow controller. The sub-sampled air flowed through a hygrometer (RH-300 water vapor analyzer, Sable Systems International, Las Vegas, NV, USA), then a desiccation column containing Drierite, and finally through an oxygen analyzer (FC-1B oxygen analyzer, Sable Systems International) that was calibrated with outside air prior to each use. A datalogger (23X, Campbell Scientific, Logan, UT, USA) controlled the solenoids and recorded the following measurements every minute throughout the duration of all trials: the temperature of the environmental chamber, the flow rate of air through the mass flow controller, and the dew point and percent oxygen concentration of the effluent air. To provide baseline measurements of the supply air, each overnight trial was minimally bracketed by baseline measurements prior to the start of all trials and after all trials for that evening. During these baseline measurements, air was run through an empty respirometry chamber via the process described above.

Basal metabolic rates were measured as the lowest O_2 consumption over at least a 10-min period. Minutely consumption values over this duration were averaged to produce a final effluent O_2 value. Basal metabolic rates were calculated by multiplying fractional O_2 (baseline proportion of O_2 – excurrent proportion of O_2) with the average flow rate

(simplified from Equation (9.4), Lighton 2008). We then divided this result by body mass to determine mass-specific BMR.

Statistics

All statistical tests were run using the open software R computing environment, Version 1.0.136. To test the acute effect of human disturbance treatment on sleep behavior, we created a generalized linear model with a binomial error distribution. In this model, sleep state (awake or sleep) was the response variable and time, treatment, and the treatment * time interaction were the predictors. Post hoc Tukey pairwise tests focused on within-timepoint differences in sleep state between treatment groups.

When examining HPAN treatment effects on finch physiological and morphological parameters, we originally ran each model with capture site (Tempe, Phoenix, South Mountain, Estrella Mountain) instead of degree of urbanization (urban vs. rural) as a predictor, but since we found qualitatively similar results, we present results from the models with degree of urbanization for ease of interpretation. To test the effect of our chronic HPAN treatment on body mass, we created linear mixed models, with body mass as the response variable and treatment, degree of urbanization, time, and their interactions as predictors. To test the effect of our chronic HPAN treatment on coccidiosis score, we created generalized linear mixed models, with a Poisson error term. Coccidia score was set as the response variable, and the predictors were the same as in the body-mass model. To test for treatment effects on mass-specific BMR at the end of the experiment, we ran a linear mixed model, with treatment, degree of urbanization, and the treatment * urbanization interaction as the predictors. In both the coccidia and body-mass models, we included both individual identity and capture site as random effects; in the BMR model, we included capture site as a random effect.

Results

Human disturbance treatment

We found a significant effect of the treatment * time interaction on sleep state ($\chi^2 = 32.8$, df = 20, $P = 0.035$; treatment main effect: $\chi^2 = 0$, df = 1, $P = 1.0$; time main effect: $\chi^2 = 22.5$, df = 20, $P = 0.31$). During the 15 min prior to the human disturbance treatment, nearly all control and HPAN birds were asleep, and post hoc analyses reveal that there were no significant differences between groups in the likelihood of wakefulness (Fig. 1).

Directly following the treatment, however, a large difference emerged in sleep state between groups, such that all HPAN birds were awake for 15 min, after which point the likelihood HPAN birds were awake steadily decreased. HPAN birds were significantly more likely to be awake 33 min after treatment, but at 36 min post-treatment and beyond, this difference disappeared. Thus, our HPAN treatment was effective in awakening birds for ca. half an hour.

Effect of HPAN treatment on parasites, body mass, and metabolic rate

We found no significant effects of time, treatment, degree of urbanization, or their interactions on coccidiosis score (Table 1 and Fig. 2a). Although body mass increased during the experiment, there were no significant effects of treatment, degree of urbanization, or any interaction terms on body mass (Table 1 and Fig. 2b). We found qualitatively similar results when analyzing body condition (Table 1). We also found no significant effects of time, treatment, degree of urbanization, or their interactions on mass-specific basal metabolic rate (Table 1 and Fig. 2c).

Discussion

We tested the hypotheses that HPAN alters sleep behavior, metabolic rate, body mass, and degree of parasitism of captive house finches, and that birds from an urban population would be more resilient to HPAN-driven changes in disease status, metabolism, and morphology. We showed that HPAN acutely increased time spent awake at night in both urban and rural birds, but we failed to find differential effects of HPAN on mass-specific BMR, body mass, or coccidia score.

Given that house finches have successfully colonized urban environments in much of North America, one way to interpret our null result is that finches (regardless of origin) are pre-adapted to living in city environments, including in their apparent muted physiological responsiveness to human presence. In future studies, it would be interesting to compare the physiological responsiveness to HPAN of rural-caught birds of species that have successfully invaded urban environments and of species that have not, despite living adjacent to cities. This would be an interesting test of whether successful urban invaders are pre-adapted to HPAN. Additionally, it would be interesting to better understand the selection pressures of avian night life and how those predict successful adaptation to city life, especially with respect to night-time disturbances.
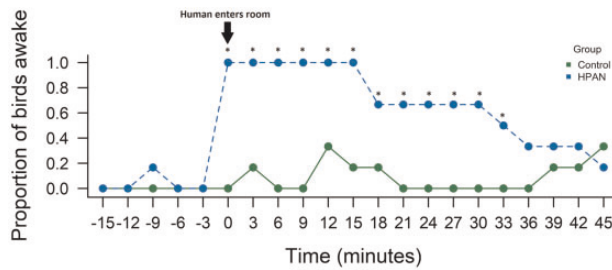
Fig. 1 Brief HPAN increases wakefulness in house finches. Prior to a human entering the room, we found no significant differences in the sleep/wake state between HPAN ($n = 6$) and control ($n = 6$) groups. However, following a human entering the room (time $= 0$), and briefly jostling the cage of each individual, likelihood of wakefulness was significantly different between groups. Despite the human being in the room for ca. 3 min, the treatment produced a prolonged awakened state that lasted ca. 33 min. Symbols above points represent timepoints where we found significant differences in sleep state between groups. Dotted lines represent the treatment group, and solid lines represent the control group.

There are few experimental studies of sleep disturbances on wild-caught animals. Wild-caught Norway rates (*Rattus norvegicus*) decrease their sleep behavior for approximately 20 min immediately following exposure to approximately 0.5–2 min of a human chasing them around the home cage with their hand. However, after some delay these rates show a rebound in sleep intensity, which might compensate for any prior sleep loss (Lesku et al. 2008). Thus, it is possible that our limited sleep disturbance was easily compensated for by subsequent increases in sleep, which may have prevented any sleep-loss mediated effects.

The aim of our HPAN treatment (i.e., one 3-min overnight visit in the housing room) was to produce a single-pulse (to avoid excessive sleeplessness), anthropogenically relevant disturbance, akin to a human briefly walking by, loitering near, or brushing against (i.e., in a bush or tree) an overnight roost. However, this short, non-invasive environmental intervention may have been too limited of a sleep disruption or direct stressor to expect cascading effects on bird physiology and morphology. Perhaps a more threatening or longer duration HPAN treatment would have kept birds awake longer and/or had more severe, long-term effects. For example, Ellenberg et al. (2013) found that the intensity of day-time human disturbance (e.g., a mobile vs. still-standing human) predicted increase in heart rate in yellow-eyed penguins (*Megadyptes antipodes*). Second, it is possible that, since birds can habituate to human disturbance (Vincze et al. 2016), finches in our study quickly habituated to our low-intensity, short-duration treatment. Additionally, the

Table 1 Outputs of the four models describing effects of HPAN treatment, habitat urbanization, time, and their interactions on coccidiosis severity, body mass, body and mass-specific BMR. Variables in bold have *P*-values of less than 0.05.

Response	Predictor	χ^2	df	*P*-value
Body mass	Treatment * Urbanization * Time	0.93	1	0.33
	Treatment * Time	0.02	1	0.88
	Urbanization * Time	0.04	1	0.85
	Urbanization * Treatment	0.15	1	0.69
	Time	**31.1**	**1**	**<0.001**
	Treatment	2.07	1	0.14
	Urbanization	1.21	1	0.27
Body condition	Treatment * Urbanization * Time	0.92	1	0.33
	Treatment * Time	0.02	1	0.88
	Urbanization * Time	0.13	1	0.71
	Urbanization * Treatment	0.16	1	0.68
	Time	**26.1**	**1**	**<0.001**
	Treatment	1.02	1	0.31
	Urbanization	1.32	1	0.25
Coccidiosis score	Treatment * Urbanization * Time	0.03	1	0.86
	Treatment * Time	0.16	1	0.68
	Urbanization * Time	0.02	1	0.86
	Urbanization * Treatment	0.02	1	0.88
	Time	2.44	1	0.12
	Treatment	0.41	1	0.51
	Urbanization	0.13	1	0.71
Mass-specific BMR	Treatment * Urbanization	1.06	1	0.30
	Treatment	1.04	1	0.31
	Urbanization	1.17	1	0.27

involvement of an acclimation period might have given rural birds enough exposure to habituate to at least daytime human presence. Despite this, our treatment was still effective in acutely reducing sleep near the end of the experiment. Nevertheless, it is possible that we had missed shorter-term effects which had rebounded within the 3 weeks of chronic treatment, and we suggest future studies explore both acute and chronic effects. Third, our treatment was conducted in near-darkness, and although others found that the avian physiological stress response is more sensitive at night (Romero and Remage-Healey 2000; Rich and Romero 2001), it is possible that the finches never identified our HPAN treatment as human-created or as a threat; indeed, birds reacted to the brief human disturbance by awakeningly quietly, and without moving throughout the cage, which
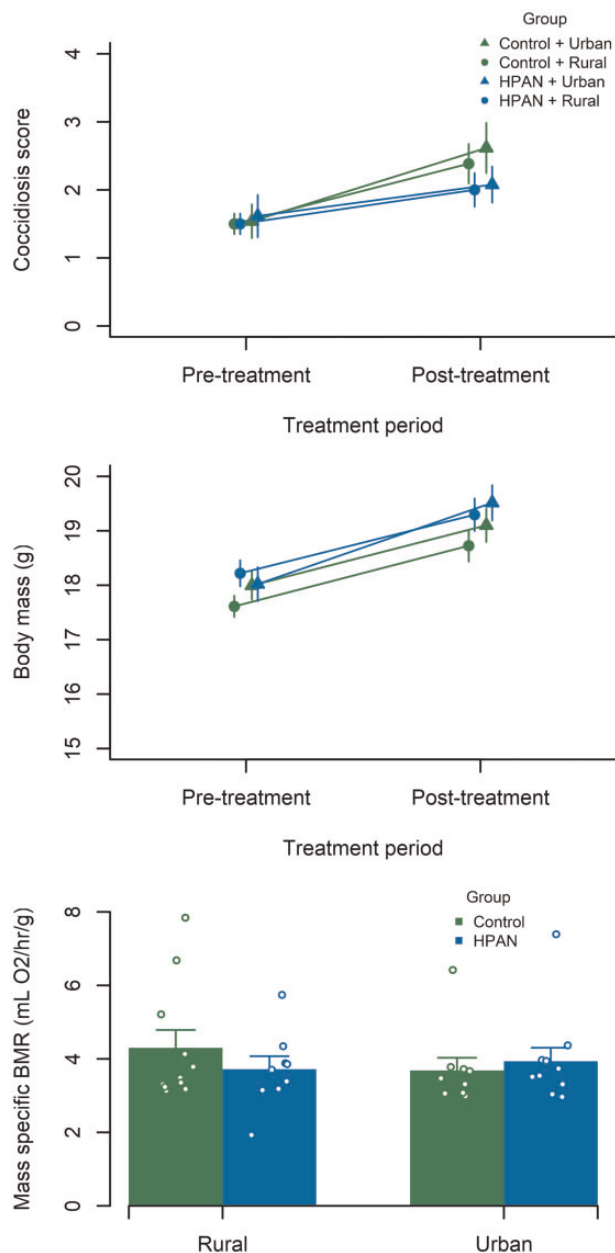
Fig. 2 Neither **a**) coccidiosis score, **b**) body mass, nor **c**) mass-specific BMR were affected by the HPAN treatment, habitat urbanization, or their interaction. Error bars represent means ± SEM.

may suggest these birds did not interpret this as a strong threat.

Although our study revealed no difference in metabolic rate between the HPAN and control groups, this result is consistent with findings from other human-disturbance studies in small passerines (Bisson et al. 2009; Butler et al. 2009). In studies of both white-eyed and black-capped vireos, the authors found no effect of prolonged (1–4 h) of day-time or night-time human disturbance on energy expenditure. In a meta-analysis of the effects of eco-

tourism on the physiology of several bird species in Antarctica, Coetzee and Chown (2016) found that human disturbance had no significant effect on endocrine activity, but a negative effect on fitness. Therefore, we suggest future studies go beyond physiological responses to also include fitness responses to human disturbance in both urban and rural animals.

Urbanization is a complex process of land use and land change, coupled with increased human presence and densities, that results in many strongly correlated environmental changes. Dissecting which urban components have major impacts on animals will be useful for predicting and remediating human impacts on wildlife. In this study, we found no effects of acute HPAN on metabolic rate, disease, and morphology in a songbird species, but this contrasts starkly with studies of how other anthropogenic or urban environmental modifications affect animal physiology. For example, artificial light at night directly suppresses sleep behavior (Raap et al. 2015) as well as haptoglobin, an acute phase protein involved in immune function (Raap et al. 2016), in wild great tits (*Parus major*). Noise pollution has been shown to suppress immunity as well as reduce body mass (Kight and Swaddle 2011), but has minimal impacts on night-time vigilance in peafowl (*Pavo cristatus*). Different urban environmental features might also combine to produce deleterious physiological effects. HPAN might interact with other modes of night-time disturbance; for example, artificial light at night could help animals better recognize threats from benign stimuli, which over time may properly tune their behavioral and physiological response to salient cues. In sum, we add to previous evidence that HPAN appears to have no effect on metabolic activity in some songbirds. We suggest that future studies focus on both day- and night-time impacts, and variation in the types, frequencies, durations, intensities, and predictabilities of human activity.

Acknowledgments

Supplementary data

Supplementary data are available at *ICB* online.

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