



Effects of experimental chronic traffic noise exposure on adult and nestling corticosterone levels, and nestling body condition in a free-living bird

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ABSTRACT

Transportation noise affects urbanized, rural, and otherwise unaltered habitats. Given expanding transportation networks, alterations in the acoustic landscapes experienced by animals are likely to be pervasive and persistent (i.e. chronic). It is important to understand if chronic noise exposure alters behavior and physiology in free-living animals, as it may result in long-lasting impacts, such as reduced reproductive success. Here, we experimentally tested the effects of chronic traffic noise on baseline and stress-induced corticosterone (the primary avian glucocorticoid), parental feeding behavior, and fitness proxies in breeding tree swallows (*Tachycineta bicolor*). Our results show that chronic traffic noise is related to altered corticosterone in both adult female and nestling tree swallows, suggesting that noise may be a stressor in both groups. In adult females, our results suggest that traffic noise is related to a limited ability to respond to subsequent acute stressors (i.e. reduced stress-induced corticosterone levels after handling). Further, our results show no evidence of habituation to noise during the breeding season, as the negative relationship between traffic noise and adult female stress-induced corticosterone became stronger over time. In nestlings, we found a positive relationship between traffic noise exposure and baseline corticosterone. Finally, we found a negative relationship between traffic noise and nestling body condition, despite no detectable effects of noise on nestling provisioning (e.g. parental feeding rate, or insect bolus size/composition). These results highlight the potential long-term consequences of chronic noise exposure, as increased baseline corticosterone and reduced nestling body condition in noise-exposed areas may have negative, population-level consequences.

1. Introduction

Anthropogenic noise, from airways, roadways and railways, continues to increase with expansion in transportation networks. This noise travels beyond infrastructure itself, permeating areas otherwise unaltered by humans and potentially affecting wildlife (Barber et al., 2011). To date, a broad range of noise impacts have been identified across taxa, with most research focused on birds. In noise-exposed habitats, the effects of noise include: acoustic masking, shifts in vocal signals, increased anti-predator and reduced foraging behavior, delayed settlement patterns and altered habitat use, altered levels of stress-associated hormones, and reduced telomere length (see Patricelli and Blickley, 2006; Shannon et al., 2016 for review).

The focus on anthropogenic noise is warranted, given that many of the alterations caused by noise exposure may serve as indicators of potentially long-lasting and/or multi-generational negative effects on

wild birds (Francis and Barber, 2013). For example, recent studies have shown that adult male greater sage-grouse (*Centrocercus urophasianus*) exposed to traffic noise have increased fecal glucocorticoid metabolites, as well as decreased attendance at the breeding ground (Blickley et al., 2012a; Blickley et al., 2012b). Additionally, adult tree swallows (*Tachycineta bicolor*) preferentially avoid noise exposed areas, with birds that settled in noise laying fewer eggs and having nestlings of reduced body condition, even when controlling for parental quality (Injaian et al., In Press). The mechanism(s) by which the impacts of anthropogenic noise on parents are passed onto offspring remain unknown, but may include changes in parental care behaviors or transfer of maternal corticosterone (avian glucocorticoid, hereafter 'cort') to eggs (Hayward and Wingfield, 2004). Therefore, traffic noise exposure may be particularly detrimental to avian populations during critical periods, such as breeding.

If noise exposure in a given habitat is persistent, chronic changes in

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the hypothalamic-pituitary-adrenal (HPA) axis may influence an individual's response to future challenges (Wingfield and Romero, 2001), potentially decreasing immune function, reproductive success, and survival (Kight and Swaddle, 2011). Decreased baseline cort (a measure of an individual's standard state) and stress-induced cort (a measure of how strongly an individual responds to an acute stressor such as handling) during exposure to a chronic anthropogenic stressor may be explained by alterations to the HPA axis (Cyr and Romero, 2007). Specifically, chronic stressors may be related to reduced synthesis of hormones (e.g. corticotropin releasing hormone (CRH)/arginine vasotocin (AVT) from the hypothalamus, adrenocorticotropic hormone (ACTH) from the pituitary, or cort from the adrenal glands) and/or enhanced sensitivity to negative feedback of cort (Fries et al., 2005). Indeed, chronic exposure to urban infrastructure and human disturbance has been found to reduce stress-induced cort in adult European blackbirds (*Turdus merula*; Partecke et al., 2006), and northern cardinals (*Cardinalis cardinalis*; Wright and Fokidis, 2016). Reduced baseline glucocorticoids have also been found in free-living birds exposed to chronic stressors (Cyr and Romero, 2007). In fact, a recent study found reduced baseline cort in adult western bluebirds (*Sialia mexicana*) exposed to anthropogenic noise, and their broods suffered from reduced hatching success, as compared to controls (Kleist et al., 2018). This decreased baseline and stress-induced cort suggests that individuals are not successfully coping with the stressor (Norris et al., 1999). However, elevated glucocorticoid concentrations (baseline and stress-induced) are often interpreted as an indication of stress and thought to lead to negative impacts (Cyr and Romero, 2007). Further complicating this story, other avian studies found no impact of chronic anthropogenic noise exposure on baseline cort levels (Angelier et al., 2016; Davies et al., 2017; Meillère et al., 2015; Morgan et al., 2012; Potvin and MacDougall-Shackleton, 2015a; Potvin and MacDougall-Shackleton, 2015b). Because chronic stress can increase, decrease, or cause no change in cort levels (Dickens and Romero, 2013), further research is needed to understand the (potentially) species-specific responses of the avian HPA-axis to chronic stressors, and the downstream consequences of altered baseline and/or stress-induced cort concentrations in free-living birds.

Traffic noise as a chronic anthropogenic stressor is of particular concern because transportation networks are expanding at a rapid rate with the growing human population (Buxton et al., 2017). Additionally, the unpredictable characteristics of traffic noise have been shown to alter behavior (Blickley et al., 2012a) and cort levels (Nichols et al., 2015) in free-living animals to a greater extent than other types of constant anthropogenic noise, such as noise from natural gas drilling rigs. More experimental research which investigates noise effects across a continuous gradient of amplitudes (as opposed to a binary factor of noise versus control) is needed, as this type of noise exposure more closely mimics what animals experience in the wild.

Here, we examined the effects of experimental exposure to chronic traffic noise on adult and nestling baseline and stress-induced cort concentrations, parental feeding behavior, and reproductive success (e.g. clutch size, nestling body condition, and fledging success) in free-living tree swallows (Fig. 1). Tree swallows are a good study system in which to examine anthropogenic stressors because they readily nest in nest boxes, allowing for better control of potentially confounding factors (i.e. predation risk based on nest placement, exposure to light pollution, visual disturbance of cars passing, etc.). Additionally, past work has shown that tree swallows respond to short-term noise exposure behaviorally, through alterations in settlement patterns and parent-offspring communication, as well as physiologically, through decreased nestling growth and increased nestling oxidative stress (Injaian et al., In Press; Injaian et al., 2018a; Leonard and Horn, 2005, 2008, 2012; Leonard et al., 2015; McIntyre et al., 2014).

We measured baseline and stress-induced cort for both adults and nestlings exposed to a continuous range of traffic noise playbacks. In adult tree swallows, we tested the hypothesis that greater noise

exposure is negatively related to adult baseline and stress-induced cort levels. Decreased adult baseline and stress-induced cort, which has been found in previous studies of anthropogenic impacts on passerines (Fig. 1, Box A; Grunst et al., 2014; Kleist et al., 2018; Partecke et al., 2006; Wright et al., 2007), may be caused by reduced AVT release from the hypothalamus (Rich and Romero, 2005) or increased negative feedback (Lattin et al., 2012). For nestlings, we tested the hypothesis that traffic noise exposure during development is positively related to baseline and stress-induced cort (Fig. 1, Box B). This hypothesis is supported by increased baseline (Kitaysky et al., 2001) and stress-induced (Love and Williams, 2008) cort for nestlings exposed to a lower quality environment during post-natal development. The mechanism by which chronic stress may be positively related to nestling baseline and stress-induced cort remains unknown, but is potentially related to a reduced concentrations of mineralocorticoid receptors (MR) in the hippocampus (Hodgson et al., 2007; Spencer et al., 2008). We also hypothesized that noise exposure would alter parental foraging behavior, resulting in decreased feeding rate and/or bolus mass and diversity (Fig. 1, Box D). Finally, we hypothesized that traffic noise would be negatively related to reproductive success, such that clutch size, proportion of eggs hatched, nestling body condition, and proportion of nestlings fledged would decrease as amplitude increased (Fig. 1, Boxes C and E).

2. Material and methods

2.1. General field methods

This study took place at two sites near Davis, CA, with a total of 30 nest boxes: the Putah Creek Riparian Reserve (38°32'18E, 121°51'01S, n = 15), and South Fork Preserve (38°31'04E, 121°41'39S, n = 15). Nest boxes were mounted approximately 1.5 m above ground on metal poles with predator guards and separated by at least 20 m to prevent aggression associated with territory overlap in this species (Winkler, 1994). We checked nest boxes every other day to record egg-laying date, and count egg and nestling number. Therefore, egg-laying dates have an associated error of one day.

2.2. Noise playbacks

We measured ambient noise levels before traffic noise playbacks began at both field sites using a sound level meter (Model 824, Larson-Davis, Inc., Depew, NY, U.S.A.). Specifically, we took five 30 s measurements, using the slow time, A-weighted dB SPL re 20 μ P (South Fork Preserve: measurements taken on 30 March 2017 at 0800 h; Putah Creek Riparian Reserve: measurement taken on 31 March 2017 at 0800 h). A-weighting was chosen, as this is the sound pressure level scale best weighted towards avian hearing (Dooling and Popper, 2007). We averaged the five Leq (equivalent continuous sound level) measurements to determine the ambient noise level for each site. The ambient noise levels at each site were typical of U.S. rural agricultural areas (Putah Creek Riparian Reserve: Leq of 43.35 ± 0.97 dBA SPL, South Fork Preserve: Leq of 41.1 ± 0.28 dBA SPL; EPA, 1971).

For traffic noise playbacks, four unique traffic noise WAV files (i.e. cars, trucks, motorcycles passing along a highway at varying time intervals) were acquired online (freesfx.co.uk) and edited in Audacity (version 2.0.6, <http://audacity.sourceforge.net>) to create four different 6 h traffic noise playbacks, with pseudorandom traffic patterns. Recordings were played from directional outdoor speakers (Model TFS14, TIC Corp., City of Industry, CA, U.S.A.), hooked to a car amplifier (Xtant1.1; Xtant Technologies, Phoenix, AZ, U.S.A.) and an MP3 player (Sansa m240; SanDisk Co., Milpitas, CA, U.S.A.). The playback system was powered with a 12 V sealed lead-acid battery. We began noise playbacks on 1 April 2017, after tree swallows had settled in nest boxes and begun nest-building, but before egg laying. This timing both avoids non-random distributions of adult quality with regards to noise

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