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Experimental anthropogenic noise impacts avian parental behaviour, nestling growth and nestling oxidative stress

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Human-produced noise, from transport, urbanization and industry, is widespread. Studies of noise pollution show a wide range of effects on birds, such as alterations in communication, parental behaviour, physiology and reproductive success. These human-induced changes are likely to have long-term impacts, such as altered nestling physiology and survival, as well as reduced local population size. Further experimental field studies that simultaneously investigate the effects of noise exposure on avian behaviour, physiology and reproductive success are needed. Here, we used an experimental field study to investigate impacts of short-term traffic noise exposure on parental behaviour (i.e. vigilance and feeding rate), nestling body size and oxidative stress (as measured by oxidative status) and nestling fledging success in tree swallows, *Tachycineta bicolor*. Our results show negative consequences of traffic noise exposure, despite a relatively modest playback regime (6 h, every other day). Adults in noise-exposed territories were less vigilant earlier in the nestling period and fed at a higher rate later in the nestling period, compared to controls. However, increased feeding rate in noise-exposed nests did not compensate for noise impacts on nestlings: noise-exposed nestlings were smaller and had higher oxidative status, compared to control nestlings. Noise-exposed nestlings took longer to fledge, but we found no effect of noise on fledging success. These results highlight the potential long-term consequences of short-term noise exposure (decreased nestling size and increased oxidative status) and add to a growing body of literature, showing that noise pollution can negatively impact birds through both direct and indirect pathways.

Human-produced noise, from transport, urbanization and industry, is pervasive and is audible within even the most pristine natural habitats (Barber, Crooks, & Fristrup, 2010). Research over the last two decades has established that some (but not all) wildlife species are negatively impacted by this noise pollution (Shannon et al., 2016), suggesting that conservation implications of noise for wildlife may be widespread (Barber et al., 2010; Francis & Barber, 2013; Kight & Swaddle, 2011). Studies of noise pollution have shown a wide range of effects on birds, such as alterations in communication (Leonard & Horn, 2008, 2012; Leonard, Horn, Oswald, & McIntyre, 2015; Lucass, Eens, & Müller, 2016; McIntyre, Leonard, & Horn, 2014; Swaddle, Kight, Perera, Davila-Reyes, & Sikora, 2012; Templeton, Zollinger, & Brumm, 2016), foraging efficiency (Quinn, Whittingham, Butler, & Cresswell, 2006), nestling physiology (Brischoux, Meillère, Dupoué, Lourdais, & Angelier, 2017; Crino, Johnson, Blickley, Patricelli, & Breuner, 2013; Potvin & MacDougall-Shackleton, 2015; Raap, Pinxten, Casasole, Dehnhard, & Eens, 2017), adult physiology (Blickley, Word, Krakauer, Phillips, Sells, Taff, et al., 2012), reproductive success (Francis, Paritsis, Ortega, & Cruz, 2011; Halfwerk, Holleman, Lessells, & Slabbekoorn, 2011; Kight, Saha, & Swaddle, 2012), telomere attrition (Meillère, Brischoux, Ribout, & Angelier, 2015) and habitat use during both breeding (Blickley, Blackwood, & Patricelli, 2012; Forman, Reineking, & Hersperger, 2002; Francis, Ortega, & Cruz, 2009; Halfwerk, Both, & Slabbekoorn, 2016; Summers, Cunnington, & Fahrig, 2011) and migration (McClure, Ware, Carlisle, & Barber, 2017; McClure, Ware, Carlisle, Kaltenecker, & Barber, 2013; Ware, McClure, Carlisle, & Barber, 2015).

These previous studies highlight the possible effects of noise exposure on many aspects of bird life history and ecology, as well as the variability between species in sensitivity to noise and type of response. Experimental field studies have been particularly

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valuable in isolating noise from other confounding factors associated with human development (e.g. light and air pollution, visual disturbance, habitat loss and fragmentation) without removing the animal from the natural environmental stochasticity and stressors present in the wild (Blickley, Blackwood et al., 2012; Blickley, Word et al., 2012; Crino et al., 2013; Lucass et al., 2016; McClure et al., 2013,; Ware et al., 2015). Further experimental field studies that simultaneously investigate the effects of traffic noise on avian behaviour, physiology and reproductive success are needed for a more complete understanding of traffic noise exposure in wild systems. For example, if noise exposure during the breeding period alters parental behaviour, long-term impacts, such as altered nestling physiology and survival, are likely. Altered nestling physiology early in development has been shown to have negative lifelong consequences in other contexts (De Kogel, 1997; Richner, Schneiter, & Stirnimann, 1989). Also, reduced nestling survival (i.e. fledging success) may ultimately lead to population level effects.

Here, we used an experimental field study to investigate impacts of short-term traffic noise exposure during the nestling period on parental behaviour (i.e. vigilance and feeding rate) and nestling body size, oxidative stress and fledging success in tree swallows, *Tachycineta bicolor* (Fig. 1). Oxidative stress, which is defined as the imbalance between the production of reactive oxygen species and both endogenous and exogenous antioxidant defences (Hall, Blount, Forbes, & Royle, 2010), has been shown to be related to somatic damage, accelerated ageing and early death (Finkel & Holbrook, 2000). Tree swallows offer an excellent system to study the effects of noise exposure because they readily nest in nestboxes, thus allowing for noise exposure (both natural and experimental) to be controlled. It is important to understand how human impacts, such as traffic noise, may affect tree swallow populations during critical periods (i.e. breeding). Population sizes of tree swallows at our sites in Davis, CA have been constant over the past 5 years; however, tree swallow populations are currently declining across a wide portion of their range (Paquette, Pelletier, Garant, & Bélisle, 2014). The reasons for these declines are not yet well understood, but are likely to be a combination of complex anthropogenic factors that affect aerial insectivores (i.e. habitat loss, climate change, traffic noise; Nebel, Mills, McCracken, & Taylor, 2010). Experimentally studying traffic noise impacts on already declining populations poses a challenge in isolating the effects of noise treatment from additional environmental factors. Therefore, our Davis, CA population of breeding tree swallows offers a good system in which to isolate the effects of traffic noise. Previous research has addressed the impacts of white noise on numerous types of parent–offspring behaviour in this species, showing that noise exposure alters the structure of nestling begging calls (Leonard & Horn, 2005, 2008), decreases nestlings' ability to detect parental arrival (Leonard & Horn, 2012) and alarm calls (McIntyre et al., 2014) and decreases parental response to begging calls (Leonard et al., 2015). This work suggests that tree swallows are a good candidate on which to further study the impacts of traffic noise on parental behaviours and nestling physiology.

We tested the hypothesis that adult tree swallows experimentally exposed to traffic noise during the nestling period would perceive greater predation risk. We predicted that adults in the noise-exposed treatment would spend more time vigilant during the nestling period, compared to control individuals, as an individual's ability to hear conspecific alarm calls is likely to decrease with increasing noise exposure (Fig. 1a; Templeton et al., 2016). It is also possible that noise exposure may reduce acoustic detection of predator cues (Barber et al., 2010; Slabbekoorn & Ripmeester, 2008); however, most predators of tree swallows in these populations are detected by visual cues (e.g. gopher snakes, *Pituophis catenifer*, magpies, *Pica hudsoni*a, scrub jays, *Aphelocoma californica*, Cooper's hawks, *Accipiter cooperii*). We also tested the hypothesis that noise decreases feeding rate, either due to a time trade-off associated with increased vigilance (Quinn et al., 2006) or due to increased distraction during foraging (Fig. 1b; Siemers & Schaub, 2011). Additionally, we hypothesized decreased nestling body size and altered nestling physiology (i.e. oxidative stress) in noise-exposed nests (Fig. 1c; Halfwerk et al., 2016). It is difficult to predict the direction in which noise may affect oxidative stress. Oxidative stress may be lower for noise-exposed nestlings, compared to controls, given that oxidative stress levels are closely tied to metabolic rate and we expect decreased growth (Hall et al., 2010). Alternatively, oxidative stress may be higher for noise-exposed nestlings, compared to controls, due to increased corticosterone (avian stress hormone; Lin, Decuypere, & Buyse, 2004). Finally, we hypothesized that noise would decrease reproductive success. We predicted decreased nestling fledging success for noise-exposed nestlings (Fig. 1d). If our hypotheses are correct and traffic noise exposure decreases fledging success through altered parental behaviour and/or nestling physiology, our results would suggest long-term impacts of short-term noise exposure.

METHODS

General Field Methods

From April to June 2015, we monitored tree swallow activity at 30 nestboxes in Davis, CA (15 in Putah Creek Riparian Reserve and 15 in South Fork Preserve). Nestboxes were mounted to metal poles approximately 1.5 m above ground. They were checked every other day to record egg laying, incubation, hatching and fledging dates; thus, all phenological dates have an associated error of 1 day. Once incubation began, each nest was alternately assigned to the 'noise' ($N = 15$) or 'control' ($N = 15$) treatment, thus controlling for any seasonal effects of temperature or food availability (McCarty & Winkler, 1999a).

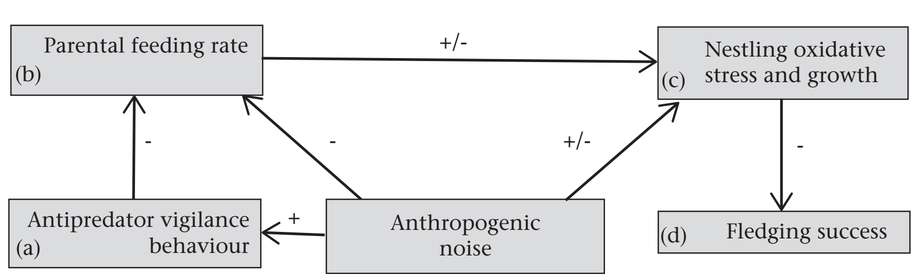

Figure 1. Potential anthropogenic noise impacts during the breeding season of tree swallows to be investigated in this study. Arrow direction represents the direction of the effect and ± symbols indicate increases or decreases in each factor, respectively.