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OUTLOOK

Noisy nests: Early-life noise exposure impacts songbird fitness

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Summary

Recent findings indicate that noise pollution – presented in the absence of other variables – has both immediate-term impacts on young birds' developmental rates and physiology as well as long-term effects on adult telomere length and reproductive success. This work highlights yet another set of negative impacts caused by anthropogenic noise, and suggests that the dramatic fitness consequences observed likely have implications for the evolution of learning and behavior in animals living in noisy environments.

Keywords Stimulus preexposure · Timing · Sensory preconditioning · Acquisition

Noise pollution is pervasive and inescapable for many animals. Anthropogenic noise is caused by ships at sea, aircraft in the sky, and vehicles traveling on the millions of miles of roads that bisect nearly all natural areas. While traffic noise has long been assumed to be less consequential for natural systems than other familiar pollutants (e.g., litter or chemical contaminants), a rapidly growing body of research is demonstrating that noise pollution has significant impacts on many animal species, including those living in otherwise pristine environments. Negative effects of noise pollution on animals are numerous and varied, including biological impacts on anatomy and physiology, behavioral impacts on stress responses, communication, and reproduction, cognitive impacts on individual and social learning, and community level impacts on habitat use, gut microbiomes, and predator–prey dynamics.

In addition to impacting adult animals, chronic noise pollution can have developmental impacts on young that experience noise during ontogeny. Research has documented significant physiological effects on a variety of vertebrate species – increasing levels of stress hormones, decreasing hatching rates of eggs, and slowing juvenile growth rates. While a growing body of literature has demonstrated negative effects of noise pollution on young birds and other animals, it is challenging to disentangle direct effects of noise on young animals from indirect effects caused by noise changing parental behavior.

A recent study by Meillère and colleagues (2024) examined the responses of young zebra finches (*Taeniopygia guttata castanotis*) to traffic noise, using a clever experimental design that allowed them to robustly isolate direct effects of noise on young birds from indirect effects caused by parents changing their behavior in response to noise. Eggs or nestling finches were moved from their home cages (and parents) to another room overnight, where they received different levels of experimental traffic noise, played at ecologically appropriate amplitudes, without altering the noise environment of the parents. The comprehensive study used a factorial design to examine the impacts of the noise environment (traffic noise vs. control finch songs) at different developmental stages (prenatal vs. postnatal), then assessed the impact of noise pollution on individual success measures, ranging from likelihood of hatching to offspring produced as adults.

Meillère et al. (2024) documented that early-life noise exposure during a relatively short period of development can have a variety of both short- and long-term effects on animals. Immediately, prenatal noise exposure significantly decreased the likelihood of eggs hatching compared with quiet or song-exposed control eggs. Surprisingly, this effect appeared to be strongest on larger eggs. Of birds that did hatch, those exposed to pre- or postnatal noise playback were significantly smaller at day 12, with the effect compounded when birds were exposed during both developmental periods. These size differences were no longer apparent at day 40 as young birds approached independence. Similar patterns were observed with other developmental measurements, including reduced hematocrit levels, and shortened telomere lengths, which are associated with increased levels of disease and even senescence.

In addition to immediate effects experienced as nestlings, this relatively brief period of early-life noise exposure also created lifelong fitness impacts. Perhaps not surprisingly, telomere length differences present as juveniles carried through to adults, with reduced telomere T/S ratios present in adults previously exposed to noise during development. Critically, this difference in telomere length was related to reproductive success, with juvenile telomere length predicting the number of offspring fledged from an experimentally naïve mate. The overall reduction in fitness was primarily impacted by the proportion of eggs that hatched, rather than clutch size or fledging success of hatched chicks. Lower reproductive success continued to a lesser extent in a second breeding attempt years later even when the focal bird nested with a new mate. Altogether, across multiple breeding attempts, spaced years apart and with different partners, birds exposed to a short period of traffic noise during development had on average a ~ 30–60% reduction in offspring produced; early-life exposure to noise pollution thus had a *dramatic* impact on lifetime fitness.

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The striking result that even short-term exposure to traffic noise during ontogeny has widespread impacts on an animal's developmental trajectory, physiology, and fitness is a clear demonstration of the unseen impacts of anthropogenic noise pollution. The substantial impacts on animal physiology and fitness have profound consequences for evolutionary trajectories of animals living in noise and raise interesting questions about underlying behavioral mechanisms and a variety of other implications for the study of animal learning and behavior.

Implication 1: Reproductive behavior

The potential impacts of noise pollution on nest success have profound implications for several aspects of breeding behavior. First, because increased prenatal noise levels decrease hatching success, selection should favor animals that avoid nesting in noisy locations. Noisy breeding sites should be less desirable so birds should avoid recruiting to noisy territories whenever possible. If a bird must breed in a noisy environment, it should attempt to minimize noise exposure of eggs by selectively building nests in quieter microhabitats within the area or even engineering sound-attenuating barriers as part of the nest construction. From a conservation perspective, this result also further reinforces the importance of preserving quiet areas as higher quality breeding habitats.

One particularly surprising finding of Meillère et al. (2024) was that noise pollution disproportionately affected hatching success for heavier eggs. Larger eggs are typically better provisioned and, in the absence of noise, this added parental investment usually translates to increased hatching success and other measures of individual quality (Krist, 2011). Thus, there is typically strong selection for birds to produce clutches with fewer but more highly provisioned eggs. While it is not clear what mechanisms are responsible for decreasing hatching rates of large eggs, one possibility might be differential resonance patterns of sound waves. Regardless of the mechanism, the unusual result implies that selection should favor lower provisioning of individual eggs and increased clutch sizes in noisy environments or when breeding with partners that themselves experienced noise pollution during development.

Implication 2: Mate choice

Meillère et al.'s (2024) demonstration that zebra finches exposed to noise pollution have consistently reduced breeding success later in life suggests that potential mates should avoid breeding with birds that have a developmental history of noise exposure. Given the dramatic disparity in reproductive success, birds that experienced noise pollution during ontogeny should be less desirable mates than other birds and selection should favor individuals who are able to discriminate among potential mates and decrease resources devoted to reproductive efforts with these lower quality individuals. Can potential mates assess an individual's prior experience with noise pollution?

Implication 3: Learning and cognition

Noise has long been suggested to impair cognitive function in human children. Recent research indicates that road traffic noise impacts learning and cognitive performance of adult songbirds, for example when zebra finches are exposed to road traffic noise, it takes them twice as long to learn a variety of novel foraging skills (Osbrink et al., 2021). Does early life noise exposure impede cognitive development in animals? Zebra finches exposed to noise during the sensitive phase of song learning have delayed vocal development and decreased song-copying accuracy (Brumm et al., 2021). Given the closed-ended nature of song learning in many species of songbirds, the songs that a bird sings as an adult could be an honest indicator of their developmental experience. While the developmental stress hypothesis has been previously described (Peters et al., 2014), the idea that song could reflect the noise environment that a bird was reared under is an intriguing extension. If noise pollution decreases brain development in a way that impacts both song learning and foraging or problem-solving abilities, and noise exposure during early life has lifelong impacts on fitness, then it would follow that song could be an honest indicator of reproductive potential that animals could use in mate assessment. Perhaps it is worth revisiting the developmental stress hypothesis from the perspective of noise pollution.

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