The effect of white noise on behavioral and flight responses of blue-tailed skinks

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As human development expands, environments are increasingly exposed to anthropogenic noise which may disrupt animals in a variety of ways. Anthropogenic noise can be disruptive both as a source of auditory masking, which prevents animals from acquiring acoustic information (Brumm and Slabbekoorn 2005), or as a source of distraction, re-allocating an individual's attention and impairing an animal's ability to engage in critical behaviors such as prey risk assessment (Chan et al. 2010). In particular, it can disrupt foraging and vigilance because they already involve a tradeoff of attention (Lima and Dill 1990). Through masking, vigilance increases in high noise environments because vital acoustic signals are blocked. For example, receivers may not be able to distinguish sounds that occupy the same frequencies (Brumm and Slabbekoorn 2005). Without sound, animals may be unable to properly assess risk level or accuracy and thus waste energy responding to anthropogenic noise in the same way they would to the presence of a predator (Frid and Dill 2002). Meanwhile, the distracted prey hypothesis suggests that the presence of a novel stimulus may cause individuals to divide their attention between multiple potential threats (Chan et al. 2010), which can either impair foraging or inhibit risk assessment by prey. In situations with visual and auditory distractors, Caribbean hermit crabs *Coenobita clypeatus* allowed humans (which were simulated predators) to come significantly closer before responding to them when compared to crabs without distractors (Chan et al. 2010). Regardless of the mechanism by which anthropogenic noise disrupts behavior, delayed reaction and flight times make animals more vulnerable to threats. To investigate whether exposure to noise affects blue tailed skinks' *Emoia impar* ability to assess risk through masking or distraction, we conducted an experiment where we quantified the behavioral response to playback of white noise and the subsequent FID for skinks exposed to white noise or to a silent control. Detailed methods are described in the Supplementary Materials.

We conducted 119 skink focal observations to study behavioral responses to noise playback. Of these, 19 individuals fled during focal observations, and we were unable to estimate their FIDs, leaving us with 100 skink FIDs. We fitted a

general linear model to explain variation in the rate of looking, which included independent variables for observers, treatment, speaker distance, and testing sites, that was statistically significant (F(7,111) = 4.63; $p < 0.001$) and explained 22.6% of the variation in looking rates (Table S1). We compared the 30-s of silence before the start of the treatment to the first 15-s of noise during the observers' initial approach. White noise had a significant and positive effect on looking rate (Table S1); skinks increased rate of looking in response to white noise when compared to silence in the 15-s following the treatment (Figure S1a). The estimated marginal mean of this increased rate of looking is an increase of 0.138 occurrences of looking per second, or 2.07 occurrences of looking per 15 seconds (Figure S1a). The entire linear model for difference in locomotion rates, which included variables for treatment, speaker distance, and testing sites, was also statistically significant ($F_{5,113} = 2.18$; $P = 0.016$). Similar to the looking rate model, white noise had a significant and positive effect on locomotion rate (Table S1). The estimated marginal mean of this increased rate of locomotion is an increase of 0.029 occurrences of locomotion per second, or 0.434 occurrences of locomotion per 15 seconds (Figure S1b). Skinks increased rate of locomotion in response to white noise when compared to silence in the 15-s following the treatment (Figure S1b).

Our entire model for FID was statistically significant ($F_{8,91} = 4.58$; $P < 0.001$) and explained 28.7% of the variation in FID (Table 1). White noise had no significant effect on FID as a main effect or as an interaction with starting distance (Figure S2; Table 1). The residuals of the difference in the looking rate model and starting distance, however, had a significant and positive effect on FID (Table 1; Figure S3); individual skinks with higher rates of looking than predicted by the behavioral response models had a greater FID (Table 1; Figure S3).

We found that exposure to white noise had no direct effect on FID, but it did increase skink looking and locomotion rates, indicating that skinks responded to noise playbacks. In addition, the most responsive skinks (i.e., those with positive residuals), characterized by having greater looking rates than predicted, had greater FIDs, and fled earlier from perceived threats. Studies across different taxa have attributed increases in responsivity and behavioral changes to situations with heightened risk (Ydenberg and Dill 1986). Our findings support previous studies which suggest that exposure to anthropogenic noise increases anti-predator behavior (e.g., Frid and Dill 2002). However, because FID was not decreased during white nose playback, we conclude that noise neither distracted skinks, nor did it impair their risk assessment as would have been predicted by the distracted prey hypothesis (Chan et al. 2010). We similarly could not conclude that white noise masked auditory signals because individuals did not flee earlier, despite an expected increase in looking rate. While white noise had no direct effect on FID, individuals who looked more often than predicted by the looking model fled sooner. This is consistent with the flush early and avoid the rush (FEAR) hypothesis, which states: "animals will flee approaching predators soon after they detect and identify them as a threat to reduce or minimize ongoing attentional costs of monitoring the approaching predators" (Blumstein 2010:440). Skinks that responded to white noise by looking at higher rates fled earlier. Previous skink research suggested that inter-individual variation in FID may be reduced by natural selection in areas with high human disturbance, where bolder individuals are favored (Williams et al. 2019). However, we suggest that while human-disturbed populations may select for boldness, individual variation in looking rates explain some of the variation in FID. Individuals with positive looking residuals are flightier and fled earlier from an approaching human than those with negative looking residuals. These individual differences in response to threats are widespread across a variety of taxa and may have fitness consequences such as increased or diminished reproductive success or survival rates (Smith and Blumstein 2008). We are unaware of prior FID studies where approaches were conducted simultaneously with sustained white noise, where individuals must make immediate attention allocation decisions. It appears that skinks do not suffer direct, negative effects from noise pollution, but further studies detailing the long-term effects of their observed behavioral changes are likely needed to better understand the full consequences of increased sound pollution on animal populations.

Data Availability

Data and code used for our analyses can be found at:

https://github.com/ckelligrew/skink-playback

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Table 1. Skink responses to approach after playback onset, shown by FID. Results of a general linear model explaining variation in FID.

FID	Estimate	SE	t	P	η²
(Intercept)	39.643	38.121	1.040	0.301	
Locomotion residual	-20.702	143.123	-0.145	0.885	0.000
Looking residual	**80.325**	**35.169**	**2.284**	**0.025**	**0.046**
Site (Gump reference)					0.022
Juice Factory	1.224	18.196	0.067	0.946	
Pineapple Plantation	-10.299	15.636	-0.659	0.512	
Dirt Road	20.361	16.186	1.258	0.212	
Starting distance	**0.459**	**0.112**	**4.095**	**<0.0001**	**0.214**
Treatment (silent reference)					0.002
White noise	33.982	61.810	0.550	0.584	
Treatment + starting distance (silent reference)					0.004
White noise + starting distance	-0.133	0.177	-0.749	0.456	

Bold = Significant effect ($P < 0.05$)