Noise pollution has limited effects on nocturnal vigilance in peahens

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Natural environments are increasingly exposed to high levels of noise pollution. Noise pollution can alter the behavior of animals but we know little about its effects on antipredator behavior. We therefore investigated the impact of noise pollution on vigilance behavior and roost selection in an avian species, peafowl (*Pavo cristatus*), that inhabits urban environments. Captive peahens were exposed to noise pollution at night and their vigilance levels and roost selections were monitored. The vigilance levels of peahens were unaffected by exposure to noise pollution within trials. Furthermore, the peahens exhibited no preference for roosting farther or closer to noise pollution. Interestingly, predators often avoided the experimental area during nights with noise pollution, which could explain why vigilance rates were higher overall during control compared to noise trials. The results suggest that peahens' perception of risk is not drastically impacted by noise pollution but longer-term studies will be necessary to assess any chronic effects.

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9   **ABSTRACT**

10   Natural environments are increasingly exposed to high levels of noise pollution. Noise pollution

11   can alter the behavior of animals but we know little about its effects on antipredator behavior. We

12   therefore investigated the impact of noise pollution on vigilance behavior and roost selection in

13   an avian species, peafowl (*Pavo cristatus*), that inhabits urban environments. Captive peahens

14   were exposed to noise pollution at night and their vigilance levels and roost selections were

15   monitored. The vigilance levels of peahens were unaffected by exposure to noise pollution within

16   trials. Furthermore, the peahens exhibited no preference for roosting farther or closer to noise

17   pollution. Interestingly, predators often avoided the experimental area during nights with noise

18   pollution, which could explain why vigilance rates were higher overall during control compared

19   to noise trials. The results suggest that peahens' perception of risk is not drastically impacted by

20   noise pollution but longer-term studies will be necessary to assess any chronic effects.

21   **INTRODUCTION**

22   Noise pollution is increasingly prevalent in natural environments. Over 85% of the contiguous

23   United States is exposed to noise pollution (Mennitt et al., 2013). Noise pollution is usually

24   louder and more frequent than natural sounds in the environment and can therefore mask these

25   natural sounds (Kight & Swaddle, 2011). In addition, noise pollution is often associated with

26   other types of disturbances, such as light or chemical pollution (Halfwerk & Slabbekoorn, 2015).

27   Because many animals use acoustic information to inform their behavioral decisions (Bradbury &

28   Vehrencamp, 1998), noise pollution can have major impacts on their fitness (Patricelli &

29   Blickley, 2006; Shannon et al., 2015).

30   Noise pollution could impact fitness because of its effect within a variety of different

31   contexts. It can affect the mating behavior of animals. Pair bonds in zebra finches (*Taeniopygia*

32   *guttata*) weaken when the birds are exposed to noise pollution (Swaddle & Page, 2007) and male

33   sage grouse (*Centrocercus urophasianus*) attendance on breeding grounds decreases with noise

34   pollution (Blickley, Blackwood & Patricelli, 2012). Noise pollution can impact territorial

35   behavior as well. Many passerines adjust their songs, which function in both territory defense and

36   mate attraction, to compensate for increased noise levels (Mockford & Marshall, 2009). They

37   vocalize louder (Brumm 2004), repeat songs (Brumm & Slater 2006), or sing during times of low

38   noise (Fuller, Warren & Gaston, 2007). Noise pollution can also impact parental investment;

39   female house sparrows (*Passer domesticus*) provide less food to their young when living in noisy

40   environments (Schroeder et al., 2012).

41   Less is known about the effects of noise pollution on antipredator behavior (Meillère,

42   Brischoux & Angelier, 2015). However, noise pollution has the potential to alter animals'

43   perception of the environment (Quinn et al., 2006; Shannon et al., 2014a). For example, animals

44   that are exposed to noise pollution may perceive the environment as more dangerous because

45   their ability to detect auditory signals and cues is low (Quinn et al., 2006). Chaffinches (*Fringilla*

46   *coelebs*) are more vigilant and peck less in response to noise pollution, suggesting that they

47   perceive their noisy environment as risky. In contrast, other animals' perception of their

48   environment may not be impacted by noise pollution (Bejder et al., 2009). These animals could

49   have already habituated to the noise if they never experienced negative effects in noisy

50   environments or if they are generally tolerant of noise. For example, noise pollution does not

51   impact gerbils' (*Gerbillus allenbyi and G. pyramidum*) selection of a safe versus risky

52   microhabitat (Abramsky et al., 1996) and therefore does not seem to alter their perception of the

53   riskiness of their environment. Finally, some animals may perceive environments with noise

54   pollution as relatively safe because noise-sensitive predators may avoid these areas (Francis,

55   Ortega & Cruz, 2009). Elk (*Cervus elephus*) are less vigilant in response to noise pollution

56   (Shannon, Cordes, Hardy, Angeloni, & Crooks, 2014), suggesting that they view noisy

57   environments as less risky. While we are beginning to understand how species perceive noise

58   pollution with respect to risk levels during their active periods (daytime for diurnal species), we

59   are unaware of any studies that have investigated this topic during their inactive periods

60   (nighttime for diurnal species). Given that animals often rely on their senses differently

61   depending on whether it is daytime or nighttime (e.g., some birds use their visual capabilities to

62   forage during the day but switch to tactile capacities at night; Robert & McNeil, 1988), animals'

63   responses to noise pollution could vary depending on this factor.

64   We therefore examined the impact of noise pollution on nocturnal vigilance and roosting

65   behavior in a diurnal avian species, peafowl (*Pavo cristatus)*, that inhabits urban environments

66   (Ramesh & McGowan, 2009). Peafowl are native to the Indian subcontinent and have also been

67   introduced to other continents (Kannan & James, 1998). While they naturally live in deciduous

68   forests and scrubby woodlands, they also live near human settlements (Ali & Ripley 1969;

69   Johnsingh & Murali, 1978). They roost atop tall structures at night (such as trees; de Silva,

70   Santiapillai & Dissanayake, 1996) and are subject to predation by mammalian and avian

71   predators (de Silva, Santiapillai & Dissanayake, 1996; Kannan & James, 1998). There are three

72   alternative explanations for how peafowl perceive noisy environments. First, if peafowl perceive

73   their environments as risky when there is noise pollution, then we expect them to exhibit high

74   rates of vigilance in response to noise pollution and avoid roosting in areas with high levels noise

75   pollution. Second, if peafowl are tolerant of noise pollution or have previously habituated to it,

76   then we do not expect their vigilance rates to change from baseline levels and expect them to

77   select their roosts irrespective of noise pollution. And third, if peafowl perceive environments

78   with noise pollution as an escape from predators, then we expect their vigilance levels to decrease

79   in response to noise pollution and we expect them to roost near high levels of noise pollution. In

80   addition, because noise pollution can be stressful to some species and cause physiological

81   changes (Blickley et al., 2012), we examined whether the mass of peahens changed depending on

82   their exposure to noise pollution.

83   **METHODS**

84   We explored the effect of artificial noise pollution on vigilance levels and roost selection in

85   captive peahens at the Purdue Wildlife Area in West Lafayette, IN, USA (40.450327°N,

86   −87.052574°E). The vigilance levels experiment was conducted between July 2014 and April

87   2015 and the roost experiment was conducted between March and June 2016. The experiments

88   were performed in an outdoor experimental cage (4.5 m x 9.0 m) that was 75 m from the outdoor

89   aviary (24.4 x 18.3 x 1.8 m) where the birds were permanently housed (the distance between the

90   experimental cage and main aviary ensured that birds in the main aviary did not hear the

91   broadcast noise from the experimental cage). The aviary was over 550 m from the nearest major

92   road and it was surrounded by trees; noise pollution from anthropogenic sources was therefore

93   minimal. The peahens were adults and were given food and water ad libitum. The study was

94   approved by Purdue University Animal Care and Use Committee (#1305000862 & 1504001232).

95   **Vigilance Levels**

96   We tested whether artificial noise pollution impacts vigilance levels in peahens (n=30). For each

97   trial, a peahen was put inside of the experimental cage for seven consecutive nights (the

98   experimental design was similar to Yorzinski et al., 2015). The experimental cage had one

99   wooden roost (0.85 m tall and 1.3 m long) that was 1.5 m from a rock-shaped speaker (150 W

100   Outdoor Rock Speaker, model: tfs6sl, TIC Corporation, City of Industry, California, USA). The

101   speaker was connected to an audio amplifier (Audioengine N22, Austin, Texas) and an iPod touch

102   (model A1509, Apple Corporation, Cupertino, California, USA). During noise trials, the speaker

103   continuously broadcast white noise (white Gaussian noise generated with Matlab; 16 bit; 44.1

104   Hz) during nights (and days) 2-5; no noise was broadcast on nights 1, 6, or 7. The white noise

105   automatically turned on at noon on the second day and turned off at noon on the sixth day

106   (Woods outlet timer, model 50002, Mississauga, Canada). During medium noise trials (n=10), the

107   white noise had a sound pressure level (SPL) of 75 dB (A weighting; slow setting) at the middle

108   of the roost; during loud noise trials (n=10), the white noise measured 90 dB SPL at the middle of

109   the roost (model 407730, Extech Instruments, Waltham, MA, USA). During control trials (n=10),

110   white noise was not broadcast on any of the seven nights. The medium and loud noise trials

111   broadcast noise at the same decibel levels as used in a previous study on noise pollution and birds

112   (Swaddle & Page, 2007); noise pollution in urban environments can exceed the decibel level that

113   we broadcast in our loud noise trials (Chepesiuk, 2005). Furthermore, the peahens were not

114   necessarily exposed to the same level of noise pollution for the entire trial. During the day, they

115   could move to the opposite side of the experimental cage and therefore reduce the loudness of the

116   noise that they experienced. And, even though the peahens could have slept on the ground at the

117   opposite side of the speaker at night, they always slept on the roost near the speaker.

118   The head movements of the peahens were continuously monitored with a 3-axis

119   accelerometer (TechnoSmart, Rome, Italy; 3mm x 1.1 mm; 0.5 g; sample resolution:

120   19.6 m s^{-2}; sample rate: 50 Hz). The accelerometer was attached to a velcro strip (3.5 mm x 1.8

121   mm) that was glued (Artiglio Super 620) to the feathers atop the birds' head (see Yorzinski et al.,

122   2015 for further details on accelerometer and attachment). The accelerometer was replaced every

123   day because the battery would not last for the duration of an entire trial. The accelerometer does

124   not impact head movement rates (Yorzinski et al., 2015). We used a custom algorithm to extract

125   the number of head movements the peahens exhibited during each night of the trial (starting 1 h

126   after sunset and ending 1 h before sunrise; "nighttime period"); the accuracy of this algorithm is

127   high (over 90% of head movements are correctly classified as head movements; see Yorzinski et

128   al., 2015 for more details).

129   The peahens were weighed at the start and end of the trial (ZIEIS Veterinary Pet Scale,

130   Apple Valley, Minnesota; 5 g accuracy). The length of the peahens' tarsus + metatarsus was

131   measured at the start of the entire experiment (Neiko digital caliper; Neiko Tools, Wenzhou,

132   Zhejiang, China; model number: 01409 A; ± 0.03 mm accuracy). Three video cameras (Swann

133   Pro-500, Swann Communications, Santa Fe Springs, California, USA) connected to a DVR

134   (Swann DVR4-2600) recorded the experimental cage and the area immediately outside the

135   experimental cage (2 m from the cage perimeter). Using these video recordings, we determined

136   the amount of time that predators (raccoons and domestic cats) and non-predators (mice, frogs,

137   flying squirrels, deer, and rabbits) were visible during the nighttime period. We also assessed the

138   time at which the peahens ascended to and descended from the roost each night. The time at

139   which a bird ascended to the roost for the night was assessed by moving backwards in the videos

140   from the nighttime period (1 h after sunset) and finding the time when the bird jumped on the

141   roost. If the bird was not already on the roost 1 h after sunset, then we moved forward in the

142   videos until the bird jumped on the roost. The time at which a bird descended from the roost for

143   the night was assessed in a similar way except that we moved forward in the videos from the

144   nighttime period (1 h before sunrise) until finding the time when the bird jumped off the roost. If

145   the bird was already off the roost 1 h before sunrise, we moved backward in the videos until the

146   bird jumped off the roost. We excluded times when the experimenters interfered with when the

147   bird ascended to the roost or descended from the roost.

148 **Roost Selection**

149 In the first roost selection experiment, we tested whether peahens' (n=20) selection of nocturnal

150 roosting locations was impacted by a medium-level of artificial noise pollution. For each trial, a

151 peahen was put inside of the experimental cage (at least 4.5 hr before sunset) for one night. The

152 cage had two wooden roosts (0.85 m tall and 1.3 m long; 5.7 m between roosts) and a rock-

153 shaped speaker (150 W Outdoor Rock Speaker, model: tfs6sl, TIC Corporation, City of Industry,

154 California, USA) that was positioned in front of each roost (1.4 m between the speaker and

155 roost). One of the speakers (randomly selected for each trial) was connected to an audio amplifier

156 (Audioengine N22, Austin, Texas, USA) and an iPod touch (model A1509, Apple Corporation,

157 Cupertino, California, USA) that continuously broadcast white noise (white Gaussian noise

158 generated with Matlab; 16 bit; 44.1 Hz). In the middle of the roost that was closer to the speaker,

159 the white noise measured 75 dB SPL; in the middle of the roost that was farther from the speaker,

160 the white noise measured 50 dB SPL (model 407730, Extech Instruments, Waltham, MA, USA).

161 Two video cameras (Swann Pro-500) connected to a DVR (Swann DVR4-2600) recorded the

162 experimental cage. Based on the video recordings, we determined whether the peahen slept on

163 the roost closer or farther from the noise.

164 In the second roost selection experiment, we tested whether peahens' (n=20) selection of

165 nocturnal roosting locations was impacted by a high-level of artificial noise pollution. The

166 experimental procedure was the same as in the first roost selection experiment except the noise

167 level was increased. In the middle of the roost that was closer to the speaker, the white noise

168 measured 90 dB SPL; in the middle of the roost that was farther from the speaker, the white noise

169 measured 65 dB SPL (Extech Instruments; model 407730). Due to a limited number of peahens,

170 we tested 8 peahens that had not been used in the first roost selection experiment. In addition, we

171 randomly selected 12 birds that we used in the first roost selection experiment and used them in

172   this second experiment as well (at least 33 days lapsed since a bird was used in the first roost

173   selection experiment; mean ± SE: 61 ± 6.1 d).

174

175   **Data analysis**

176   We tested whether artificial noise pollution impacts nocturnal vigilance rates. We ran a repeated-

177   measures mixed linear model (PROC Mixed with a variance components covariance structure

178   and the between-within degrees of freedom approximation) to examine whether vigilance rates

179   differed among trials. The dependent variable was the natural log of the head movement rate

180   (number of head movements during nighttime period divided by the total time in the nighttime

181   period). The independent variables were the trial night (the specific night of the trial: 1–7), trial

182   type (control trial, medium noise trial, or loud noise trial), trial night by trial type interaction,

183   wind speed, precipitation, temperature, moon illumination, mass at the end of the trial, tarsus +

184   metatarsus, and predator and non-predator presence. We included environmental and

185   morphological variables within the model because these factors have been shown to impact

186   antipredator behavior (e.g., wind speed: Carr & Lima, 2010; mass: Jones, Krebs, & Whittingham,

187   2009). We performed *a prior* contrasts to compare specific trial nights.

188   The climate variables were obtained from a local weather station (http:

189   //iclimate.org; ACRE- West Lafayette). We calculated the mean of the wind speed (natural log

190   transformed) and temperature across the nighttime period. Since there was no precipitation during

191   82% of trial nights, precipitation was categorized as being present or absent. Moon illumination

192   was the fraction of the moon's surface that was illuminated from the sun's rays

193   (http://www.timeanddate.com; Lafayette, IN). Predator and non-predator presence was whether

194   predators or non-predators, respectively, were visible inside the cage or along the outside of the

195   cage perimeter or not during the nighttime period (predators and non-predators were visible in

196   only 50.8% and 68.5% of nights, respectively). We analyzed whether the amount of time that

197   predators and non-predators spent near the experimental area (total time that predators or non-

198   predators were visible during the nighttime period divided by the nighttime period) was related to

199   trial type, trial night, trial type by trial night interaction, and environmental variables with a

200   repeated-measures mixed linear model. We performed *a prior* contrasts to compare specific trial

201   nights. We also performed a mixed linear model to assess whether the mass of the birds changed

202   during the experiment; we calculated the percentage that the mass changed (mass on night 7

203   minus mass on night 1 divided by mass on night 1) and determined whether the trial type (control

204   trial, medium noise trial, or loud noise trial) impacted this percentage.

205   We ran another two repeated-measures mixed linear models to determine the factors

206   influencing when the birds ascended to the roost and descended from the roost for the night. The

207   independent variables were the trial type (control trial, medium noise trial, or loud noise trial),

208   trial night (the specific night of the trial: 1–7), trial type by trial night interaction, environmental

209   variables during the nighttime period (wind speed, precipitation, temperature, and moon

210   illumination), morphological measurements of the bird (mass and tarsus + metatarsus), and

211   predator and non-predator presence. We performed binomial tests (Proc Freq) to assess peahens'

212   roosting preferences (the peahens did not switch to a different roost during a given night). We

213   examined whether trial type (medium or loud noise), environmental variables (wind speed,

214   temperature, and moon illumination), and morphological variables impacted roost choice using a

215   binomial logistic regression (PROC Logistic). The wind speed and temperature at sunset during

216   the night of the trial were used in the analysis; precipitation at sunset during the night of the trial

217   was excluded from this analysis because precipitation was recorded in only 7.5% of trials.

218   Analyses were performed in SAS (9.3; Cary, NC, USA) or Minitab (15.1; Minitab Inc., State

219   College, PA, USA). The data supporting this article are available in Harvard Dataverse:

220   http://dx.doi.org/10.7910/DVN/FFEZQC.

221 **RESULTS**

222 The head movement rate of peahens was similar regardless of trial night, the interaction between

223 trial type and trial night, environmental variables (wind, precipitation, temperature, and moon

224 illumination), morphological variables (mass and tarsus + metatarsus:), and predator presence

225 and non-predator presence. However, the head movement rate of peahens was lower during noise

226 trials compared to control trials (Table 1A). Comparing noise versus control trials on nights with

227 and without noise, the head movement rates were similar (Table 2A: Treatment effects). There

228 was a non-significant trend for head movement rate to be lower during nights with noise

229 compared to nights without noise, especially during medium noise trials. Within the noise trials,

230 the head movement rates were similar on nights with and without noise pollution; within the

231 control trials, the head movement rates were similar across nights (Table 2A: Time effects; Fig.

232 1). The results were qualitatively similar when the medium and noise trials were pooled. There

233 was no change in body mass within trials with respect to whether the birds were exposed to

234 artificial noise pollution or not ($F_{2,24}$ = 1.29, p=0.29).

235   The amount of time that predators spent near the experimental area varied depending on

236 trial type, the interaction between trial type and trial night, wind speed, and temperature but not

237 trial night, precipitation, or moon illumination (Table 1B). Predators spent more time near the

238 experimental area during control versus noise trials (Fig. 2), when the wind speed was low, and

239 the temperature was high. They also spent more time near the experimental area during control

240 trials compared to noise trials during nights when the noise was broadcast in noise trials (Table

241 2B: Treatment effects). Within the noise trials and within the control trials, the amount of time

242 that predators spent near the experimental area did not vary (Table 2B: Time effects). The amount

243 of time that non-predators were near the experimental area was only impacted by the

244 temperature; the other variables were not significant (Table 1C). Non-predators spent more time

245 near the experimental area when the temperature was high.

246   Peahens ascended to the roost later in the evening when the temperature was higher; the

247   other independent variables did not affect when the birds ascended to the roost (Table 1D).

248   Peahens descended from the roost later in the morning during control trials compared to noise

249   trials (control: 24.3 ± 7.8 min after sunrise; medium noise: 16.9 ± 7.5 min after sunrise; loud

250   noise: 12.2 ± 6.5 min after sunrise) and when their tarsus + metatarsus was longer; the other

251   independent variables were not significant predictors of the time when the peahens descended

252   from the roost (Table 1E). Peahens did not exhibit a preference for roosting closer or further from

253   artificial noise (medium noise: 60% of the birds roosted away from the noise, p=0.50; loud noise:

254   55% of the birds roosted away from the noise, p=0.82; two-tailed binomial test). The type of

255   noise (medium or loud), wind speed, temperature, moon illumination, mass, and tarsus +

256   metatarsus did not impact whether the peahens roosted near or far from the noise (Table 1F).

257   **DISCUSSION**

258   The nocturnal vigilance levels of peahens were not significantly impacted by noise pollution

259   within trials. Individual peahens exhibited similar rates of head movements (a proxy of vigilance;

260   Jones, Krebs & Whittingham, 2007) at night regardless of whether noise pollution was present or

261   absent. Furthermore, they showed no preference for roosting away from artificial noise pollution.

262   The results suggest that peahens' perception of risk is not drastically impacted by noise

263   pollution. They did not increase their vigilance behavior to compensate for a potentially reduced

264   ability to detect threats nor did they decrease their vigilance levels to take advantage of a

265   potentially safer environment within trials. In most of the studies examining vigilance behavior

266   and noise pollution, individuals elevate their vigilance levels in response to noise pollution

267   (however, these studies were conducted on diurnal species during the day while this study was

268   conducted at night; reviewed in Beauchamp, 2015): California ground squirrels

269   (*Otospermophilus beecheyi*) are more vigilant in areas with turbine noise (Rabin, Coss &

270   Owings, 2006), great tits (*Parus major*) are more vigilant when exposed to aircraft noise (Klett-

271   Mindo, Pavón & Gil, 2016), prairie dogs (*Cynomys ludovicianus*) and white-crowned sparrows

272   (*Zonotrichia leucophrys*) are more vigilant in response to traffic noise (Shannon et al., 2014a;

273   Ware et al., 2015), chaffinches are more vigilant in response to white noise (Quinn et al., 2006),

274   and koalas (*Phascolarctos cinereus*) are more vigilant when hearing zoo visitors (Larsen Sherwen

275   & Rault, 2014). This increased level of vigilance may allow animals to detect threats faster

276   (Meillère, Brischoux & Angelier, 2015). However, some species may decrease their vigilance

277   levels in response to noise pollution because their risk perception is lower. Elk are less vigilant in

278   response to traffic noise (though human activity may have also contributed to this effect; Shannon

279   et al., 2014b).

280   In addition, noise pollution did not influence the peahens' selection of nocturnal roosting

281   locations. The peahens selected roosts irrespective of noise pollution levels, indicating that they

282   did not perceive noise pollution as impacting their risk. Because both roosts were exposed to

283   some level of noise pollution, it is possible that the peahens did not distinguish between them

284   since they were both noisy. Additional experiments in which one of the roosts is completely free

285   of noise would be important. Previous studies have found that some species avoid areas with

286   noise pollution (Blickley, Blackwood & Patricelli, 2012; Ware et al., 2015) while other species do

287   not (Neo et al., 2015); an understanding of ecological differences between species could elucidate

288   why they respond differentially.

289   Even though we did not find that vigilance levels differed within trials, we did find that

290   peahens were more vigilant overall during control compared to noise trials. And, peahens

291   descended from the roost later in the morning overall during control trials compared to noise

292   trials. These overall effects could be related to predators being more frequent during control trials

293   (see below) and peahens adjusting to this increase in predator presence throughout the trial (i.e.,

294   carry-over effects). In fact, head movement rates across all nights during control trials in this

295   study (171 ± 9.9) were higher than control trials from a previous study conducted under similar

296   experimental conditions (99 ± 6.5; Yorzinski et al., 2015); this suggests that changes in the

297   external environment, such as increased predators, may have resulted in the higher vigilance rates

298   during our control trials in this study. Because predator presence can impact vigilance behavior,

299   future experiments could be conducted in which predator presence is controlled. Additional

300   experiments will also be necessary to determine whether long-term effects of noise pollution

301   impact vigilance behavior.

302   Peahens may not rely strongly on acoustic cues when detecting nocturnal predators,

303   potentially explaining why they do not alter their perception of risk based on noise pollution

304   within trials. Nocturnal vigilance levels in peahens dramatically increases with exposure to

305   artificial light pollution (Yorzinski et al., 2015), suggesting that the birds heavily rely on vision to

306   detect predators. Given that peahens in the wild roost atop tall trees, they also likely rely on

307   vibrations to detect the approach of large predators. Noise pollution may mask acoustic cues from

308   predators but be less important than visual or vibrational cues to the peahens. Given that their

309   antipredator vocalizations are loud and cover a wide frequency range (Yorzinski, 2014), peahens

310   may also be able to hear conspecific warning calls despite noise pollution (Francis, 2015;

311   Pettinga, Kennedy & Proppe, 2016). Additional studies that examine whether peahens use

312   acoustic cues during predator detection in the daytime would be useful. A comparative study

313   examining variation in species' response to noise pollution would help elucidate the factors

314   impacting the perception of risk in response to noise pollution across species.

315   It is possible that the peahens in this study had previously habituated to noise pollution.

316   The peahens were captured from feral populations located in country areas or suburban

317   neighborhoods at least two years prior to the onset of this study. They may therefore have

318   habituated to noise pollution while they were feral. However, the loudness and duration of the

319   noise pollution they experienced while they were feral were likely less than the loud noise

320 treatment in this study. It is also possible that the birds habituated to the noise during the trials

321 because the noise was broadcast for four consecutive days. However, their nocturnal vigilance

322 levels were similar on the first and last day when the noise was broadcast, suggesting that

323 habituation within trials was not influencing vigilance rates.

324   Because nocturnal vigilance is inversely correlated with sleep in peahens (Yorzinski et al.,

325 2015), noise pollution did not likely impact the amount of time the birds spent sleeping within

326 trials. In addition, they ascended the roost in the evening and descended from the roost in the

327 morning at similar times regardless of whether noise pollution was present or not within trials.

328 However, noise pollution could have affected their sleep patterns in subtler ways. In humans,

329 noise pollution can alter the amount of time spent in different stages of sleep (Pirrera, De Valck &

330 Cluydts, 2010). Further research investigating the impact of noise pollution on sleep in birds

331 would be useful. One study found that European robins (*Erithacus rubecula*) sing at night when

332 they are exposed to noise pollution but how this behavioral change impacted their sleep behavior

333 was not explored (Fuller, Warren & Gaston, 2007).

334   In our study, predators often avoided the experimental area during nights with noise

335 pollution. Similarly, Francis, Ortega & Cruz (2009) found that avian predators avoided

336 depredating nests in areas exposed to noise pollution. In addition, three-spined sticklebacks

337 (*Gasterosteus aculeatus*) and greater mouse-eared bats (*Myotis myotis*) are less efficient hunters

338 when subjected to noise pollution (Purser & Radford, 2011; Siemers & Schaub, 2011). Because

339 some predators may be sensitive to noise pollution, prey may be safer and have higher

340 reproductive success in noisy environments (Francis, Ortega & Cruz, 2009). However, in other

341 species, prey are more easily captured by predators when exposed to noise (Simpson, Purser &

342 Radford, 2015; Simpson et al., 2016). The mechanisms underlying differences in hunting

343 behavior across species in response to noise are not well understood.

344   Other types of anthropogenic disturbances, such as light and chemical pollution, often

345   accompany sources of noise pollution (Halfwerk & Slabbekoorn, 2015). Understanding how

346   different types of disturbances singly and jointly influence antipredator behavior would be

347   informative. While we found that noise pollution had limited effects on nocturnal vigilance rates

348   in peahens in this study, we previously found that light pollution significantly increases their

349   nocturnal vigilance rates (similar sample size as used in this study; Yorzinski et al., 2015). Across

350   nights with exposure to pollution, nocturnal vigilance rates in response to noise pollution in this

351   study (medium noise: 118 ± 3.5; loud noise: 112 ± 6.0) were two times lower compared to

352   vigilance rates in response to light pollution in a similar study (246 ± 38.6; Yorzinski et al.,

353   2015). Based on the evidence thus far, management practices aimed at minimizing artificial

354   disturbances to peafowl might therefore invest more in reducing light pollution compared to noise

355   pollution.

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476   Figure 1. Head movement rates (means ± SE) of peahens during noise (medium and loud) and

477   control trials.

478   Figure 2. Amount of time that predators were present (means ± SE) during noise (medium and

479   loud) and control trials.

480   Table 1. The impact of trial type, trial night, environmental and morphological variables, and

481   predator and non-predator presence on head movement rate, the amount of time predators and

482   non-predators spent near the experimental area, the times at which the birds ascended to and

483   descended from the roost, and roost selection. F values (numerator degrees of freedom,

484   denominator degrees of freedom) are displayed along with p-values for A-E; chi-square values

485   (degrees of freedom) are displayed along with p-values for F.

	A: Head Movement Rate	B: Predators	C: Non-predators	D: Ascend Roost	E: Descend Roost	F: Roost Selection
Trial Type	3.57 (2,25) **0.043**	5.80 (2,27) **0.008**	0.52 (2,27) 0.60	0.33 (2,25) 0.72	6.48 (2,25) **0.0054**	1.39 (1) 0.24
Trial Night	0.55 (6,108) 0.77	0.87 (6,138) 0.52	1.85 (6,138) 0.095	0.43 (6,123) 0.86	0.57 (6,121) 0.75	-
Trial Type * Trial Night	0.24 (12,108) 0.99	2.58 (12,138) **0.0041**	0.43 (12,138) 0.95	0.50 (12,123) 0.91	0.97 (12,121) 0.48	-
Wind	0.03 (1,108) 0.85	7.21 (1,138) **0.0081**	1.11 (1,138) 0.29	0.24 (1,123) 0.62	3.11 (1,121) 0.081	0.40 (1) 0.53
Precipitation	0.77 (1,17) 0.39	0.15 (1,19) 0.70	1.08 (1,19) 0.31	0.06 (1,18) 0.81	2.14 (1,18) 0.16	-
Temperature	3.04 (1,108) 0.084	15.49 (1,138) **0.0001**	5.74 (1,138) **0.018**	24.06 (1,123) **<0.0001**	0.79 (1,121) 0.38	1.37 (1) 0.24
Moon	0.23 (1,108)	1.31	0.04	0.53	2.09	0.12 (1)

illumination	0.63	(1,138)	(1,138)	(1,123)	(1,121)	0.73
		0.25	0.85	0.47	0.15	
Mass	1.16 (1,25)	-	-	0.35	3.09	1.17 (1)
	0.29			(1,25)	(1,25)	0.28
				0.56	0.091	
Tarsus + Metatarsus	3.42 (1,25)	-	-	2.80	12.15	0.089 (1)
	0.076			(1,25)	(1,25)	0.77
				0.11	**0.0018**	
Predator Presence	0.39 (1,23)	-	-	0.82	1.89	-
	0.54			(1,22)	(1,23)	
				0.37	0.18	
Non-predator Presence	0.34 (1,14)	-	-	0.15	0.15	-
	0.57			(1,15)	(1,14)	
				0.70	0.70	

486 Table 2. Specific contrasts were performed to compare treatment effects and time effects with

487 respect to head movement rate (df=108) and the amount of time that predators spent near the

488 experimental area (df=138). Within the treatment effects, we examined whether the control and

489 noise trials differed on night 1, nights 2-5 (averaged), and nights 6-7 (averaged). Within the time

490 effects, we examined whether there were differences within the control or noise trials on night 1

491 compared to night 2-5 (averaged), nights 2-5 (averaged) compared to nights 6-7 (averaged), night

492 1 compared to night 6-7 (averaged), and night 2 compared to night 5. Contrasts were considered

493 significant if they are less than the Bonferroni corrected p-value (18 contrasts; $p<0.0028$).

			A: Head Movement Rate	B: Predators
Treatment effects				
	Night 1	Control vs. Medium	0.14 (0.89)	0.86 (0.39)

		Noise		
	Night 1	Control vs. Loud Noise	0.39 (0.70)	0.58 (0.56)
	Nights 2-5	Control vs. Medium Noise	2.82 (0.0056)	**4.62 (<0.0001)**
	Nights 2-5	Control vs. Loud Noise	1.66 (0.099)	**3.61 (0.0004)**
	Nights 6-7	Control vs. Medium Noise	0.93 (0.35)	0.47 (0.64)
	Nights 6-7	Control vs. Loud Noise	0.60 (0.55)	1.45 (0.15)
Time effects				
	Control	Night 1 vs. Night 2-5	1.19 (0.23)	2.4 (0.018)
	Medium	Night 1 vs. Night 2-5	0.53 (0.60)	1.66 (0.10)
	Loud	Night 1 vs. Night 2-5	0.56 (0.58)	0.89 (0.38)
	Control	Night 2-5 vs. Night 6-7	0.02 (0.98)	1.92 (0.057)
	Medium	Night 2-5 vs. Night 6-7	1.44 (0.15)	1.15 (0.25)
	Loud	Night 2-5 vs. Night 6-7	0.54 (0.59)	2.98 (0.0034)
	Control	Night 1 vs. Night 6-7	1.04 (0.30)	0.71 (0.48)
	Medium	Night 1 vs. Night 6-7	0.53 (0.60)	0.65 (0.51)
	Loud	Night 1 vs. Night 6-7	0.90 (0.37)	1.40 (0.16)
	Control	Night 2 vs. Night 5	0.74 (0.46)	0.12 (0.91)
	Medium	Night 2 vs. Night 5	0.15 (0.88)	1.33 (0.19)
	Loud	Night 2 vs. Night 5	0.39 (0.70)	0.07 (0.94)

494   Figure 1.

495   Figure 2.