The effects of chronic moderate noise on animal behavior and distribution

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"It is clear that the acoustical environment is an interconnected landscape of information networks and adventitious sounds; a landscape that we see as more connected with each year of investigation."[16]

"Noise may present similar problems in terms of connectivity as do physically altered vegetation structure."[10]

Masking of listening/communication

3dB increase in background ambient

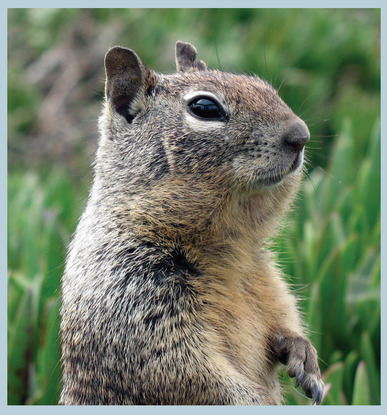
→ *50% reduction in listening area*

10dB increase in background ambient

→ *90% of natural listening area is lost*

Calls of own species
Sounds of prey when hunting
Approach of predators

Why does a slight increase in background sound matter?



Behavioral changes

Reduced call time for mating

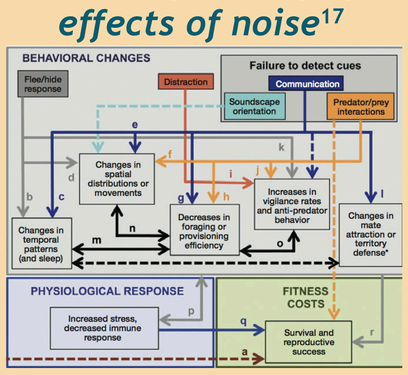
Increased vigilance and other anti-predator behaviors
Perceived risk of sound itself
Masking of auditory cues from predators
Distraction from necessary activities

Interrupted and/or reduced foraging

Physiological effects

Stress: wide range of fitness consequences
(hard to study in animals in the wild)

Potential pathways for effects of noise[17]



- Startle/hide responses are more likely to occur in response to noise stimuli that are perceived as a threat (acute, erratic, or sudden sounds).
- Problems arising from a failure to detect cues are more likely to occur when noise stimuli are chronic and overlap with biologically relevant cues used for communication, orientation, and predator/prey detection.
- Lowercase letters indicate studies [listed in paper] providing evidence for the link made for each arrow. Dashed arrows signify a link that we predict as important but for which no current evidence exists.

Biologically significant effects may occur without observed behavioral changes

"An organism might show little to no response to noise in terms of habitat occupancy or foraging rate, for example, but may experience strong negative impacts in terms of pairing success, number of offspring, physiological stress, or other measures of fitness."[17]

Habituation does not imply lack of impact

"Habituation is an oft-cited reason for persistence and an absence of noise impacts, yet research on other stressors indicates that acclimation to a stressor might not release an organism from costs to fitness. Additionally, we have shown how behavioral modifications among individuals confronted with noise – even those individuals that outwardly appear to habituate – can lead to decreased fitness."[17]

Animals remaining in noisy areas may bear higher fitness costs than those displaced

"From a population viewpoint, the species most likely to be adversely affected by disturbance are those for which the fitness costs are high but they have little excess habitat to move to and are thus constrained to stay in disturbed areas and to suffer the costs in terms of reduced survival or reproductive success." [By contrast, animals who can readily find alternate habitat may be displaced even when the disturbance is minimal.][18]

"This research is providing insight into the sublethal consequences of acoustic habitat loss or degradation."[7]

Most studies address traffic noise or oil and gas development noise, rather than wind farm sounds. While not ideal, like turbine sounds these are predominantly low frequency, with broadband components; received levels in the studies vary, but generally range from levels consistent with inside wind farms to levels likely to occur at distances similar to those at nearby homes (1200-1500ft)

Responses from animals are far from uniform; there is notable variation between species and among individuals in a population. Likewise, response rates vary with different types of noise (largely dependent on frequency overlap with animal hearing), and—importantly—depending on the behavioral context of the animal. **There are some indications that intermittent noise is more troublesome than constant noise.**

Lower-frequency callers

Field and lab playback studies—Investigating the effects of road noise without other road factors present

Sage Grouse: lek attendance, stress, masking effects

73% lower male attendance in leks with traffic noise than in paired controls[1]
"Intermittent road noise was associated with lower relative lek attendance than continuous drilling noise, in spite of the overall higher mean noise levels and greater masking potential at leks treated with drilling noise."

17% higher mean Fecal Corticosteroid Metabolites (FCM) levels in traffic noise[2]
"Taken together, [these two studies] suggest that noise alone can cause greater sage-grouse to avoid otherwise suitable habitat and increase the stress responses of birds that remain in noisy areas"

50%+ reduction in call detection and discrimination distances[3]
60m rather than 160m for three key components of mating calls in 48dBA of road noise

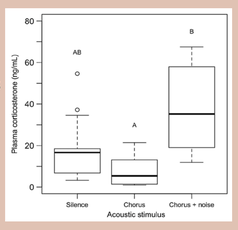
Frogs: call rates change, stress increases

Male call rates increase 2-3x in traffic noise, duration of nightly calling reduced[4,5]
"Male frogs exposed to anthropogenic noise decreased both the number of days present at the chorus and the nightly chorus duration relative to controls. Because females generally join choruses late at night to breed, the effects of noise shown here are likely to substantially decrease frog reproductive success."[5]

Three frog species call less in traffic noise, but one calls more[6]
"The reduction in heterospecific calling evoked by man-made sounds may be indirectly increasing R. taipehensis's likelihood of mating while simultaneously reducing that of other species"

Frogs show stress-related immobilization in traffic noise, fail to seek out mates[7]
67dBC, potentially similar to sound in a wind farm, though not outside it

5x increase in stress hormone in traffic noise[7]
Noise was loud, 80+dBA; effect likely smaller in less noise
"Our results [right], combined with recent studies identifying linkages between increased anthropogenic noise and elevated glucocorticoid levels in fish, birds and cetaceans, suggest that the physiological consequences of noise span vertebrate taxa."



Mammals

Prairie dogs: community behavior patterns changed[13]

Traffic noise playback (mean 52dBA)
21% decrease in above-ground numbers
18% fewer seen foraging
48% increase in vigilance behavior
Social, resting behavior halved

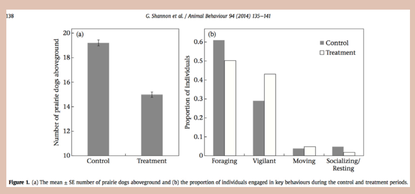


Figure 1. (a) The mean ± SE number of prairie dogs aboveground and (b) the proportion of individuals engaged in key behaviours during the control and treatment periods.

Ground squirrels: Masking of calls, increased vigilance within a wind farm[14]

"There is great potential for noise at turbine sites to interfere with the detection and assessment of alarm calls. In turbine environments, animals have shifted their antipredator tactics to utilize the visual modality more as seen by increased levels of ALERTNESS and PROXIMITY TO SHELTER. In doing so, squirrels appeared to attempt to compensate for acoustic masking as a result of turbine noise."

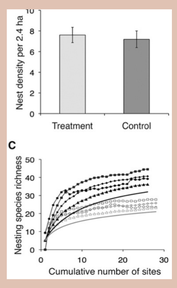
Many terrestrial noise sources produce noise that travels through the ground as well as the air. Seismic noise is likely to impact fossorial animals and animals that possess specialized receptors for seismic detection, many of which communicate by seismic signals. We do not address seismic noise in this paper, but it is an issue that warrants further discussion.[15]

Songbirds

While their songs are predominantly mid- and higher-frequency, notable effects found in presence of lower-frequency sounds

Nesting density reduced in noise[8]

30% reduction in overall nesting density around noisy oil/gas installations



Noise changes species composition and distribution[9,10]

Species react differently to noise:
some prefer noise, more prefer quiet[9]
While overall nest density remains similar [left, top], noise markedly reduces species diversity [left, bottom]
14 species nested only at quiet/control sites; 3 only in noisy sites
Nest predation *much lower* in noisy sites[9]
Key local predator prefers quiet sites
"This pattern may not exist in other landscapes exposed to noise where different nest predators may fail to respond to noise, or even respond positively, which may be the case for those nest predators that rely primarily on olfactory and visual cues to locate prey."[10]

"Phantom road" shows many migratory birds avoid noisy locations[11]

Half-mile string of speakers in migratory songbird habitat
Overall bird density 22% lower in noise-on periods than during noise-off
Among the 22 most common species:
2 nearly totally avoided noise-on periods, 1 was *more numerous* during noise
12 showed significantly lower occupancy as noise increased from 35dB to 60dB

Nesting patterns near wind farms show similar species variability[12]

9 of 12 species showed some avoidance to 500-800m
In 6 species with the most response, population density down 38-53%

Considerations

While it's clear that noise can have consequences on behavior, energy budgets, communication, and stress, studies have not yet investigated whether these changes lead to measurably decreased fitness
health, food intake, mating and fledgling success, etc.

Habituation and/or displacement of more sensitive individuals may lead to long-term effects smaller than those found in studies of naïve animals
But see Habituation paragraph above; and note, **"the loss of sensitive individuals from the group through site abandonment could increase predation risk for the group as a whole through the removal of the most vigilant group members."[17]**

Uncertainties

Not all studies find a correlation between noise and behavioral or distribution changes[19,20]

Noise effects will not all be one direction
"In terms of avian reproductive success, the way in which each breeding variable (e.g., breeding occupancy, pairing success, clutch size, nest predation) responds to changes in noise amplitude and frequency will probably differ."[10]

Noise effects can be modest and difficult to separate from many other possible factors
e.g., subtle differences between control and test sites, observer skill, younger/older animal (experience), seasonal effects, etc.

Future Research Needs

Playback experiments using wind turbine sounds rather than traffic noise

Examine effects across gradients of noise levels, rather than binary quiet/noisy study designs

Investigate health and mating/fledgling success in locations with noise-related changes in vigilance, foraging, animal density, or masking.

Begin developing species- or family-specific hearing and behavioral sensitivity guidelines[15]

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