Responses to anthropogenic noise by urban and rural bird species

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Abstract

With increasing urbanization comes the spread of anthropogenic noise. Birds rely on auditory signaling for much of their communication, from mate attraction to predator warning calls. Background noise disrupts this communication, affecting birds' success in areas of high human activity. While birds of the same species are sometimes different depending on if they live in cities or rural areas, all members of certain species also share traits regardless of habitat. Such traits predispose some species to live in urban habitats and one of these traits may be a greater tolerance to anthropogenic noise. At the University of Notre Dame Environmental Research Center near Land o' Lakes, Wisconsin, I studied calling responses to anthropogenic noise in bird species that live exclusively in rural areas and those that thrive in both rural and urban locations. I used people and a car as anthropogenic noise and measured the time it took birds to resume their calls and the decrease in call rate after the treatment. From this I determined overall effect of anthropogenic noise and the difference in its effect on urban and rural species. Overall, the birds did not show a significant response to anthropogenic noise treatments, though there was significant interaction between noise treatment and bird type regarding their effect on time it took birds to resume calling. Urban birds tended to decrease their call rates more than rural birds following treatments, suggesting that urban birds, even when living in rural habitats, can better adapt to anthropogenic noise.

Introduction

Humans are continually developing land and with increased development inevitably comes increased noise from roads and human populations. A part of our everyday lives, anthropogenic noise can have far-reaching effects. Birds rely on calls to find mates, defend territories and warn each other of predators (Mockford et al 2011). Thus the effect of

anthropogenic noise on birds is of key interest. Composition of bird communities differs between urban and rural environments, and bird populations are likely to shift with human populations. As humans alter the landscape to fit their needs, specific habitats will inevitably be destroyed and once-quiet regions will be exposed to increasing noise and habitat disturbance. Marzluff (2001) predicts that bird numbers will increase but their diversity will decrease as urbanization continues. Understanding the mechanisms behind this changing community structure in response to human presence will help predict changes in biodiversity.

There are several factors involved in birds' reactions to human presence. One factor is differing effects of anthropogenic noise on different species. Research suggests that breeding success for some bird species declines in forests with added noise (Habib et al 2007). Moreover, urban birds, those that can live in populated areas, have broader ranges than rural species (Bonier et al 2007a), which suggests that urban species have greater tolerance to anthropogenic disturbances than rural ones. Such tolerance is multifaceted, likely shown in behavior such as the ability to use unique resources as well as the ability to adapt calls. There is evidence that some species are able to alter their calls when living in a noisy environment (Nemeth and Brumm 2010). However, it has been shown that different species change their calls in different ways. So, while it is likely that being able to adapt is important for birds to thrive in urban areas, there does not appear to be a consistent pattern for how this adaptability is manifested (Francis et al 2011).

There are also physiological differences between urban and rural birds of the same species, including aspects such as changes in certain hormone levels (Bonier et al 2007b) and lower stress responses in birds in the cities (Partecke et al 2006). This suggests that tolerance varies on an individual level, though it also seems that if some species have broader ranges it is likely that all individuals in the species have some wider tolerance than those of species with

narrow ranges. Further, species with larger brains are predisposed to adapt to urban settings due to their increased ability to respond to new conditions (Sol et al 2005). Thus it is clear that there are aspects of both species evolution and individual adaptation at play in a bird's ability to thrive alongside humans. A greater understanding of this interplay is imperative as we strive to effectively predict anthropogenic effects on birds. Understanding if the communities of species that can thrive in urban areas but live in rural areas are tolerant of anthropogenic noise will help predict the effects of increasing human activity in previously isolated areas, which will improve conservation efforts.

Studies have analyzed long-term impact of continuous noise on the reproductive success of forest birds (Habib et al 2007). It is broadly understood that anthropogenic noise affects bird species and that responses to noise vary by both species and individual. Some successful urban species have been shown to sing differently in cities than in forests (Slabbekoorn and den Boer-Visser 2006). This suggests that flexibility is key in the species that can live in both rural settings and cities. However, it is unclear whether this flexibility is a distinguishing characteristic of all birds in those species, or if it is selected for on an individual level in populations that live near anthropogenic noise. Examining short-term responses of birds to anthropogenic noise in an otherwise undisturbed environment is one way to investigate this adaptability. I examined the question: do species that can live in urban areas have different reactions to anthropogenic noise than those that tend to only thrive in rural areas? Since species that can live in populated areas are shown to have physiological traits predisposing them to tolerate greater disturbance I predicted that those species that also live in urban areas would have less of a response to anthropogenic noise.

Methods

Location

I collected my data in the Northwoods of the University of Notre Dame Environmental Research Center (UNDERC) near Land o' Lakes, Wisconsin. This remote area allowed me to minimize unplanned anthropogenic noise. While occasional cars use these roads, and some other noise is present, it is far away from towns and regular human activity.

I collected data at six sites, chosen to be equally remote. I randomly chose sites along two roads in similar conditions. There were three sites on each road, at least 250m apart and 50m into the forest. UNDERC is a wet area with many bogs and the six sites ranged from sugar maple dominated forests to deciduous spruce and hemlock dominated areas.

Data Collection

The experiment included two treatments and a control. The treatments of anthropogenic noise were a car honking while driving by and a group of people talking while walking through the site. The control was no added noise. Treatments were applied to every site in a random order. Data was collected between 5am and 8am on days that did not have considerable rain. Upon arrival at the site we waited for 10 minutes in silence so that the birds could acclimate to our presence. After the acclimation period, a colleague and I noted every birdcall we heard and the time at which we heard it for 10 minutes. Then other colleagues applied a treatment (driving a car on the nearby road or walking through the site), and we again wrote down everything we heard and the time of the calls for another 10 minutes. This data collection method was modeled on the BBIRD protocol from the Montana Cooperative Wildlife Research Unit (Martin et al 1997). We noted all of the birdcalls we could identify, which was about 85% of the calls we

heard. We combined our data, counting calls only once if we both recorded them within 5 seconds.

Data Analysis

I classified birds as "urban" and "rural" based on their habitats. While they may live in undisturbed habitats, "urban" birds are also common in urban areas, such as gardens or parks (Table 1). "Rural" birds tend to only live in rural areas, such as forests (Table 2).

I examined two response variables: the time for birds to resume calling after the treatment and the decrease in call rate after the treatment. To determine if anthropogenic noise and bird type affected bird calling, I performed a two-way Analysis of Variance (ANOVA) on the average time it took the birds to resume calling, after it had been arcsine square-root transformed. The two factors were bird type (urban vs. rural) and anthropogenic noise treatment (car, people, and control). I ran a second two-way ANOVA on the decrease in the birds' call rate, with the same factors.

Results

Overall, urban species were present more than rural ones. Of the 12 species we recorded, eight were classified as urban. These birds were the American Robin, Black-and-White Warbler, Blue Jay, Least Flycatcher, Red-eyed Vireo, Red-winged Blackbird, Rose-breasted Grosbeak, and White-throated Sparrow. Together they made up 52.4% of the analyzed birdcalls, while the rural species made up 47.6%. The rural species were the Black-throated Green Warbler, Hermit Thrush, Nashville Warbler, and Ovenbird. (Erickson et al 2015; Bull and Farrand 1994)

All birds resumed calling in an average of 40.5±29 S.D. seconds after the car treatment, 66.7±67 S.D. seconds after the people treatment, and 25.5±21 S.D. seconds after the silent control, (Fig.1, $p=0.75$, $df=2$, $F=0.30$). On average, urban birds resumed calling in 22.0±32.1

S.D. seconds after the car treatment, 96.8±99.6 S.D. seconds after the people treatment and 69.0±65.8 S.D. seconds after the silent control, while rural birds averaged 48.2±32.7 S.D.seconds to resume after the car treatment, 16.7±10.5 S.D. seconds after the people treatment, and 9.0±7.6 S.D. seconds after the silent control ($p=0.18$, $df=1$, $F=1.89$). Rural birds resumed more quickly on average than the urban birds after the people and control treatments and the urban birds resumed more quickly on average than the rural birds after the car treatment, showing an interaction between the factors ($p=0.03$, $df=2$, $F=4.01$).

Overall, birds' calling rate had an average decrease of 13.6±20.2 S.D. calls per five minutes after the car treatment and 13.5±25.5 S.D. calls per five minutes after the people treatment and an increase of 2.6±15.2 S.D. calls per five minutes after the silent control (Fig.2, $p=0.34$, $df=2$, $F=1.12$). On average, urban birds decreased their calling rate by 29.3±35.8 S.D. calls per five minutes after the car treatment, 22.0±46.6 S.D. calls per five minutes after the people treatment and 4.42±34.1 S.D. calls per five minutes after the silent control, while rural birds decreased their call rates by an average of 2.1±6.2 S.D. calls per five minutes after the car treatment and 5.1±7.4 S.D. calls per five minutes after the people treatment and increased their rates by an average of 4.9±8.0 S.D. calls per five minutes after the silent control ($p=0.07$, $df=1$, $F=3.58$). Urban birds consistently decreased their call rate more than rural birds after the treatments, showing a lack of interaction between the factors ($p=0.74$, $df=2$, $F=0.31$).

Discussion

Anthropogenic noise did not cause birds to change their calling behavior. While I predicted that humans talking and a car driving would prompt a noticeable response by interrupting the birds' communication, it is possible that the birds here are used to noise in this capacity and thus were not affected by the treatments. The birds also may not have responded if

the noise of our treatments was at a different frequency than the types of noise that do disrupt them. Anthropogenic noise such as machinery and traffic is relatively low in frequency (Wood and Yezerinac 2006) while human voices are at a higher frequency. Acoustic masking occurs when noise that is at the same frequency as a birdcall blocks out the call (Halfwerk et al 2011), and research shows that this is a way in which urban noise has negative impacts on birds (Rheindt 2003). Thus, if the birds studied in the experiment did not sing in the frequency ranges of the treatments they may not have been negatively impacted. Further, many birds sing at a higher frequency when they are in the presence of lower frequency urban noise (Slabbekoorn and Peet 2003; Halfwerk et al 2011). Since we did not measure call frequency, it is possible that the birds were reacting in this way rather than taking longer to resume their calls or decreasing their call rates. Another possibility is that the anthropogenic noise treatments were not loud enough to provoke a response from the birds. Studies show that anthropogenic noise does affect birds (Wood and Yezerinac 2006). So having louder treatments of noise may have caused the birds to react in a more noticeable way.

Rural birds took longer than urban birds to resume their calls after the car drove by, while the reverse was seen with the people and control treatments. This inconsistency suggests that the type of anthropogenic noise influences separate bird types differently. It is likely that the birds I studied were relatively familiar with hearing people talking and cars driving by. While other noises are not common in the sites, these would be the most common. The urban birds resumed calling more quickly than rural birds after the car treatment, supporting the idea that urban birds are more adaptive. It is beneficial to resume calling after one car drives by because once the car passes it is gone for good. The urban birds may have adapted to this, while the rural birds take longer to resume calling because they have not developed this quick recovery time in response to

a brief disruption. From this reasoning it follows that the urban birds took longer to resume their calls after the people walked by. While cars pass abruptly, people may linger and if they stop momentarily they have not necessarily left. Urban birds may have evolved to treat humans as they treat predators, being more cautious in case they are still in the vicinity. The ability of these birds to make these connections may support findings that bird species that thrive in urban environments do so because they are better at adapting to new conditions (Sol et al 2005).

Urban birds tended to decrease their rate more than rural birds for both anthropogenic noise treatments. While this was not a significant relationship, it was nearing significance. It is likely that a larger sample size would have decreased variation and allowed us to see a stronger trend. Although this result is contrary to my hypothesis, it demonstrates that urban birds may be resistant to the negative impacts of noise because they can adapt to it. The decrease in rate of urban birdcalls after a noise treatment supports the idea that species thriving in urban environments do so because they are more flexible. A study on Great Tits shows that, when living around anthropogenic noise, these birds tend to cease calling if their neighbors do not respond and they will not respond to their neighbors if they cannot hear their neighbors' calls clearly (Slabbekoorn and Ripmeester 2008). So a decrease in call frequency after a loud noise is likely a strategic response to not waste energy on calls that cannot be heard. This data suggests that individuals of species that can live in urban areas are good at adapting and changing their habits when necessary even when they are living in rural areas.

In addition to the response variables studied here, change in amplitude of call (Brumm 2004), change in length of call (Francis et al 2011) and change in frequency of call (Hu and Cardoso 2010) are ways that birds react to anthropogenic noise. Studies show that an increase in call duration in addition to an increase in call pitch are strategies employed by species, likely to

increase neighbors' ability to hear their calls when there is increased background noise (Francis et al 2011). However, these strategies each come with specific costs (Brumm 2004). Studies suggest that these strategies may be tradeoffs; so different species use one or two strategies, rather than using several (Francis et al 2011). This may explain the large amount of variation seen in the data. In the future, conducting studies that analyze the interplay of other response variables such as increase in frequency and amplitude of call would broaden our knowledge of these coping mechanisms. It would also be beneficial to conduct future studies focusing on one or two behaviorally similar species, both to limit variation and to increase understanding of the various strategies used by different species.

Urbanization tends to bring homogenization of the landscape because it creates specific environments designed for the human species (McKinney 2006). A relatively small number of nonnative species that thrive in urban conditions often replace the wider variety of native species that do not do as well in these conditions (Blair 2001). Such homogenization takes place along a gradient, with city centers having the lowest diversity and the outskirts having higher diversity. (McKinney 2002). Research shows that traits allowing some species to thrive in urban areas go beyond call adaptability and include the ability to eat novel items and nest in certain places that exist in cities (Kark et al 2006). It is clear that the future of birds is multifaceted and more research is needed to improve our understanding.

This study suggests that certain species are better at adapting to anthropogenic noise than others. If this is the case it has positive implications for conservation efforts because it suggests that some species are able to change their habits on a short-term basis. Added human activity in rural areas is likely to have little impact on the communication of these species. However, components such as food sources and nesting sites must also be considered. Further, this data

suggests that adaptation to urban living is on a species level rather than an individual level. It is likely that the species that have never thrived in cities will never thrive in cities without drastic evolutionary changes, because they do not adapt as well as more successful species. These findings support other studies that encourage careful environmental monitoring during urban development (Ortega-Alvarez 2009) in addition to the protection of green spaces and larger parks that may provide a sanctuary from the louder sounds of the city.

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Tables

Table 1. Urban birds. Birds present at UNDERC that can also live in urban areas including lawns, roadsides, and parks.

Common Name	Scientific Name	Habitat
American Robin	*Turdus migratorius*	Forests, mountains, city parks, lawns, and gardens
Black and White Warbler	*Mniotilta varia*	Mostly deciduous forests, but will use lawns and gardens during migration
Blue Jay	*Cyanocitta cristata*	Forest, urban areas and suburbs
Least Flycatcher	*Empidonax minimus*	Woodlands, orchards, fields, along roads and trees in parks
Red-eyed Vireo	*Vireo olivaceus*	Deciduous forests and residential areas with large trees
Red-winged Blackbird	*Agelaius phoeniceus*	Wet areas such as marshes and places such as alfalfa fields, woodlots, and pastures
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Wet woods and edges, suburban gardens, parks, and orchards
White-throated Sparrow	*Zonotrichia albicollis*	Coniferous forest edges in summer and suburban yards, fields, and parks in winter

(Bull 1994 and Erickson et al 2015)

Table 2. Rural birds. Birds present at UNDERC that tend to only live in wild habitats such as uninterrupted forests or meadows

Common Name	Scientific Name	Habitat
Black-throated Green Warbler	*Setophaga virens*	Coniferous forests
Hermit Thrush	*Catharus guttatus*	Many forest types and openings like trails, around ponds, and glades
Nashville Warbler	*Oreothlypis ruficapilla*	Deciduous or mixed forests and thicket edges or swamp borders
Ovenbird	*Seiurus aurocapilla*	Large stretches of mature forests

(Bull 1994 and Erickson et al 2015)

Figures

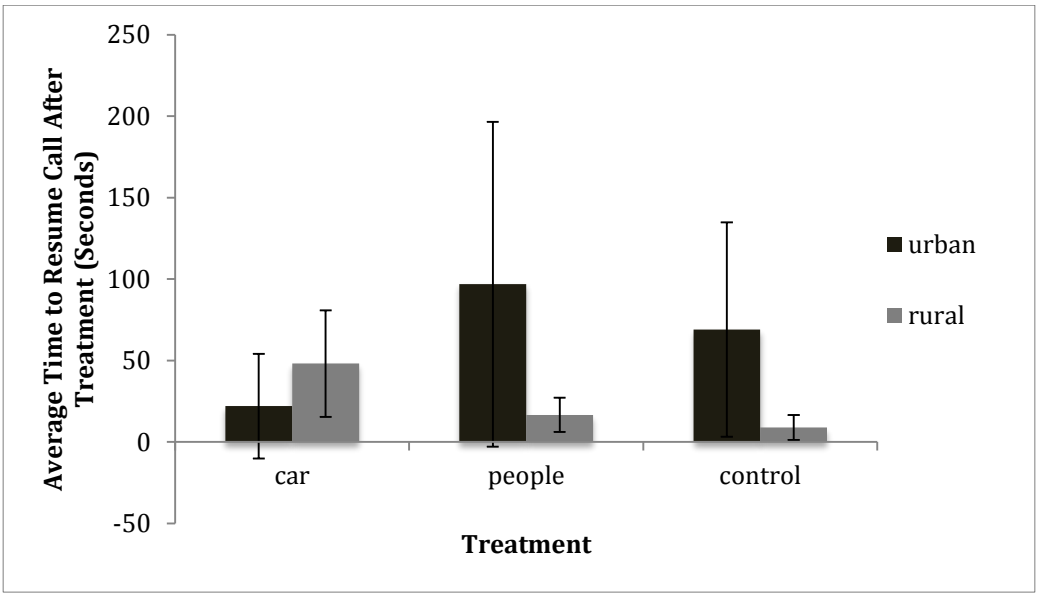

Figure 1. Differences between urban and rural birds in time to resume call after anthropogenic noise treatments. Urban birds took longer to resume calling after the silence control and the people treatment, while rural birds took longer to resume after the car treatment (anthropogenic treatment p=0.75, bird type p=0.18, interaction p=0.03). Error bars represent one standard deviation.

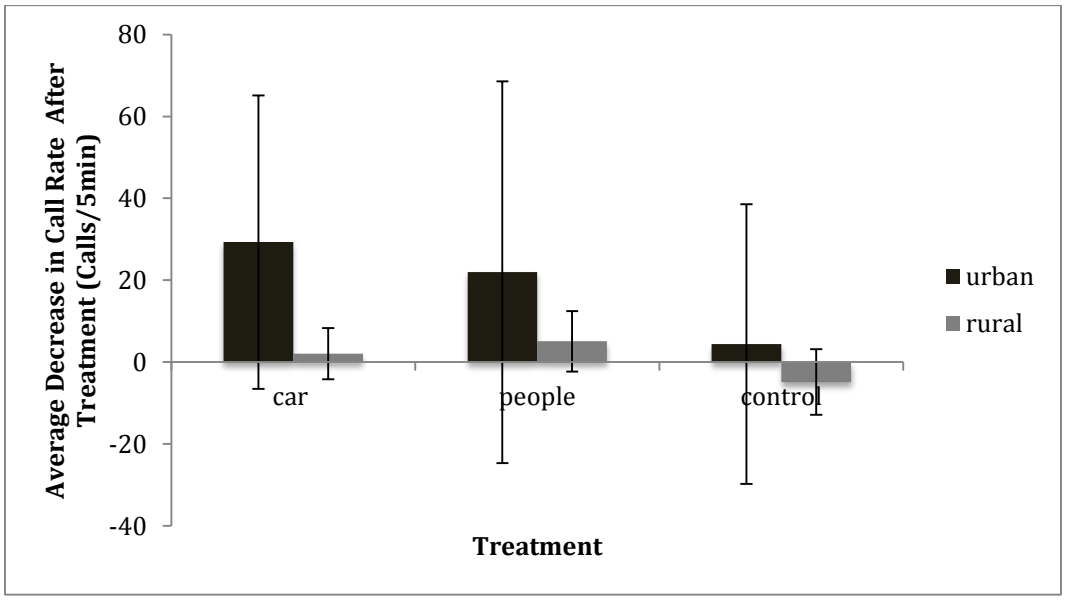

Figure 2. Difference between urban and rural birds in decrease in call rate after anthropogenic noise treatments. While there is high variation, the general trend was for urban birds to decrease their call rates more than rural birds in response to all treatment (anthropogenic treatment p=0.34, bird type p=0.07, interaction=0.74). Error bars represent one standard deviation.