Spatial and temporal variation in vibratory noise and its impact potential on a common urban arthropod

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**INTRODUCTION**

Questions

* To what degree does vibratory noise vary across space?
* How does vibratory noise vary over time?

**MATERIALS AND METHODS**

**Survey sites**

We recorded substrate-borne (vibratory) noise at 21 private properties in Lancaster County, Nebraska, United States in 2020 and added an additional private property and the University of Nebraska-Lincoln city campus in 2022. To acquire access to the properties, we sent an email to listservs of the biological sciences and entomology departments at the University of Nebraska-Lincoln (UNL) in 2020 asking for volunteers to allow us to record ambient vibrations at their properties. We received permission to access private properties for the duration of the study from faculty, staff, and graduate students, as well as a few personal connections with properties well-scattered across Lincoln, Nebraska, and into the surrounding rural area (Fig. 1A). We added the two sites in 2022 (8A and 8B) because we collected *Agelenopsis pennsylvanica* spiders from these sites for experiments.

We sorted the 23 sites into two categories based on land cover class: urban and rural. Anthropogenic sources of vibratory noise are thought to travel up to 1 kilometer from the source (Lecocq et al., 2020). As such, we used QGIS (3.16.3-Hannover, ESRI 102704) to calculate the area of each land cover class from the 2019 National Land Cover Database (U.S. Geological Survey, 2019; 30-meter resolution) within a 1-kilometer radius of each site. We combined designations of ‘Developed’ to describe urban area and designations of ‘Planted/Cultivated’ to describe agricultural area (https://www.mrlc.gov/data/legends/

national-land-cover-database-class-legend-and-description). The remaining classes were combined as other area. We categorized sites as urban that had more urban than agricultural area and sites as rural that had more agricultural than urban area (Fig. S).

**Recording ambient vibratory noise**

To record ambient vibrations, we deployed recording units at each of the sites (Fig. 1B). We recorded ambient vibrations by attaching a contact microphone (Kmise, Model KP-01, China) to substrates using XFasten double-sided tape. The microphone was connected to a Tascam DR-05X digital recorder (TEAC Corporation, Tokyo, Japan) where the files were stored on a Sandisk 32 GB microSD card. The recorder was powered by a 10000 mAh portable battery (onn. Walmart, 3x charge, Bentonville, Arizona), which could power the recorder for approximately 24 hours. We stored the recorder and portable battery in water-resistant containers and applied caulk around the entrance of the audio cable leading to the microphone.

We used 12 recording units in total. At each of the sites in 2020, we deployed four recording units to record ambient vibrations for 24 hours next to webs of *Agelenopsis pennsylvanica*. Thus, we could survey three sites in a single day. Of the four recording units, we connected two to plant substrates and two to manmade substrates (e.g., cement, paneling, wood fences/porches, metal, etc.) to test whether substrates differ in vibratory noise levels (Table S). We repeated recordings on the same substrates during three subsequent visits, for a total of four visits that occurred between August 3 and October 23, 2020. Visits to the same sites occurred approximately every three weeks to understand how vibratory noise varies across the penultimate and adult season of *Agelenopsis pennsylvanica*. Recordings only took place on weekdays to avoid changes in anthropogenic activity patterns on weekends. We also only recorded on days when chances of rain were below 20% (both to protect the recording units and remove vibratory noise from rain) and the temperature was not forecasted to exceed about 33 oC (to protect the recording units). We switched out the portable battery for a fully charged one approximately 10 hours after deployment to ensure the recorders remained charged throughout data collection (see Table S for data on start, end, and check times). We excluded recordings where the microphone fell from the substrate at any point during recording (see Table S for final sample sizes).

In 2022, we added a private property and UNL city campus to determine vibratory noise levels at sites where *Agelenopsis pennsylvanica* spiders were collected. We deployed six recording devices (three on plants and three on manmade substrates) at the private property (8B) for three consecutive days (August 11-13, 2022). We deployed four recording devices (two on plants and two on manmade substrates) on UNL city campus for four consecutive days (August 17-20, 2022). We returned approximately every 24 hours to replace the portable batteries.

To measure vibratory noise levels, we used Raven Pro (v. 1.6.1) to divide each 24-hour recording into five-second time bins and calculate the equivalent continuous sound pressure level (Leq) for each bin. We did this for the frequency range of 20 to 1000 Hz since anthropogenic noise is thought to occur predominantly below 1000 Hz (CITE). We removed the first five minutes of each recording to ensure that vibratory noise from setup was not included in the analysis. For the same reason, we removed about a minute of the recording where we replaced the battery.

**Vibratory noise across space**

To determine the range of variation in vibratory noise that *Agelenopsis pennsylvanica* would be exposed to, we took the average the Leq for all five-second time bins for each of the 23 sites. We also suspected that vibrations from nearby traffic likely contributed significantly to the recorded ambient vibrations. To test this, we first gathered four variables related to road noise for each site: (i) impervious (i.e., building and pavement) cover in a 1 km radius, (ii) the average daily vehicles passing on the nearest road, (iii) the distance of the site to the nearest road, and (iv) the total length of roads in a 1 km radius. We used one kilometer because vibrations from traffic are thought to reach up to a kilometer from the source (CITE).

(i) We used the 2019 Impervious Cover Data from the National Land Cover Database (30-meter resolution, U.S. Geological Survey, 2019b). In QGIS, we polygonized the file and used the intersection tool to calculate the percent cover for the entire 1 km buffer region for each site (as in Pessman et al., 2023?). (ii) We used data from Lincoln Transportation and Utilities (<https://www.lincoln.ne.gov/City/Departments/LTU/Transportation/Traffic-Engineering/Average-Daily-Traffic-Volume>) and the Nebraska Department of Transportation (<https://gis.ne.gov/portal/apps/webappviewer/index.html?id=8ed4b009b0d546f19f0284e5bba0f972>) to determine the average number of vehicles per day that pass the nearest road for each site. (iii) We also calculated the distance of the site to its associated traffic data. (iv) We used the street centerlines layer (https://www.nebraskamap.gov/datasets/nebraska::street-centerlines/about) in QGIS to sum the lengths of all of the roads within a 1 km radius of each site.

We wanted to see the degree of variation in vibratory noise levels across large-scale space (across 23 sites) and small-scale space (between substrates – manmade vs plant). We reduced the four traffic impact potential variables through principal component analysis using the FactoMineR and factoextra packages in R (Fig. S) and used principal component 1 for statistical analyses. We calculated the mean Leq for each 24-hour recording to get the average daily Leq. To determine if vibratory noise levels are correlated with traffic impact potential and substrate type, we computed a linear mixed-effect model that included the daily average Leq as the response variable and principal component 1, substrate type, and the interaction as predictor variables. We used site as a random factor since each site had multiple recordings.

**Vibratory noise across time**

* Season and harvest
* 24 hours

Spider choice test

Spider activity patterns

**RESULTS**

**DISCUSSION**

**CONCLUSIONS**

**ACKNOWLEDGEMENTS**

**REFERENCES**

**FIGURE LEGENDS**

**TABLES**