



Herbert Hoover Acoustic Analysis

Summary of acoustic monitoring in 2019

Overview

Herbert Hoover National Historic Site (HEHO) protects sensitive tallgrass prairie habitat that abuts Interstate 80 in eastern Iowa. Transportation noise from the highway spreads across the park and is a concern for wildlife (Figure 1) and visitors. Construction of a water detention basin in the park created an opportunity to use the excavated soil to build a berm that would block the road noise. To determine how best to design the berm to reduce highway noise and improve communication conditions for wildlife, different berm configurations were modeled using sound propagation software.¹ **We found that installation of a noise berm along Interstate 80 would reduce highway noise entering the park by 1 to 20 dB $L_{Aeq, 24hr}$ (12.5Hz - 20kHz) re 20 μ Pa.**

Based on the noise model results, the park decided to install two berms in 2020 (Figure 2).

To measure the extend of benefits to wildlife habitat, field measurements of highway noise and bioacoustic activity before berm construction were collected. A comparison of pre and post measurements, summer 2019 and 2021 respectively, will determine how effective the noise berms are at reducing highway noise levels and if wildlife responds to the change.



Figure 1. Two common species of song birds found at HEHO. Left: Red-winged Blackbird (Photo: NPS/John Eicher). Right: Eastern Meadowlark (Photo: NPS/Jim Schmidt).

Transportation noise is known to reduce effectiveness of communication for a variety of wildlife species.

Additionally, the literature predicts decreases in bird density and foraging efficiency in response to transportation noise.² We hypothesize that reduction in traffic noise will result in improved communication conditions for wildlife and therefore, bioacoustic activity will change after the berm is installed. Differences in bioacoustic activity before and after the berm installation could reflect changes in the number of birds, changes in the number of sounds per bird, or both.

Research Objectives

The goal of this interim 2019 report is to summarize the baseline acoustic condition before berm installation, by addressing two study objectives:

1. Quantify the existing sound levels.
2. Quantify the existing bioacoustic activity.

Acoustic Monitoring Sites

Acoustic data were collected at eight sites in 2019 (Figure 2) from May 31 to July 1. Two different acoustic monitoring systems were deployed.

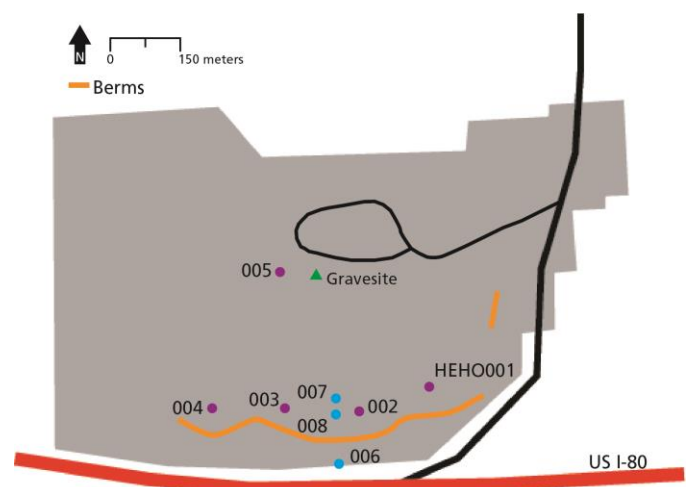


Figure 2: HEHO study area with eight acoustic monitoring sites. Purple circles show bioacoustics monitoring sites; blue circles denote existing highway noise monitoring sites.

¹ Nuessly, K. (2018). Noise modeling to determine soundscape benefits to berm implementation along US Highway I-80. Internal NPS report.

² Ware, H., McClure, C., Carlisle, J., & Barber, J. (2015). A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. *PNAS*, 112(39), 12105-12109.

Five SM2 song meters (Wildlife Acoustics, Figure 3) were used to measure baseline bioacoustic activity at sites HEHO001 through HEHO005 (Table 1). The SM2s recorded audio between 0400 and 0800 daily for 30 days to capture the dawn chorus. Bird vocalizations were recorded by the five SM2s at a sampling rate of 44.1 kHz and saved to internal memory as 16-bit depth, mono WAV files. Each microphone was covered by a foam windscreens and was given a gain setting of 12 dB.



Figure 3: Bioacoustic monitoring site HEHO001 (Photo: KNUessly). Song Meters (Wildlife Acoustics) are attached to steel posts above prairie grasses, but within close proximity of known song birds.

Table 1. Summary of Acoustic Recordings in 2019.

Site	Lat	Lon	Elev	Start	End	Total
HEHO001	41.666	-91.349	235 m	Jun 2	Jul 1	30 days
HEHO002	41.665	-91.351	239 m	Jun 2	Jul 1	30 days
HEHO003	41.666	-91.353	236 m	Jun 2	Jul 1	30 days
HEHO004	41.666	-91.355	237 m	Jun 2	Jul 1	30 days
HEHO005	41.668	-91.353	222 m	Jun 2	Jul 1	30 days
HEHO006	41.664	-91.352	240 m	Jun 1	Jun 1	0 d 4 hr
HEHO007	41.665	-91.352	240 m	May 31	May 31	0 d 8 hr
HEHO008	41.666	-91.352	240 m	Jun 1	Jun 1	0 d 1 hr

Two Larson Davis 831 (LD831) sound level meters (Figure 4) were deployed to measure baseline highway noise at sites HEHO006 through HEHO008 for several hours (Table 1). The standard NPS acoustic monitoring protocol³ was used to take LD831 measurements with one change: the sampling period was several hours long, instead of 30-days. Only a few hours of recordings were needed to measure highway noise because of the consistency of this noise source.

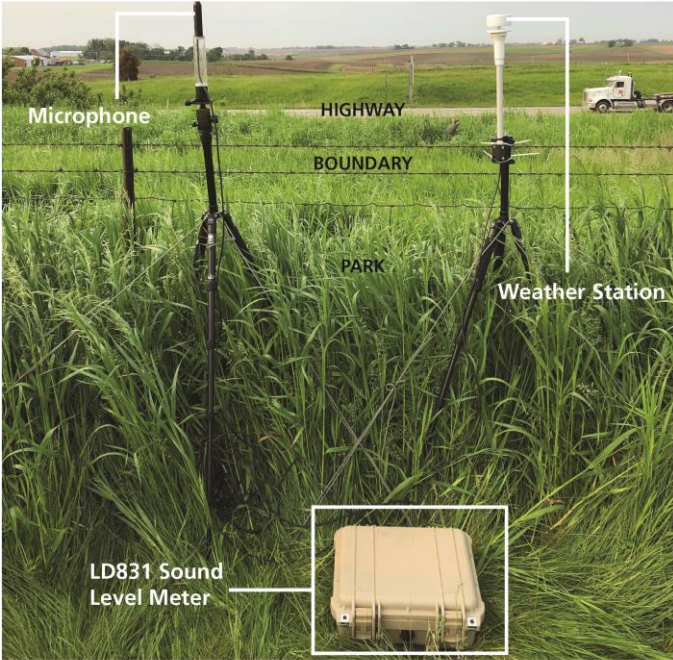


Figure 4: Highway noise site HEHO006 (Photo: KNUessly). The microphone (left) and the weather station (right) were placed on the park boundary, closest to the highway.

The LD831s recorded 1-second A-weighted time averaged sound levels ($L_{Aeq, 1s}$) measured in dB re 20 μ Pa between 12.5 Hz - 20 kHz for the entire monitoring period.

Interpreting Results

The sound levels in this report were measured on a logarithmic scale and reported as decibels (dB). Though the decibel scale is a useful way to express the wide range of sound pressure levels, it can be difficult to understand what the reported levels sound like. Compare the results in this report to the examples of A-weighted sound levels measured in national parks (Table 2) to understand what HEHO sites sound like.

Table 2. Sound level examples.

Park Sound Sources	Common Sound Sources	Sound Level*
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Cruiser motorcycle at 15m (BLRI)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL (YUCH)	Train horn at 1m	120

* dB re 20 μ Pa A-weighted broadband (12.5 Hz–20 kHz) sound level over varied measurement durations and at the distances indicated

³ NPS Acoustical Monitoring Training Manual, May 2013.
https://www.nps.gov/subjects/sound/upload/NSNSDTrainingManual_AcousticalAmbientMonitoring-508.pdf

Existing Sound Levels

LD831 acoustic data were collected on one day in 2019 to capture the existing sound levels before berm installation. Data were collected at three sites that varied in their distance to the highway. HEHO0006 was closest to the highway (40 m); HEHO008 was furthest from the highway (185 m).

Percentile Metrics

The existing sound levels were reported as three percentile metrics. Day-hour percentile levels were calculated from $L_{Aeq, 1s}$ measurements. The average acoustic condition at HEHO006 was louder than at sites HEHO007 and HEHO008 (Table 3).

Table 3. Percentile sound levels for existing conditions in HEHO at existing highway noise sites, measured with LD831s.

Site	Freq (Hz)	Distance to I-80 (meters)	Percentile Sound Levels (dB)*		
			L_{A90}	L_{A50}	L_{A10}
HEHO006	12.5-20,000	40 m	72	75	78
HEHO007	12.5-20,000	147 m	65	68	70
HEHO008	12.5-20,000	185 m	60	63	66

* $L_{Aeq, 1s}$ in dB re 20 μ Pa (12.5 Hz–20 kHz)

The first percentile metric, L_{A90} , reports the sound level exceeded 90% of the time for the specified time period. This is a preferred metric to quantify the *quietest conditions* (ANSI/ASA S12.18). The average sound level at HEHO006 exceeded 72dB 90% of the time ($n = 4hr$).

The second metric called the median L_{A50} is the sound level exceeded 50% of the time for the specified time period. This level is referred to as the **existing ambient sound level** and is the preferred metric for *chronic conditions*, as it is insensitive to infrequent loud events. The existing ambient sound level at site HEHO006 was 75dB ($n = 4hr$).

The third metric, L_{A10} , is the sound level exceeded 10% of the time for the specified time period. This is a preferred metric to quantify the *loudest conditions* or infrequent loud events. The average sound level at HEHO006 exceeded 78dB 10% of the time ($n = 4hr$).

Measurement differences of 5-6dB separated the quietest conditions (L_{A90}) and the loudest conditions (L_{A10}) at all three sites. The little variation between the percentile metrics suggest that acoustic conditions at sites HEHO006 through HEHO008 are consistent.

Hourly Variation

The median L_{A50} percentile level data reported in Table 3 were broken down by the hour of day to determine which hours contribute more noise than others. HEHO006 was louder at each sampled hour when compared to sites HEHO007 and HEHO008 (Figure 5).

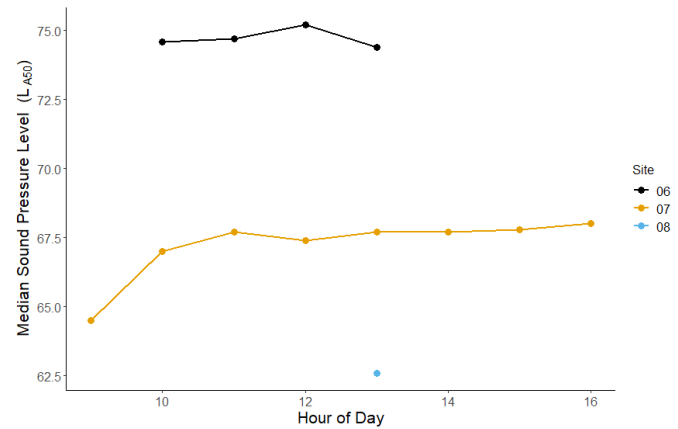


Figure 5: Hourly median L_{A50} percentile sound levels at sites HEHO006 ($n = 4hr$), HEHO007 ($n = 8hr$), and HEHO008 ($n = 1hr$).

Frequency Content

The median L_{A50} percentile level data reported in Table 3 were also broken down into 33 one-third octave band frequencies. High frequency sounds (such as a cricket chirping) and low frequency sounds (such as flowing water) often occur simultaneously, so the frequency spectrum is split into 33 smaller ranges in order to determine what types of sounds are contributing to the overall sound pressure level of a site.

Traffic noise, found in the frequency bands between 12.5 and 1250 Hz, contributed the most energy to the overall sound pressure level at the three highway noise sites (Figure 6). The two L_{50} peaks at 80 and 1250 Hz are likely due to tire and aerodynamic vehicle noise (U.S. DOT Volpe Center, pers. comm., 3/2/2020). Additional investigation during the planned 2021 monitoring trip is necessary to provide further interpretation of the frequency data.

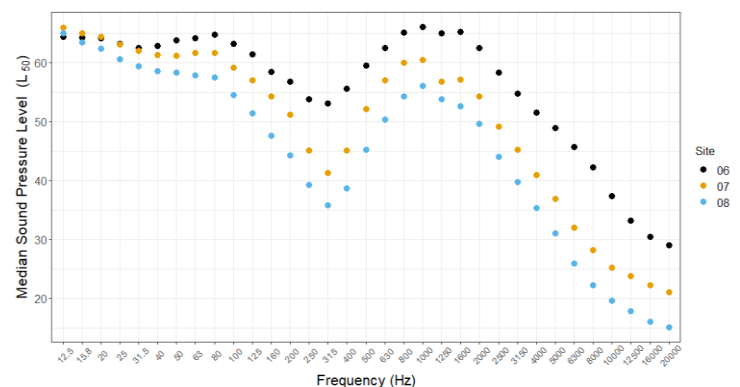


Figure 6: Median L_{50} percentile sound levels at each frequency band at sites HEHO006 ($n = 4hr$), HEHO007 ($n = 8hr$), and HEHO008 ($n = 1hr$).

Note: The microphone at HEHO006 experienced signal overloads when recording frequency band measurements. The microphone overloads likely resulted from bursts of loud sounds outside of the range of the microphone. The broadband measurements (Table 3) are

unaffected by these overloads. The potential error created by the frequency band overloads will not impact the direct comparison of frequency content between years because we are comparing the same site measurements with the same equipment.

Existing Bioacoustic Activity

Reduced noise, and perhaps microhabitat changes caused by the berm, could affect the bioacoustic chorus in several ways. Changes in the species composition, changes in calling rates, and changes in diel patterns of calling could occur. Accordingly, analyses of before-after patterns will likely utilize methods that detect and identify specific sounds. Though exploratory analyses using specific detectors is underway, this report will utilize a generic index of bioacoustic activity to confirm that these recordings will yield pertinent results.

The **Acoustic Complexity Index** (ACI) is an algorithm created to produce a direct quantification of the complex biotic songs present in a recording. ACI represents the variability of the intensities registered in audio-recordings, despite the presence of constant human-generated-noise.⁴ High values indicate a variety of signals are present; low values indicate constant (e.g. wind) or minimal signals present.

The bioacoustic site sound level data were recorded as WAV audio files. To calculate ACI, the WAV files were converted to calibrated 1-sec $\frac{1}{3}$ octave band sound pressure levels based on the system specifications and saved in NPS format, NVSPL.⁵ ACI was calculated from the NVSPL files using NVSPL to Acoustic Indices output scripts.⁶

Each NVSPL file was divided into 10-minute samples and ACI was calculated for each sample. Visual and audio analysis⁷ of the data was conducted to determine the frequency range of background noise (vehicle noise) and bird calls. Based on this analysis, the input parameters for the NVSPL to AI scripts were set to capture all bird calls from 1.6 kHz to 16kHz and background noise from 25 Hz to 16 kHz.

Site Variation

Median ACI values were similar across sites with little variation between sites (Figure 7). Median ACI values ranged from 6.0 at site HEHO005 to 7.5 at site HEHO003.

Large outlier ACI values were observed at several sites, including HEHO001, HEHO003, and HEHO004.

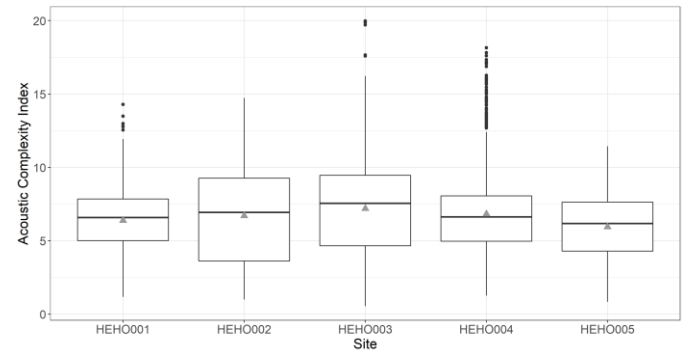


Figure 7: Acoustic complexity across all 2019 bioacoustic sites. From the bottom of the y-axis to the top, each box plot displays the minimum, first quartile, median, third quartile, and maximum respectively. Black data points represent outlier values. Grey triangles represent mean ACI values at each site.

To investigate the outlier ACI data, the five highest and lowest ACI values were extrapolated and then examined by listening to the corresponding audio clip to confirm the accuracy of the ACI values.

Initial analysis confirms that the five largest ACI values resulted from high bird call occurrence. The maximum ACI value was 20.0 and occurred at site HEHO003 on June 17 from 0620 to 0630 (Figure 8).

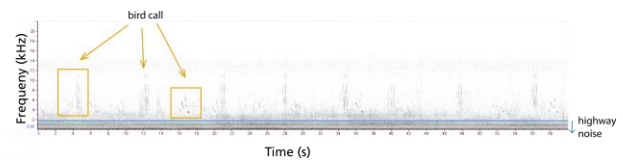


Figure 8: Sample (0620 to 0621) of the 10-minute audio clip recorded at site HEHO003 on June 17 from 0620 to 0630. Yellow boxes show two of the many bird calls present in the spectrogram. The area below the blue line represents highway noise.

The five lowest ACI values resulted from audio samples with zero or low bird call occurrence. The minimum ACI value was 0.6 and occurred at site HEHO003 on June 13 from 0410 to 0420 (Figure 9).

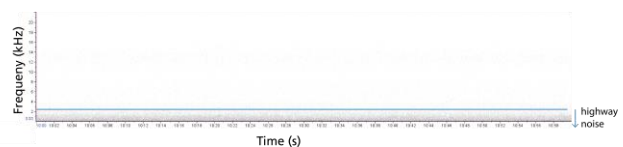


Figure 9: Sample (0410 to 0411) of the 10-minute audio clip recorded at site HEHO003 on June 13 from 0410 to 0411. No bird

⁴ Pieretti, N., Farina, A., & Morri, D. (2011). A new methodology to infer the singing activity of an avian community: The Acoustic Complexity Index (ACI). *Ecological Indicators*, 11(3), 868-873.

⁵ code available on [GitHub](https://github.com/PAMGuideSongMeterToNVSPL): PAMGuideSongMeterToNVSPL. Merchant et al. (2015). Measuring Acoustic Habitats. *Methods in Ecology and Evolution*, 6(3), 257-265.

⁶ Buxton, R. T., Brown, E., Sharman, L., Gabriele, C. M., & McKenna, M. F. (2016). Using bioacoustics to examine shifts in songbird phenology. *Ecology and evolution*, 6(14), 4697-4710.

⁷ Raven Pro 1.5, Cornell Lab of Ornithology.

calls are present. The area below the blue line represents highway noise.

Hourly Variation

When examined by hour, median ACI values were consistent across hours 5 (ACI = 7.8), 6 (ACI = 7.4), and 7 (ACI = 7.1; Figure 10). In comparison, median ACI values were lower in hour 4 (ACI = 3.0). Based on initial analysis of the audio data, bird calls were mostly absent in hour 4 and the dawn chorus began in hour 5.

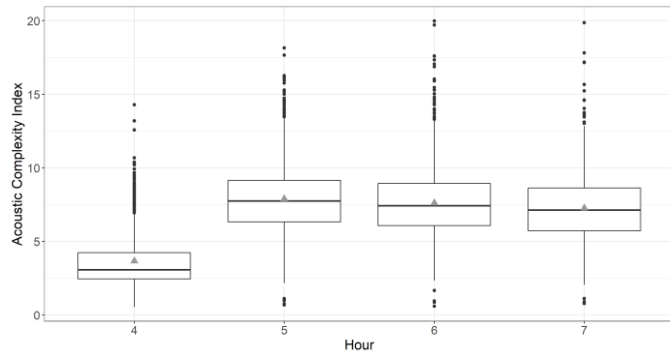


Figure 10: Acoustic complexity across all sampled hours. Grey triangles represent mean ACI values at each hour.

Sampling Period Variation

Finally, ACI values were also similar across the 30-day sampling period, with an increase in large outlier ACI values in the second half of the sampling period. Median ACI values ranged from 4.4 on July 1 to 8.4 on June 2 (Figure 11). We will conduct additional audio analysis to determine trends in this data and the variation in species-specific bird calls over the sampling period.

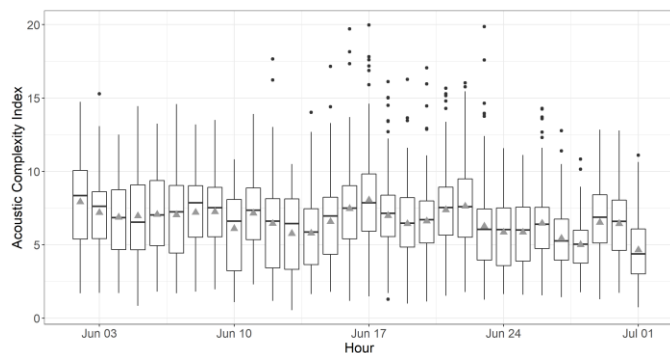


Figure 11: Acoustic complexity across all sampled days. Grey triangles represent mean ACI values at each day.

Next Steps

- NSNSD will continue to analyze the bioacoustic data in order to detect individual bird calls. This species-specific data will be summarized, compared to post-berm installation bioacoustic data, and presented in a final report.

- Field work is planned for year 2021 to measure sound levels and bioacoustic activity behind the newly constructed berms.

More Information

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