



Acoustic Conditions during Interpretive Programs at Tusayan Ruins and Museum: A Pilot Study

NPS Report No. GRCA-08-01
Laura Levy and Sarah Falzarano
Soundscape Program
Science and Resource Management
Grand Canyon National Park
April 18, 2008

Introduction

Air tours fly within one to two miles of the Tusayan Ruins and Museum (Figure 1) on their way to view the Grand Canyon. NPS rangers have noted instances of aircraft noise interfering with interpretive talks at the Tusayan Museum. Specifically, the rangers sometimes needed to raise their voices or paused speaking because aircraft sounds caused speech interference. Acoustic data was collected on October 3rd, 2007, during the 11:00 am and 1:30 pm interpretive ranger talks at the Tusayan Ruins and Museum. Although October is not a peak month for visitation at the Tusayan Ruins or air tours over the canyon, this preliminary study provides a description of the sound conditions during interpretive programs at the Tusayan Ruins and Museum.

Methods

A hand-held acoustic system was used to collect sound pressure level (SPL) data every second. The system consisted of a Larson-Davis sound level meter (model 824; powered by AA batteries), a microphone (GRAS 40AE; protected by a foam windscreen) and a preamplifier (Larson-Davis 902). The sound level meter was kept about 5 meters from the ranger during the programs at a height of ~1 meter. The talks at Tusayan Ruins and Museum start inside the museum where the ranger orients the visitor and discusses the artifacts housed in the museum. After 10-15 minutes the tour moves outside to the ruins where the rangers stop at two locations. The total program length is about 40 minutes. Concurrent observer logging occurred close to the sound level meter to document sound sources. Non-natural sound sources were logged (aircraft and vehicles) and times were noted when the tour moved from indoors to outdoors, when the ranger and visitors were walking and when aircraft sounds interfered with the interpretive program. Rangers Glenn Reynolds led the 11:00 am talk and Kris Bowline conducted the 1:30 pm talk.

The SPL and observer logs were used to determine average, maximum, and the range of sound levels during the interpretive programs. The data were plotted as spectrograms which display frequency (Hz) on the y-axis, time (minutes) on the x-axis, and amplitude (decibels) in color. Different sound sources have their own signatures which make spectrograms a useful tool to display sound sources.

Definitions (Courtesy of the Natural Sounds Program)

Audibility: The ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, other simultaneous interfering sounds or stimuli, and by the frequency content and amplitude of the sound.

Decibel (dB): A logarithmic measure of sound. The decibel provides the possibility of representing a large span of signal levels in a simple manner as opposed to using the basic unit Pascal. The difference between the sound pressure for silence versus a loud sound is a factor of 1,000,000:1 or more, therefore it is less cumbersome to use a small range of equivalent values: 0 to 130 decibels.

A-Weighted Decibel (dBA): A-weighting de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of human hearing.

Frequency: The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz). Frequency equals speed of sound/wavelength.

L_{max} and L_{min}: The maximum and minimum sound pressure level for a given period.

Octave: The interval between two frequencies having a ratio of 2:1.

One-third octave band: A frequency band whose cutoff frequencies have a ratio of 2 to one-third (approximately 1.26). Humans have the ability to differentiate one-third octaves.

Sound Pressure Level (SPL): The logarithmic form of sound pressure. In air, 20 times the logarithm of the ratio of the actual sound pressure to a reference sound (20 micropascals, the assumed threshold of human hearing).

Results

Potentially interfering sounds of propeller planes, helicopters, jets and automobiles were heard only during the outside portion of both interpretive programs measured on October 3rd, 2007 (Table 1). Fewer aircraft and automobiles were heard during the later talk, but this may have been a function of the increased wind which can mask distant or quiet sound sources.

Automobile sounds originated from both the parking lot at the Tusayan Museum and from Desert View Drive (less than 0.25 miles away). Potentially interfering sounds were heard an average of 47.4% during the outside portion of the programs. The interpretive ranger raised his voice only once because of a loud passing helicopter (audible from 11:26:37 to 11:28:53) during the 11:00 am talk.

Table 1. Percent time audible of potentially interfering sound sources, outside portion of program.

Sound Source	11:00 am Program	1:30 pm Program	Average
Propeller plane	9.5	9.9	9.7
Helicopter	19.8	10.4	15.1
Jet	1.5	2.3	1.9
Automobile	20.5	22.8	21.7
Total potentially interfering sounds	51.4	43.4	47.4

The average dBA for the inside portion of the talk was 55.9 dBA (Table 2). Once outside, the average dropped to 48.5 dBA. The higher SPL values collected indoors are likely due to the enclosed area of the museum causing refraction and reflection of sound in contrast to the outdoors where the sound of voices dissipates. The maximum SPL (L_{max}) for the 11:00 am talk, 70.9 dBA, occurred during the first minutes of the talk while the talk was still indoors. The L_{max} of the 1:30 pm talk, of 74.7 dBA, also occurred during the indoor portion of the talk. The one-third octave frequency bands associated with the maximum sound levels are listed in the Appendix.

Table 2. Decibel levels for the 11:00 am and 1:30 pm interpretive programs.

	11:00 am Program	1:30 pm Program	Average
Average decibel level indoors (dBA)	57.0	54.8	55.9
L _{max} indoors (dBA)	70.9	74.7	NA
Range of indoor sound levels (dBA)	43.1 – 70.9	43.8 – 74.7	NA
Average decibel level outdoors (dBA)	48.7	48.3	48.5
L _{max} outdoors (dBA)	69.0	65.2	NA
Range of outdoor sound levels (dBA)	33.2 – 69.0	35.6 – 65.2	NA

Spectrograms of the interpretive programs (Figures 2 and 3) show the ranger's voice in yellow (about 60 dBA) between 125 and 4000 Hz (shown within brackets). At about 9 minutes into the 11:00 am talk when the tour moves outside, the signature of the ranger's voice is less prominent. Attenuation causes a lower dBA level to reach the receiver. In addition, other sound sources (wind, helicopter, automobiles) become more prominent in the lower frequency range. Helicopter sounds (in squares) occur at lower frequencies (~12.5 to 125 Hz) and have a corkscrew shape signature. Propeller plane sounds (in circles) occur at slightly higher frequencies (between 80 and 250 Hz) and have a stair-shaped signature. Automobiles starting, idling, and horns (in diamonds) in the museum parking lot appear to have a similar frequency range to propeller planes. Cars and buses traveling on Desert View Drive, although heard during the data collection, are at low SPL levels and are masked by other sounds on the spectrograms. Wind appears as sharp spikes at low frequencies (12.5 to 80 Hz). The increased wind during the second session obscures the signature of the helicopter at about 34 minutes. The sounds of the propeller planes are not obscured by the wind because they occur at higher frequencies.

Discussion

During data collection of the two interpretive programs, there was only one instance of aircraft interference, when the ranger needed to raise his voice in order to be heard over helicopter sounds. Although numbers of tour flights for 2007 have not been reported as of the date of this report, data from 2003 are available. In 2003 the month of October had 80% of the flights that occurred in August of that year (approximately 2000 less flights). Because the frequencies of the aircraft and the rangers' voices only overlap in the 125-250 Hz range, it is hard to pinpoint the decibel level at which aircraft sounds would cause interference with the human voice. Other factors such as wind, number and proximity of aircraft, and the specific frequency range and amplitude of the ranger's voice would also contribute to the decibel level at which interference would occur.

While automobiles were audible more of the time than helicopters or propeller planes, cars on Desert View Drive were at low SPL levels, making them hard to discern on the spectrograms. Potentially interfering sounds include loud automobile (horns, vehicles starting or idling) and aircraft events, which appear on the spectrograms in yellow. Loud motorcycles or other louder vehicles (common during warmer weather) would likely cause speech interference.

Future acoustic data collection at this site should occur over a longer period of time and during summer months when visitation at the Tusayan Ruins and Museum is high and the number of daily air tours and vehicular traffic are at their peak. Collecting continuous recordings (an option not previously possible) to accompany the SPL data would also be useful for future data analysis.

Acknowledgements

Thanks to Rangers Glenn Reynolds and Kris Bowline for allowing us to collect acoustic data during their interpretive programs, and to Lisa Collins for background information and scheduling data collection.

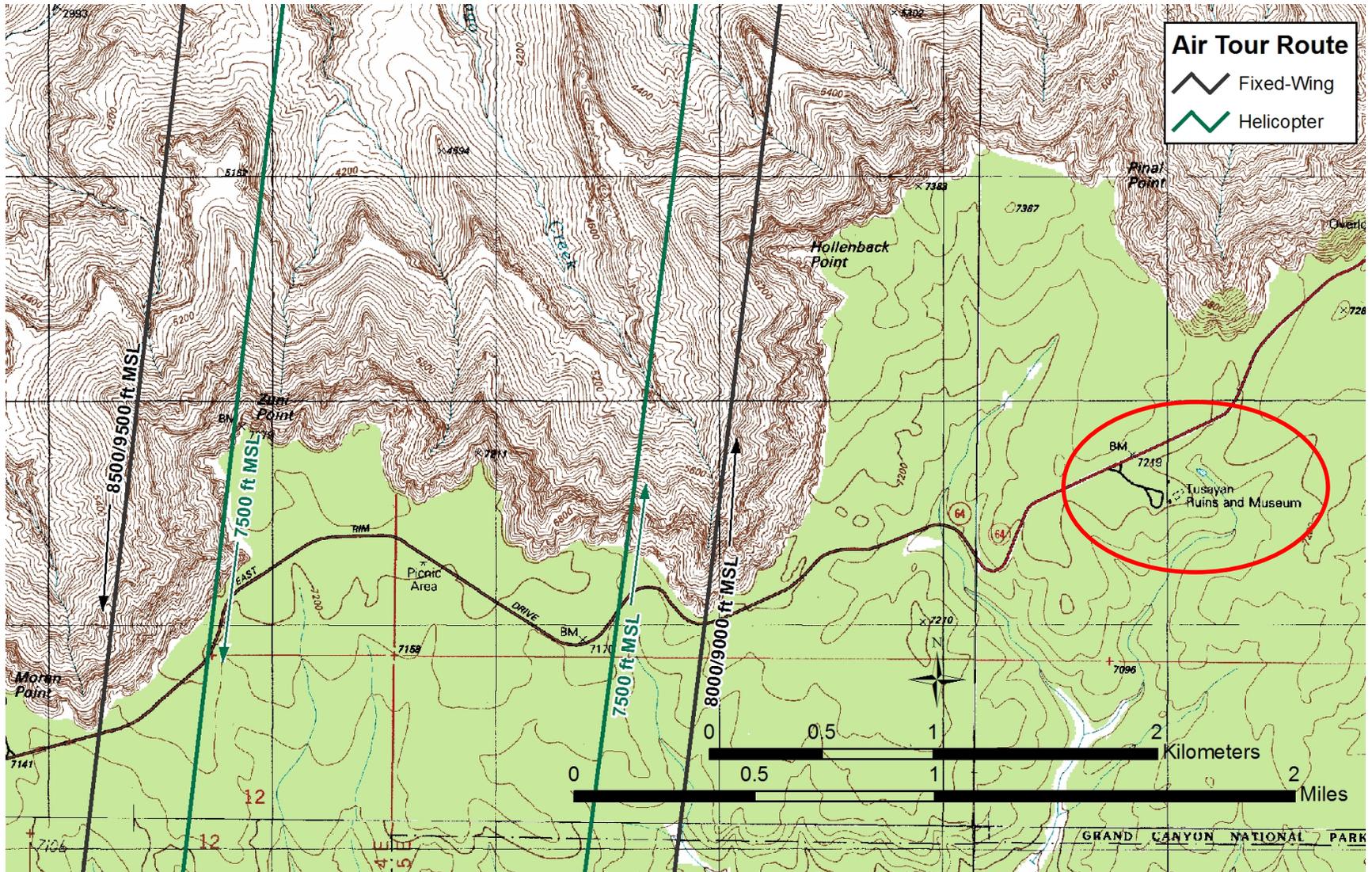


Figure 1. Air tour routes are 1¼ miles (±½ mile) from Tusayan Ruins and Museum (circled).

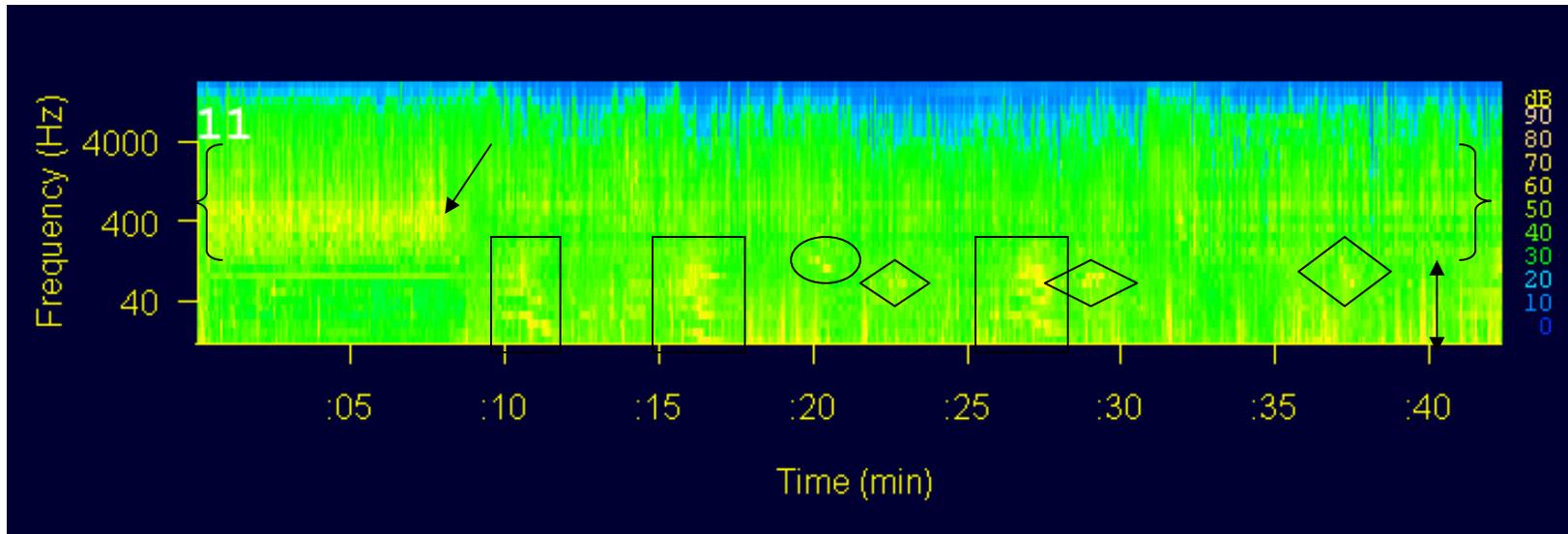


Figure 2. Spectrogram of SPL data from 11:00 am talk. Brackets mark the range of the interpretive ranger's voice, one-sided arrow indicates when the tour moved outdoors, rectangles outline helicopter signatures, circle outlines propeller plane, diamonds indicate automobiles, wind is marked by two-way arrow.

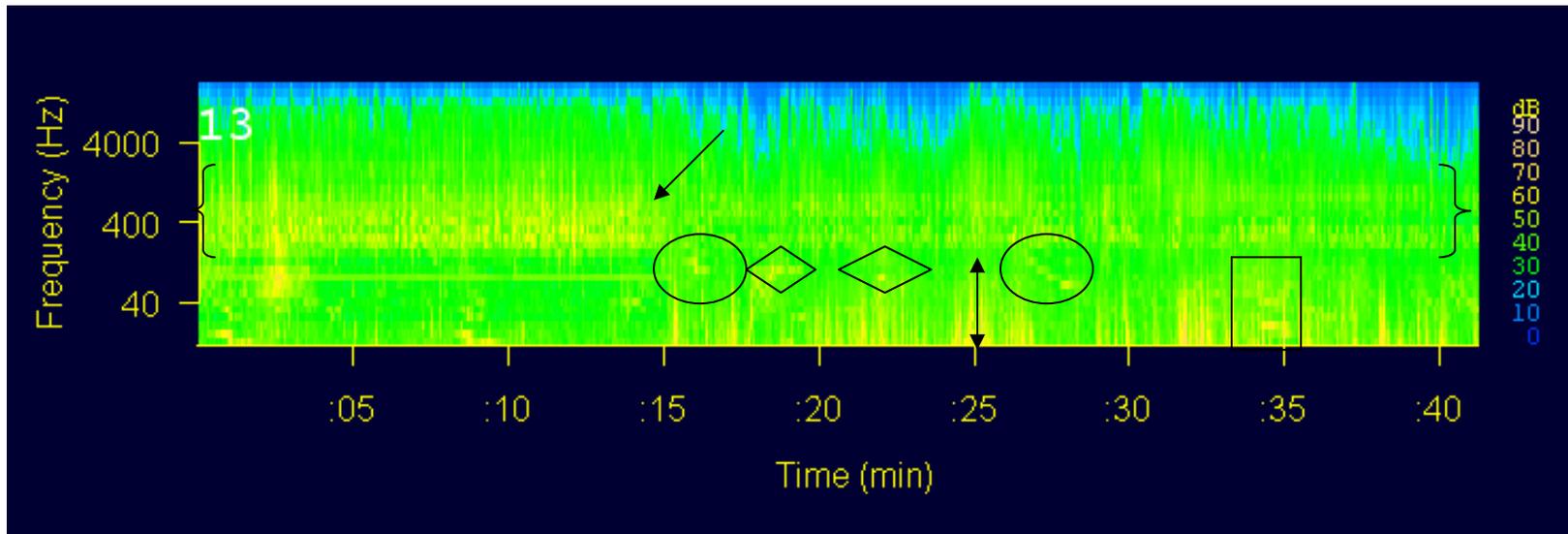


Figure 3. Spectrogram of SPL data from 1:30 pm talk. Brackets mark the range of the interpretive ranger's voice, one-sided arrow indicates when the tour moved outside, rectangle outlines helicopter signatures, circles outline propeller planes, diamonds indicate automobiles, wind is marked by two-way arrow.

Appendix

Overall sound pressure level (dBA) and SPL for each 1/3 octave band frequency for the maximum SPL (L_{max}) of the indoor and outdoor portions of the two interpretive programs.

Frequency	11:00 am Program		1:30 pm Program	
	L_{max} Indoors	L_{max} Outdoors	L_{max} Indoors	L_{max} Outdoors
dBA	70.9	69.0	74.7	65.2
12.5	37.3	35.5	44.7	57.7
16	37.6	43.7	42.8	57.8
20	34.2	43.9	43.7	53.7
25	29.1	42.8	42.6	52.9
31.5	26.2	41.2	47.2	49.1
40	30.1	42.7	50.5	47.9
50	29.1	43.2	59.5	49.1
63	29.6	40.1	56.6	44.9
80	44.5	42.0	53.3	40.4
100	27.7	44.6	53.9	36.8
125	41.1	38.9	43.4	38.2
160	56.7	43.5	54.1	41.8
200	60.9	37.9	61.4	47.4
250	55.9	36.5	68.7	59.2
315	63.3	50.4	58.2	60.2
400	72.8	58.3	56.7	39.8
500	66.2	47.4	63.9	56.9
630	61.5	59.3	67.3	62.8
800	54.2	69.3	71.7	59.4
1000	53.9	49.3	62.9	55.7
1250	48.8	43.7	60.5	42.5
1600	55.7	44.5	63.4	47.9
2000	57.5	41.2	62.3	53.2
2500	52.9	45.5	61.7	45.7
3150	52.1	42.5	58.4	42.2
4000	42.8	38.6	48.1	40.6
5000	39.9	37.5	45.3	35.1
6300	40.8	38.4	50.1	31.6
8000	38.9	37.7	47.7	31.4
10000	35.6	32.7	39.3	31.2
12500	30.7	29.0	35.7	26.5
16000	25.1	19.8	27.9	19.7
20000	18.6	12.9	19.8	14.3