NATURAL AMBIENT SOUND SAMPLE SITE SELECTION

Grand Canyon National Park

Overflights and Natural Soundscape Program

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Introduction

The 1987 Overflights Act mandated that Grand Canyon National Park (GCNP) substantially restore natural quiet to the Park. In 1994, the NPS defined "substantial restoration of natural quiet" to mean that 50% or more of the Park has no aircraft audible for 75 to 100% of the day, each and every day. Natural ambient sounds can mask aircraft noise. Therefore, natural ambient sounds of the Park must be measured and quantified to determine the baseline above which aircraft noise is audible.

Natural ambient sounds vary by vegetation community and terrain features. Different vegetation communities attract different birds, insects, and other wildlife, which have different sounds associated with them. They also respond to physical processes such as wind, snow, and rain with different natural sounds. A balance between too many and too few vegetation classes must be struck. Too many classes result in an enormous field data collection effort; too few classes do not separate significantly different natural ambient sound level classes from each other. The objective of this report is to provide information on the methods and materials used to select representative sites in GCNP for natural ambient sound data characterization.

Methods

Selection of a Vegetation Map

Several vegetation community maps exist for GCNP. They were assessed for suitability based on the following criteria: thematic resolution, spatial resolution, and familiarity with the map.

Thematic resolution refers to the type of vegetation classification. Due to the high wind noise associated with vegetation structure, a classification that incorporates vegetation structure and height is most appropriate. For example, a classification that distinguishes between a forest and shrubland is more valuable than a classification that combines forests with shrublands. In addition, the pinyon-juniper habitat is an important vegetation type at GCNP, and should be discernable in the vegetation classification.

Spatial resolution refers to the scale for appropriate use of the map. Some maps are made of the whole nation, and thus have a coarse scale if being applied to a smaller area like GCNP. A scale finer than 1:100,000 is desirable for use in this project.

Familiarity with the map is important for assessing accuracy and determining the proper way to combine classes. The strengths and weaknesses of the candidate maps were determined by feedback from Natural Resource Management Specialists, Fire Ecologists, and Exotic Plant Management staff who often use these maps in their daily work.

The following vegetation maps were evaluated for use in selecting sampling sites for natural ambient sound data collection at GCNP:

1. *Küchler's Potential Natural Vegetation* map as revised by the USDA Forest Service (Schmidt et al. 2002). This map has one kilometer grid cells making it usable at a 1:1,000,000 scale or coarser. It classifies 72% of the Park as pinyon-juniper, including most of the below the rim vegetation, which is incorrect. Its spatial and thematic resolutions are too coarse for use in this project.
2. *1992 National Land Cover Dataset* (Vogelmann et al. 1998). This map is derived from early to mid-1990s satellite imagery (Landsat 5 Thematic Mapper). Its 21-class land cover classification scheme is based on an Anderson classification (1976) applied consistently over the United States. The spatial scale appropriate for use is 1:100,000. The thematic resolution is not appropriate for use in this project because pinyon-juniper was sometimes classified as a shrubland and sometimes as an evergreen forest.
3. *2001 National Land Cover Dataset* (Homer et al., 2004). This map is incomplete for the Grand Canyon region.
4. *Arizona Gap Analysis Project Vegetation Map* as modified by Halvorson et al. (2001). This map was made from supervised and unsupervised classification of satellite imagery (Landsat 5 Thematic Mapper), mostly from 1991. It is a 1:100,000 scale map of Arizona, using a modified Brown, Lowe, and Pase (1979) classification system. The spatial and thematic scales are reasonable for use in this project, but the map's accuracy is low, and it is not used by Park staff.
5. *Provisional Digital Landcover Dataset for the Southwestern United States* (Utah State University 2004). This map was created by using a regression type of modeling with 1999-2001 satellite imagery (Landsat 7 Enhanced Thematic Mapper Plus) and National Elevation Dataset information. It is a 1:100,000 scale map of Arizona, Nevada, Utah, Colorado, and New Mexico. The classification is a modification of Ecological Systems (Comer et al. 2003), which are recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. Due to the provisional nature of the map and the Park's lack of familiarity, it was not chosen for use in this project.
6. *Vegetation of Grand Canyon National Park* (Warren et al. 1982). This map (the Warren map) was created from interpretation of aerial photographs taken in 1978 and 1980. It is a 1:62,500 scale map using a modified Brown, Lowe, and Pase (1979) classification system. The map is commonly used for resource studies in the Park, and was selected for use in this project.

Vegetation Classification

The Warren map contains 68 vegetation association classes for GCNP. Many of these classes occur at similar elevations, have similar vegetative structures, and were assumed to have similar natural ambient sounds. Working with vegetation specialists, the classes were lumped into dominant vegetation types to optimize field data collection efforts, while capturing the variability of natural ambient sounds between classes. The NPS concluded that sampling six to eight classes would effectively document significant characteristics in the natural ambient character of each class while capturing significant differences between the classes.

The 68 classes of the Warren map were grouped into seven classes (Table 1 and Figure 1). Four of these classes, ponderosa pine, pinyon-juniper, warm desert scrub, and cold desert scrub, make up over 96% of the Park area, and are the focus for the first field data collection effort. The other 4% of the Park consists of important riparian, high elevation forest, and grasslands. Because they are a relatively small part of GCNP, they will be the focus of future data collection efforts.

Table 1. Major vegetation classes for Grand Canyon National Park.

Class	Description	Characteristic species	% of Park[1]
Mixed Forest	Higher elevation conifer forests	spruce, fir, Douglas-fir, aspen	2.1
Ponderosa Pine	Pure and mixed stands of ponderosa pine typical of mid to high elevation forests.	ponderosa pine, gambel's oak	7.9
Pinyon-Juniper	Mixed stands of mid-elevation shrublands and woodlands.	pinyon, juniper, scrub oak	32.9
Cold Desert Scrub	Often referred to as the Great Basin Desert. Mid-elevation desert scrub typically above the rim with limited species diversity.	big sagebrush	37.5
Warm Desert Scrub	Often referred to as the Mojave and Sonoran Desert. Low elevation desert scrub typically found below the rim with high species diversity.	blackbrush, Mormon tea, yucca, cactus	18
Grassland	Both high elevation meadows and mid-elevation altered grasslands	black gramma, cheatgrass	0.65
Riparian	Vegetation located close to rivers and streams.	Cottonwood, willow, tamarisk	0.31

[1] The percentages do not add up to 100% of the Park area because the river corridor and Kanab Point area were not mapped.

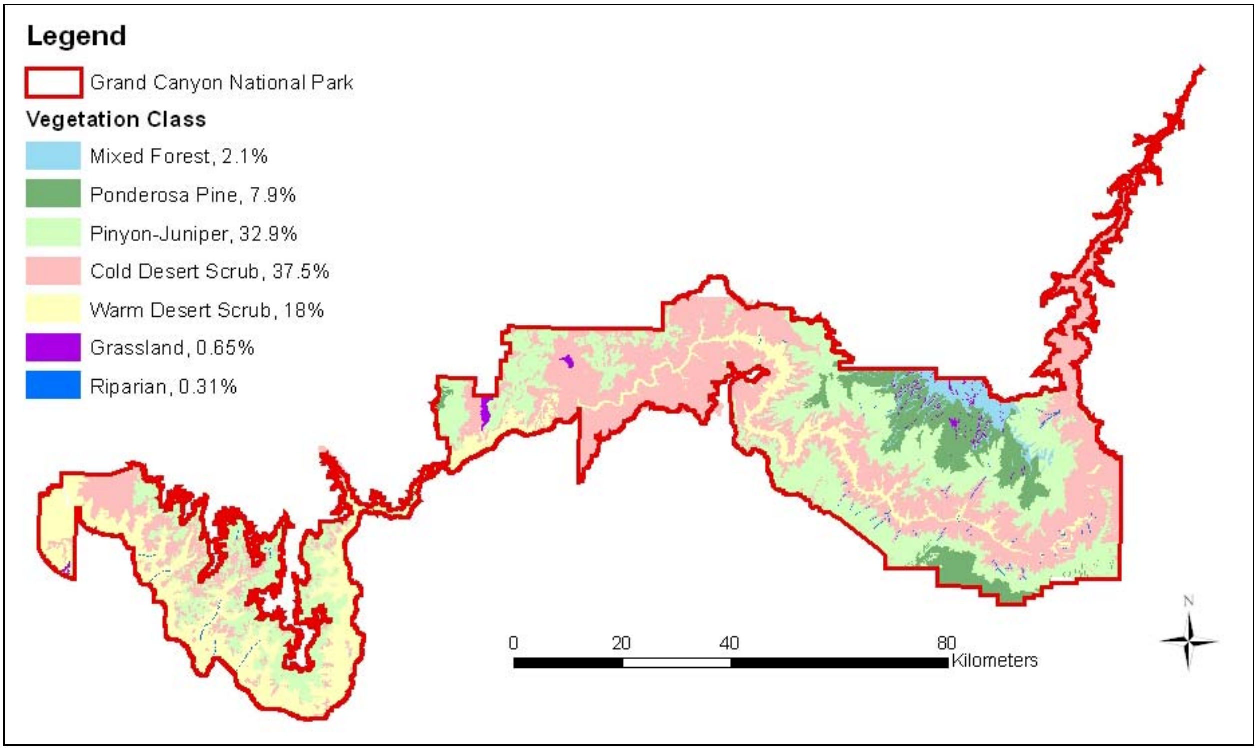

Figure 1. Vegetation classes based on Warren map.

Equipment and Data Collected

Acoustic measurement equipment meets ANSI/IOC Type 1 standards (Figure 2). A microphone passes information to a Sound Level Meter that translates the signal to decibel levels for each frequency (sound spectra) every second. The microphone also passes information to a laptop that makes periodic recordings for latter use to identify noise sources. The system is designed to be left in the field for months at a time; it is powered by 12 Volt gel cell batteries and recharged by solar panels. However, the systems are checked every two weeks for operational problems, to download data, and conduct one hour of observer logging to identify noise sources. Table 2 identifies the data collected at each site. Each system weighs over 100 lbs and costs more than $20,000. Four systems are available for use in this project, making placement of one system in each of the four primary vegetation classes feasible.

Figure 2. Sound data collection equipment. The laptop, sound level meter, and gel cell batteries are underneath the solar panels.

Table 2. Data collected at each sample site.

Type of Data	Description and Frequency of Collection
Sound Pressure Level Data	1-second dB for ⅓ octave bands, 20-20,000 Hz
	1-second L_{eq} dBA
Digital Recordings	10 second recordings every two minutes
	recordings of loud events
Observer Logging	One hour every two weeks

Sample Site Selection

The following constraints affected the selection of sites for collection of natural ambient sound levels:

- Absence of human-caused noise. The sound systems were placed in remote areas of the Park, away from human noise sources (paved roads, viewpoints, train tracks, etc.) wherever possible. These places tend to correspond with backcountry use areas of the Park, as defined in the Park's management zones.
- Accessibility for instrument placement and servicing. Due to the weight of the systems, and the fact that they are checked every two weeks, accessible sites are desirable.
- The extreme topography of the Park and limited road access. Eighty-two percent of the Park is managed as wilderness, where motorized vehicles and mechanized equipment are limited or prohibited. This fact further limited potential sample sites.

GIS was used to identify potential sampling areas using the vegetation classes, management zone, airports, air tour routes, roads, and topography. Proximity to administrative and lesser-used public roads was desirable for ease of access with the heavy equipment and the servicing schedule. Avoiding air tour routes and airports is necessary to avoid excessive human-caused noise. A one mile buffer around roads and five mile buffer around air tour routes and airports (Figure 3) was established for the site selection process. Expert knowledge of the Park terrain, visitation, and site access ultimately determined the sample locations for each primary vegetation class. During visits to potential sites, vegetation type was assessed and specific sites were selected that represented the vegetation classes.

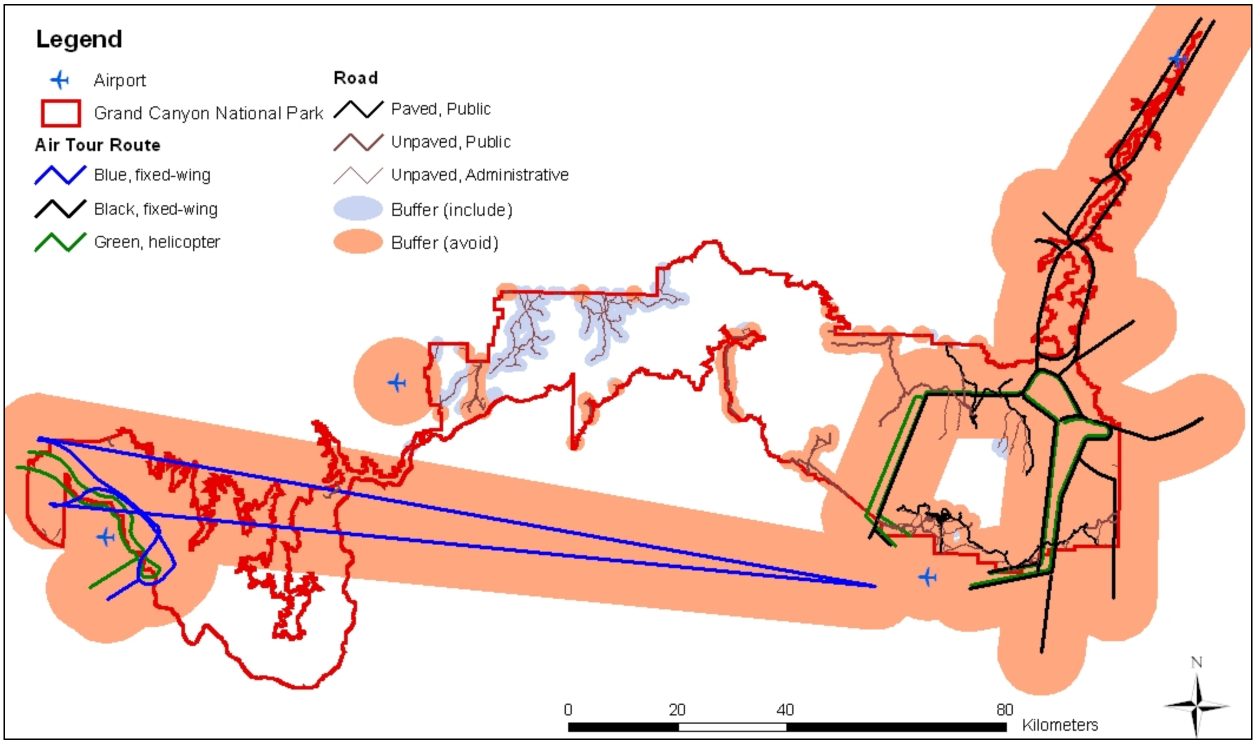

Figure 3. Sample sites are located away from airports, air tour routes, and public roads, but close to administrative roads.

Temporal Sampling

Natural sounds vary by time of day, season, weather, and other variables. Collection of longterm data is necessary to capture the variability of natural sounds. Since a change of 3 dBA is noticeable by a person of normal hearing engaged in an activity other than attentive listening (Brüel & Kjær 2000), the NPS will strive to collect data that is repeatable within ±3 dBA between sampling periods. Analysis of several year-long datasets (NPS 2005) at nearby Parks show that summer and winter natural ambient sounds are significantly different from each other, and that a minimum sampling period of 25 days in each of those two seasons are required.

Previous natural ambient sound characterization for GCNP relied on a few hours or days of data collected at several locations in the east end of the Park to characterize natural ambient sounds for the entire Park. During the current effort, we will have systems in each of the four primary vegetation classes for an entire year which will give us a large dataset to characterize natural ambient sounds. Finally, the efforts will verify the assumption that a minimum of 25 days in summer and 25 days in winter are sufficient to accurately characterize the natural ambient sounds of GCNP.

Natural ambient sounds for summer and winter will be characterized for the time period between 7:00 am and 7:00 pm to correspond with typical seasonal daylight hours and air tour activity. The natural ambient sounds for winter will be characterized for the time period between 8:00 am and 5:00 pm for the same reasons.

Results

Two sites in the Tuweep/Toroweap area of the Park were selected to collect natural sounds in the warm desert scrub (Figure 4) and cold desert scrub (Figure 5) vegetation types. One site in the Pasture Wash area was selected to collect natural sounds associated with the pinyon-juniper type (Figure 6). One site on the South Rim was selected to collect natural sounds in the ponderosa pine type (Figure 7). A few of our sampling sites are close to public roads; however, the roads are used very infrequently, and the sample sites are protected from road noise by terrain features.

Figure 4. Warm desert scrub sample site.

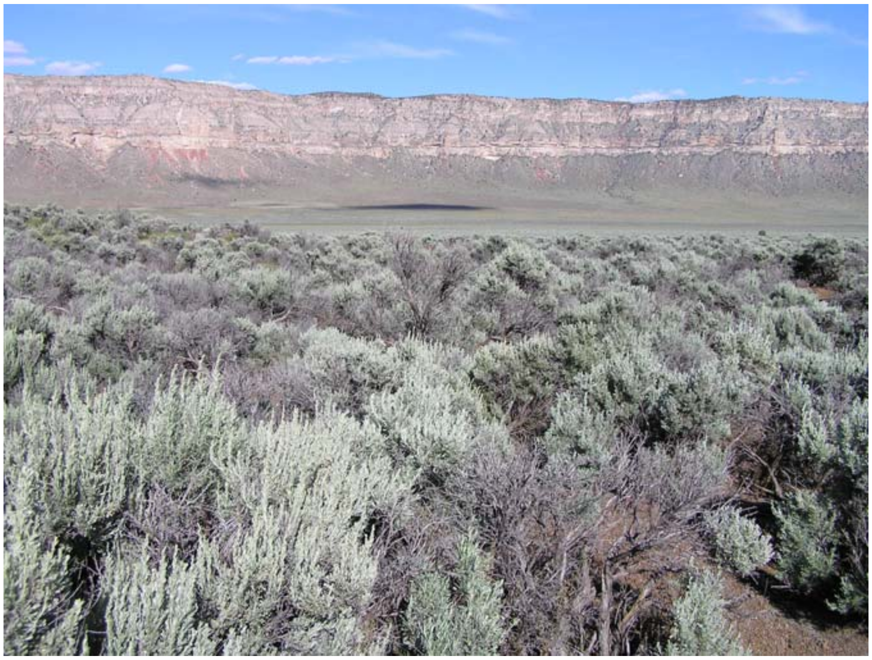

Figure 5. Cold desert scrub sample site.

Figure 6. Pinyon-juniper sample site.

Figure 7. Ponderosa pine sample site.

Calculation of Natural Ambient Sound Levels

The data from all of the sample sites in this study will contain natural and non-natural (aircraft and human noise) sounds. The most appropriate estimator of natural ambient sound levels is the median of data without the influence of human-caused sounds. The following description on calculation of natural ambient levels is based on the Draft NPS Acoustics Manual (National Park Service 2005).

Acoustic data in rural or park-like settings are rarely normally distributed. In many backcountry areas of parks, sound pressure levels are relatively low (15 dBA to 30 dBA), with occasional loud events such as thunder or aircraft. On a graph of decibel level vs. frequency of values, these types of data are generally skewed towards the infrequent but much louder sounds. As a result, it is inappropriate to use the arithmetic mean to characterize the central tendency of the data. The median is the most appropriate measure of central tendency for data that are not normally distributed.

The median of the natural sounds data will be calculated using the percent exceedence (L_x) concept. L_x refers to the sound level (L), in decibels, exceeded *x* percent of the time. The L_{50} value represents the sound level exceeded 50% of the measurement period, and is the same as the median. If the dataset contains only natural sounds, L_{50} is the appropriate metric to characterize the natural sound levels. However, even in remote areas, non-natural sounds are audible.

It is not feasible to physically remove all human-caused sounds from long-term data sets. The most practical method to estimate the natural ambient sound level is to listen to a sample of recordings made throughout the time of interest and determine what percent of the time non-natural sounds are audible. The decibel dataset is ordered from loudest to quietest and, assuming non-natural sounds are the loudest sounds, the percentage determined above is removed from loud end of the decibel dataset. The median of the remainder represents the natural ambient sound level.

For example, if non-natural sounds are audible for 40% of the time at our cold desert scrub sample site, L_0 to L_{40} corresponds to the non-natural sounds, and L_{40} to L_{100} corresponds to natural sounds. The median of L_{40} to L_{100} is L_{70}. Therefore, the decibel value at L_{70} would be used to characterize the natural ambient sound level of cold desert scrub.

A shortcoming of this approach is that some loud natural sounds, such as thunder and wind, could be removed from the data before natural ambient sound levels are calculated, and thus the result would be biased low. However, such events in nature are rare, particularly relative to the length of the measurement period, and thus removing these data would not have a significant impact on calculations of natural ambient sound levels.

Conclusion

The data collected and analyzed from these four sites will characterize the natural ambient sound levels for 96% of GCNP. The data will be used in noise modeling to assess the spatial nature of aircraft noise, and to ultimately determine if the NPS is meeting the goal of 50% or more of the Park being naturally quiet 75% or more of the day.

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