# Introduction to Metrics in Acoustic Data Collection

## *INTRODUCTION*

Acoustic data collection supports two different phases of management: 1) finding out about current conditions, or inventory; and 2) monitoring conditions in order to detect changes, relative to some baseline or standard. Collecting data purposefully as an aid to management requires planning. This paper discusses acoustic data, or soundscape, inventory as an element of soundscape management planning, and introduces the metrics used in acoustic science.

## *Relationship of Resource Inventory to Planning*

As an initial step in planning, it is necessary to determine the existing soundscape condition. Inventorying resources can help determine baseline conditions, from which planners would evaluate potential changes due to proposed management activities. For soundscape management planning, an inventory of soundscape resources represents the affected environment in either an EA or EIS through which alternative plans would be evaluated against the need to restore or enhance the natural soundscape. It is the basis for determining what human-caused sounds (both types and levels) are consistent with park resources and values, and what sounds are deemed to be inappropriate. Development of an inventory is normally a short-term process of finding out what resources are located where, and measuring the extent to which those resources are vulnerable to management activities or other park uses.

In order to match planning goals or objectives with the means for measuring soundscape resources, and effects on them, the development of techniques and use of metrics must translate to terminology used in the objectives. Conversely, objectives must be formulated in terms that can be measured using available means. A common language is needed for the inventory (and monitoring) of soundscape resources so that alternative effects can be estimated, and so that progress toward plan goals can be measured effectively. The following section presents metrics to be used in inventorying soundscape resources. After that, discussions specifically on the measurement of natural soundscapes and existing sources of human-caused sound may be found.

*A fundamental difficulty with defining soundscapes, including natural and human-related components, is that no single metric or measure can adequately describe a soundscape.* Rather, a combination of acoustic metrics and biological measures are needed to quantify and qualify soundscapes. Put simply, we need acoustic metrics to quantify (measure) the soundscape, and we need biological measures to qualify (identify) the soundscape. Acoustic metrics and measures include sound pressure levels (minimum 33one-third octave bands, from 12.5 to 20,000 Hz), $L_{eq}$ (an average), $L_{90}$ and $L_{50}$ (overall exceedence metrics), event exceedence metrics (for events over a given amplitude and duration), SEL (a sound exposure measure), Noise Free Interval, percent time above a given level, percent time audible to a given animal or visitors (and area of audibility for a given animal or visitors), and several others. Some metrics and measures are appropriate for

defining the natural soundscape, while other are appropriate for defining the human-related soundscape.

Sound pressure levels in national parks can be very low. For example, in the crater in Haleakala National Park, sound pressure levels can be between 0 and 10 dBA. In Grand Canyon National Park along some remote trails, sound pressure levels can be between 10 and 20 dBA. In contrast, sound pressure levels in a typical suburban area can be between 50 and 60 dBA. An increase of 10 dB represents a perceived (to human hearing) doubling of sound pressure level; hence, 50 dB would be perceived as 16 times greater than 10 dB. In actual acoustic measurements, an increase of 6 dB is a doubling of sound pressure level; hence, 50 dB is actually about 128 times greater than 10 dB.

Table 1 illustrates metrics and measures that are available and suitable for describing natural and human-caused sounds. These metrics are also useful in analysis techniques for identifying alternatives or impacts of inappropriate sound. The sound environment, or soundscape in the present context, is not meaningfully defined unless both elements are measured and attributed to known sources (of natural or human origin). These metrics are precisely defined in the acoustic terminology glossary.

**Table 1. Metrics and Measures for describing soundscapes.**

| Type of Sound Source | Available Metrics for Soundscape Inventory and Monitoring |
|---|---|
| Natural | Sound pressure level metrics (1/3 octave bands, and dBA for historical comparisons), including $L_{eq}$ (an average) and $L_{50}$ (medium) for periods without human-caused sounds. In most cases it is not feasible to make calculations without human-caused sounds, so the $L_{90}$ metric is used. Identifcation of sources of natural sounds is needed for a complete understanding of natural soundscapes. |
| Human-Caused | Sound pressure level metrics (1/3 octave bands and dBA), such as $L_{eq}$, SEL, $L_{max}$, event exceedence metrics (events over selected amplitude levels and/or durations), Number of events per hour, Noise free interval (NFI), Percent Time Above Natural Ambient, Percent Time Audible (can be measured relative to the hearing ability of a specific animal, or can be measured relative to park visitors), and Area of audibility (soundprint). |

## *Defining the Natural Soundscape*

Defining the natural soundscape is a quantitative and qualitative exercise using available methods for measuring sound pressure levels and frequency content of naturally produced sounds, assessing the audibility of those sounds to species in the park, and identifying the sources of those sounds. In practical terms, this means measuring the total soundscape and separating out the portion that is attributable to natural sources. Selection of measurement sites should entail consideration of areas having the greatest probability of measuring the range of natural sounds without significant levels of human-caused noise.

Natural soundscapes in parks are reflections of a park's mix of flora and fauna, its topography, natural physical processes that occur there, and its climate. It is a misnomer to call the natural soundscape "natural quiet" because most parks naturally contain a great deal of sound. With any use of the term "natural quiet" it should be understood that this means a natural condition without the interference of human-caused sound. Qualitatively, the natural soundscape is composed of animal and bird sounds, rushing or falling water, wind through the vegetation and physical features of the landscape, thermal features, volcanic activity, and the silence of a heavy snowfall.

The most accurate and appropriate acoustic metrics for defining natural soundscapes are the $L_{50}$ (the median) and the $L_{eq}$ (an average) values for 1/3 octave bands and dBA, calculated only for those periods without human-caused sound. Further, identification of sources of natural sounds is essential for a complete understanding of the natural soundscape. Identification of sources of natural sounds could also provide insight into soundscape management considerations (such as the presence of an endangered species). Very often, it is not feasible to calculate acoustic metrics without any human-caused sounds (because human-caused sounds are so prevalent in many places). In these cases, the $L_{90}$ is the most commonly used metric to measure the natural soundscape and estimate sound pressure levels in the absence of human-caused sounds.

## *Defining Human-Related Components of the Existing Soundscape*

Human-related components of the existing soundscape are, by convention, defined as impacts on the natural soundscape, discussed above. Through analysis, certain types and levels of human-caused sound may be found to be acceptable or necessary to meet park purposes. Please see the discussion of appropriate and inappropriate sources of noise in Section 5.5.

As part of the affected environment discussion in an EA or EIS, NPS must identify all sources of human-caused sound in the park. The use of metrics, as explained above, helps to achieve this purpose. Useful metrics in characterizing human-caused sound are sound pressure level metrics (1/3 octave bands and dBA) such as $L_{eq}$, SEL, $L_{max}$, $L_{50}$, $L_{90}$, event exceedence metrics (events over selected amplitude levels and/or durations), number of events per hour, noise free interval (NFI), percent time above natural ambient, percent time audible (can be measured relative to the hearing ability of a specific animal, or can be measured relative to park visitors), and area of audibility (soundprint). These metrics and measures of the human components of the soundscape, in conjunction with metrics and measures of the natural components of the soundscape, are the basis for assessing impacts of human-caused sound on the natural soundscape

Detailed mitigation analyses, including comparing natural soundscapes, current soundscape conditions, and proposed or potential soundscape conditions, will rely on using or developing metrics to assess impact and will include some or all of those listed above. Describing noise free intervals adds a further perspective in this assessment. To conduct such analyses accurately will likely require detailed acoustic information about the natural ambient and the human-produced sound levels.