The Analysis and Protection of the Natural Soundscape in National Parks

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The Basic Ideas:

- The "soundscape" is the totality of sounds – the ambient sound levels. The "natural soundscape" = (the soundscape) – (human-caused sounds) = (the sounds of critters) + (the sounds of the wind in the trees, water, etc.) The natural soundscape is a protected natural resource of the National Park Service.

- It is neither necessary nor practical to return NPS soundscapes to their pre-1492 conditions. However, in order to protect this resource it is necessary to have quantitative information about it.

- Monitoring the soundscape is neither as difficult as you might fear nor as easy as you might hope.

- There is no time like the present to start.

The Fundamentals of Sound:

What is sound? Sound is a physical disturbance in a transmitting medium, e.g., the air, in the form of a pressure variation that sometimes can be detected by a particular receptor, e.g., the ear. In other words, sound is energy. Sound is characterized by the frequency of the vibration and the sound's pressure level.

Frequency. Sound is composed of various frequencies just as white light is composed of different colors. When you pass white light through a prism you see a color spectrum. When you pass sound through an analyzer you see a spectrum of the sound's frequencies. These frequencies are divided into octaves, just like a piano. Often times they are further divided into 1/3 octave segments or finer subdivisions for detailed study.

The normal youthful human ear can hear frequencies from 20 Hz, to 20,000 Hz (cycles per second). The range for animals is quite a bit broader. Elephants, to name a species that is not of immediate concern to the NPS, communicate in the *infrasound* range, i.e., less than 20 Hz. Cats and dogs can hear sounds in the *ultrasound* range, i.e., on the order of 35-40 KHz. Bats use frequencies on the order of 50 to 80 KHz to hunt and navigate. The champion we know of is the blind Ganges dolphin that uses frequencies higher than 350 KHz for echolocation.

Sound pressure levels. There are a number of methods for characterizing sound, each with its own units of measurement. For reasons of convenience, the acoustic community typically uses the decibel, a unit of measurement that employs a logarithmic scale to characterize sound energy. One of the reasons for a logarithmic scale is that the range in sound energy of interest is large. For example, the range in sound pressure that the normal human ear can detect is about from zero (the threshold of hearing -- 20 Pa x 10^{-6}) to about ten million times higher (the threshold of pain – 200 Pa). Using the decibel (dB) scale, the range from the threshold of hearing to the threshold of pain is 0 to 140 dB. That provides a measure of convenience but also leads to some problems communicating information to people that don't think in logarithmic terms.[1]

Frequency weighting. Much of the attention to sound revolves around the sounds that humans hear. The ear's response to sound is not linear. It varies with the frequency. In an effort to relate sound at various frequencies (and for other reasons) acousticians frequently use a weighting scale in which the sound levels at various frequencies are "filtered" to produce a composite or weighted sound level. The most common of these are "A-weighting" or "C-weighting" and the sound pressure levels are usually so indicated, e.g., dB(A) (or dBA), dB(C) (dBC), etc.[2] While A-weighting is sometimes described as having been developed to correspond to human hearing, it wasn't. As the sketch below suggests, the relationship is also not precise. The sketch also indicates that the human ear is not equally sensitive to all frequencies – a factor called the threshold of hearing.

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[1] **Complications in communicating about noise using the decibel.** If you have two adjacent sources of sound, each at 70 dB, what is the resultant sound pressure? (Hint. It isn't 140 dB.)

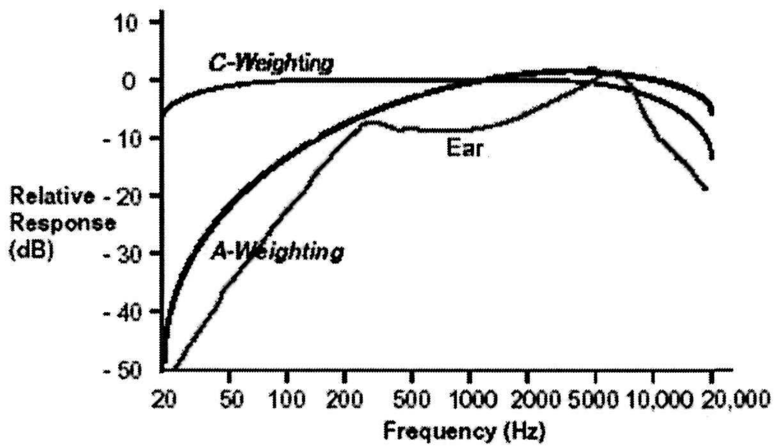
Since the decibel is measured on a log scale, to get the cumulative value of the two sources you can't just add the two numbers. You first work backward to determine the antilog of each value, add those values together arithmetically, and recalculate the dB value. The result is 73 dB.

One of the complications related to explaining and understanding increases or decreases in decibel levels is that the human ear does not interpret a doubling of energy as being twice as loud. In fact, a 3 dB increase is generally judged to be at the threshold of perception, a 5 dB change is clearly perceptible, and a 10 dB change represents a doubling of noise to most humans.

On the face of it, the result might lead one to conclude, "Oh, it is only a 3 dB increase – that's not significant." However, as the example would suggest, that 3 dB represents a doubling of energy -- one source plus another equal source equals two times the energy of the first source.

[2] There are other decibel weighting schemes used for various purposes, e.g., dB(B), dB(D), dB(Z), dB(PN), dB(TPN), etc. In addition, sound levels are occasionally reported as unweighted levels, i.e., just plain dB. When in doubt, ask.

Weighting Networks



Metrics: Acousticians and others involved in dealing with sound use a series of descriptors or metrics to characterize sound. Some of these include:

Decibel (described above) – The dB = 20 Log_{10} ((sound pressure in Pascals)/20 x 10^{-6} Pascals)) (20 x 10^{-6} is the reference pressure in air. 1 x 10^{-6} is the reference pressure in water.)

SEL (Sound Exposure Level) – This metric is the unit used to describe the total amount of sound for an event. All of the sound is totaled and compacted down into a one second reading. An SEL for an aircraft fly over would be the noise level experienced if it took one second for the entire sound of the aircraft flyover to occur.

L_{max} and L_{min} – The highest and lowest instantaneous sound levels within a certain time period, e.g. the L_{max} during that hour was 112 dBA.

L_{eq} (Equivalent sound level) – The average sound level in a period of time, e.g., the average sound level over 1 second (a 1 second L_{eq}) or the average over an hour (a 1 hour L_{eq}).

T_A (Time above) – The amount of time in a given period that the sound level exceeds a specified threshold, e.g., the amount of time during daylight hours that the level exceeds 40 dBA.

Ln (Exceedance levels) – These are statistical values for a series of readings. For example, L_{90} = 43 dBA means 43 dBA was exceeded 90 percent of the time.

DNL Day night level (also called Ldn) – This is a 24-hour average hourly noise level with a 10 dB penalty for nighttime noise events between 10 PM and 7 AM. This metric is used by the military and transportation planners as part of their regulations and guidelines. It is generally used in conjunction with related measures of human annoyance. For a number of reasons related to relevance, the NPS has rejected applying this metric in parks.

These terms (and others) are commonly used in acoustic studies related to parks.

Transmission of sound. Sound transmission in air is significantly affected by the conditions in the atmosphere. Wind, temperature and humidity all affect the propagation and attenuation of sound. Similarly the conditions of the medium also affect sound transmission in water – density, temperature, currents, etc. These effects are particularly important for issues involving long-range propagation of sound.

Some useful facts and rules of thumb.

- Low frequency sounds, e.g., mechanical noise, suffer less attenuation in air than high frequency sounds, i.e., they can be heard at greater distances.
- The decrease in sound pressure levels from a point source, i.e., one whose lateral dimension is small relative to distance, is about 6 dB per doubling of distance – about 5 dB over water. For example, a boom box whose SPL at 50 feet is 80 dB, would have a SPL of about 74 dB at 100 feet, 68 dB at 200 feet, etc.
- The decrease in SPL for a line source, e.g., a highway, is about 3 dB for each doubling of distance.

Some References:

B&K Environmental Noise Handbook
(http://www.nonoise.org/library/envnoise/index.htm)

Cirrus Research, UK
http://www.cirrusresearch.co.uk/glossary.html

National Physics Lab, UK
http://www.npl.co.uk/npl/publications/acoustics/

Sound Dictionary
http://www.nonoise.org/library/diction/soundict.htm

Why worry about the soundscapes?

Because it is part of our job.

NPS policy defines the natural soundscape as a natural resource of the parks, to be protected under the Organic Act. ". . . The natural resources, processes, systems, and values that the Service preserves are described generally in the 1916 NPS Organic Act and in the enabling legislation or Presidential proclamation establishing each park. They are described in greater detail in management plans specific to each park. Natural resources, processes, systems, and values found in parks include:

- Physical resources such as water, air, soils, topographic features, geologic features, paleontological resources, natural soundscapes, and clear skies;. . ."

There is a long history of issues related to impacts on the soundscape in the parks. A number of parks have authorizing legislation that speaks to the purpose of the park in terms like "tranquility, " "enjoyment of nature," and similar phrases. A particular issue of concern to a number of parks has to do with aircraft overflights, whether from nearby airports or from military overflights and air tours. In the Grand Canyon Enlargement Act of 1975, Congress spoke to this issue. "Whenever the Secretary [of the Interior] has reason to believe that any aircraft or helicopter activity or operation may be occurring or about to occur within the Grand Canyon National Park, as enlarged by this Act . . .which is likely to . . .cause a **significant adverse effect on the natural quiet and experience of the park**, the Secretary shall submit ... such complaints, information, or recommendations for rules and regulations or other actions as he believes appropriate to protect . . . **the natural environment** within the park."

In 1994, at Congressional direction, the NPS submitted a report to Congress, "Report On Effects Of Aircraft Overflights On The National Park System" that identified a number of parks where noise was an issue. While the report was focused on the effects of overflights, many of the issues and recommendations apply to the broader issue of noise. These are some of the parks that reported particular concerns:

EXTREMELY CONCERNED	VERY CONCERNED
Bandelier National Monument	Big Cypress National Preserve
Cape Lookout National Seashore	Bryce Canyon National Park
City of Rocks National Reserve	Channel Islands National Park
Fort Vancouver National Hist. Site	Crater Lake National Park
Glacier National Park	Guadalupe Mountains National Park
Great Smoky Mountains N.P.	Joshua Tree National Monument
Haleakala National Park	Kalaupapa National Historical Park
Hawaii Volcanoes National Park	Lassen Volcanic National Park
Isle Royale National Park	Manassas National Battlefield Park
Kings Canyon & Sequoia N.P.	Mesa Verde National Park
Minute Man National Historic Park	Mount Rainier National Park

Organ Pipe Cactus Nat. Monument	Navajo National Monument
Shenandoah National Park	Perry's Victory & Int. Peace Memorial
Southern Utah Group	Statue of Liberty National Monument
	Prince William Forest Park
	Pu'uhonua o Honaunau National H.P.
	Puukohola Heiau National H.S.
	Saguaro National Monument
	San Antonio Missions NHP
	White Sands National Monument

The NPS is also developing specific guidance on what parks should be doing to protect their soundscapes. Director's Order 47 (DO 47) addresses this issue.

DO 47 directs the parks to do certain things:

- Develop Plans to protect the soundscape (Sections C.3, 6, and 7)
  These plans can be made part of a park's general management plan or resource management plan or can be made an ad hoc plan, a soundscape management plan.
- Deal with noise on interim basis by enforcement of noise regulations and correcting park-caused noise.
  There are 2 generally applicable NPS noise regulations:
  - **36CFR Section 2.12** – prohibits devices making noise in excess of 60 dBA measured at 50 feet or, if below that level, nevertheless makes noise which is unreasonable, considering the nature and purpose of the actor's conduct, location, time of day or night, purpose for which the area was established, impact on park users, and other factors that should govern the conduct of a reasonably prudent person under the circumstances.
  - **36CRF Section 2.34** – A person is guilty of disorderly conduct if that person makes noise that is unreasonable, considering the nature and purpose of the actor's conduct, location, time of day or night, and other factors that would govern the conduct of a reasonably prudent person under the circumstances.
- **Inventory and monitor the soundscape** (Section C.5)
- Educate Visitors (Section C.10)
- Work with neighbors to minimize impacts (Section C.8, 9)

In addition, DO 47 establishes certain standards and definitions that are relevant to any work affecting a park's soundscape.

- Section C.7 directs the parks to use the natural soundscape as the "affected environment" for NEPA matters related to the impacts of sound.

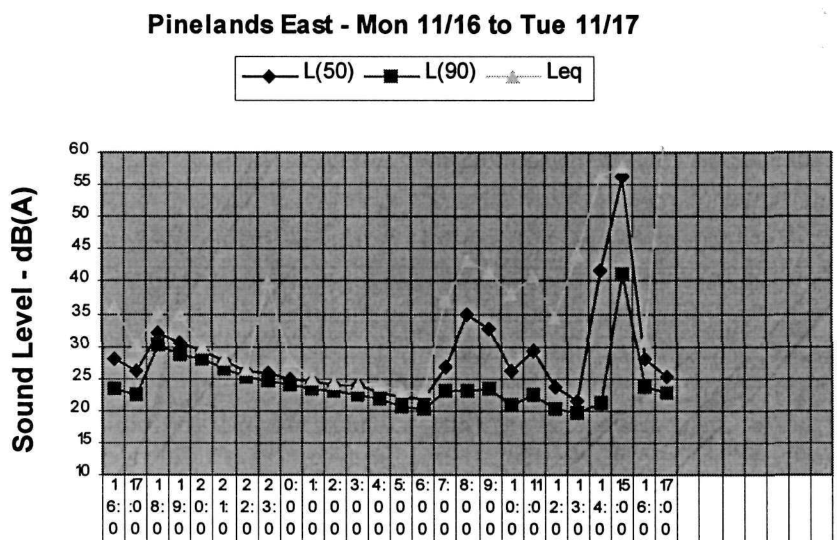
- Section D.4 says that, unless there is better information, parks are to use the L_{90} exceedance levels as the level of the natural ambient. Better information can be developed through detailed monitoring of a park's soundscape but the L_{90}, also referred to as the background level, is commonly used as a baseline for determining normal conditions under state and municipal codes around the country.

These two points are extremely important for protecting the soundscapes of the parks. Let's deal with the L_{90}/natural ambient point first.

In the "fundamentals" section above it was noted that the L_{90} is the sound level exceeded 90 per cent of the time. The critics of the NPS policy have argued that using L_{90} ignores 90 per cent of the sound but that misrepresents facts. Suppose one was to attempt to accurately determine the "natural ambient" level, how would one do that? One could place an observer with a meter in the field with instructions to note those times when no human caused sounds were controlling the soundscape. When the time record of the meter coincides with the period(s) when the observer noted nothing but natural sounds, note that/those readings and you have good estimate of natural soundscape levels. However, obtaining natural levels for a number of sites for all hours of a day would be a fairly expensive proposition in terms of the labor involved and the L90 provides a reasonable indicator of the natural soundscape.

The flaw in the argument against the use of the L90 is that it fails to recognize the nature of the various metrics. Take the L_{eq}, the L_{50} and the L_{90} for example. If one were to pool the 1 second Leq values for a slice of time, say a half an hour or an hour, and calculate the exceedance values for that time slice and repeat that process for as many hours as are of interest, the Leq values would respond most quickly to intrusions on the soundscape followed by the L_1, the L_2, . . . and the L_{99}. During those time slices when there are no intrusions (or a constant source of sound, e.g., a generator) there are no perturbations of the soundscape and the Leq and the exceedance values tend to collapse to a single value for that period of time as in the 1 AM to 6 AM period on the following graph taken from some earlier NPS work in FL. (This graph uses 1-hour slices of data.) The point is that the sound levels <u>not</u> captured by the L90 are basically the intrusions that are not part of the natural ambient.

Returning to the point of Section C.7 – does this mean that parks must return soundscapes to completely pristine conditions? The answer is "no." The point is rather that any action affecting a park's soundscape must be assessed from the standpoint of knowing the consequences in terms of further degradation. The NEPA assessments you will most frequently encounter are those prepared by proponents of a proposed action. Almost universally they deal with noise from the standpoint of how much noise they will generate, not with the effect of that noise on the receiving soundscape. In other words, they conclude that "this proposed action will only add another 2 (or 5, or 10) dB compared to the noise generated by the previous highway (or airport or whatever). In addition, they commonly deal with "average" values for an extended period of time like a year or 10 years. Rarely do the proponents of an action collect acoustic data from the affected environment preferring instead to assume a value, e.g., "assuming that the sound levels in the park are 45 dBA . . ." and even when data are collected they are generally presented in a manner most favorable for the proposed action, e.g., the daytime average L_{eq} values for the park are. . ." (That data set stresses the noisy times.) The intent of Section C.7 is to force the focuses of analysis on the natural (or L90) levels and assess consequences on that basis. The alternative is to allow the soundscapes of the parks to be further degraded.



	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
L(50)	28	26	32	30	29	28	26	26	25	25	24	24	23	22	22	27	35	33	26	29	24	21	42	56	28	25
L(90)	23	22	30	29	28	27	25	25	24	24	23	22	22	21	20	23	23	23	21	22	20	20	21	41	24	23
Leq	36	30	35	35	30	28	26	40	28	25	24	24	24	23	23	37	43	41	38	41	34	44	56	58	31	66

Because the critters are depending on you.

The whole issue of the effect of noise on the biota from the standpoint of NPS obligations is poorly understood. If one looks at most NEPA analyses of the effects of noise on animals one finds that the attention is directed at things like the "startle effect" and bird/animal strikes. Having concluded that there is little or no evidence of such effects, the authors conclude that the animals become habituated and therefore noise is not a problem. Not considered are the consequences of habituation, e.g., the long-term effects of habituation like higher stress effects such as those observer in humans exposed to noise and the interference of noise on the animal's place in the ecosystem. Animals vocalize for a number of reasons including location of food, procreation, and definition of territory. Noise can, and likely does, interfere with all of these functions.

One acoustical approach to animal behavior is to use recordings for identification of particular species present or absent in a given area. With the reduction in the size and weight of recording equipment and the development of better computer analysis software, researchers have been collecting recordings of the sounds of various fauna. One such system, the "froglogger" has been deployed at a number of locations in the US, including a number of national parks as part of the study of amphibian decline. Systems like these allow researchers to identify species of particular interest by analyzing their unique sounds. Unfortunately this approach doesn't contribute much to the understanding of the effects of noise intrusions on the soundscape nor to an understanding of the larger ecosystem.

In the last 30 years another field of study has been developing. Rather than focus on particular species (the trees), this approach seeks to understand the biophony, the sounds of living animals in the context of their overall environment (the forest). This approach offers a number of potential benefits:

Biophonic dating[3]. When examined from an aural perspective, territory becomes defined in dimensions well beyond the 3-D topographical one might experience on a traditional map. Furthermore, examining habitats from an aural perspective may allow us to actually determine their approximate age. For instance, in younger environments, birds and mammals seem to occupy only one acoustic niche at a given moment. However, in older environments, some vocalizations are so highly specialized that their voices occupy several niches of the audio bio-spectrum.

Determining habitat health. These types of observations may also reveal a great deal more about the ways in which birds, for example, respond to the sounds of their environment. For example, many migrating eastern American warblers, able to learn only one song and call in their lives, might find themselves unable to adjust to the changes in ambient sound when they fly to their rapidly disappearing Caribbean or Latin American wintering sites. Where these environments have been deforested, and when birds try to move nearby to ostensibly similar or secondary growth habitats, they may discover that they are unable to be heard. Analyses of field recordings are beginning to indicate the possibility that survival might be impaired because territorial and/or gender related communications are masked. As a result, the concept of biophony might be utilized as an indicator of habitat health insofar as it demonstrates soundscape's relevance to the support of creature life.

Ethics and responsibility. During the past four centuries, modern humans have moved some distance away from two important methods of connecting to our natural world.

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[3] These next 3 items are paraphrases of material that is being prepared by Bernie Krause of Wild Sanctuary and Wes Henry of Ranger Activities as a guide for NPS interpretive personnel interested in educating visitors about the biophony of the parks.

One has been the apparent need to abstract creatures out of context in an attempt to study and understand them. The other has to do with the manner in which we have forsaken our reliance on hearing as a necessary window of knowledge. This unwitting deafness has impaired our ability to make ethical and responsible decisions with regard to the preservation of precious habitats and, in particular, the natural soundscape that so eloquently defines them and reveals their respective stories.

A true understanding of the effects of noise on the biota, particularly with respect to the NPS' mandate, is years and many dollars away. The 1994 NPS Report to Congress mentioned above has a recommended approach for dealing with this issue that would appear quite rational if one believes that the first obligation of the NPS is to "do no harm."

Some References:

Cornell Lab Of Ornithology
http://birds.cornell.edu/

Wild Sanctuary
http://www.wildsanctuary.com/

Michigan State Envirosonics Lab
http://www.cevl.msu.edu/

Nature Sounds Society
http://www.naturesounds.org

Wild Soundscapes: Discovering The Voice Of The Natural World, (Wilderness Press, Berkeley, 1-800-443-7227 or http://www.wildernesspress.com

Because it is important to visitor enjoyment.

Dealing with another factor of NPS concern, many of our parks provide some of the few places left in the United States where certain key types of undisturbed habitats remain for study and visitor enjoyment The Executive Summary of the 1994 NPS Report to Congress provides the results of a system-wide visitor survey. 15,000 visitors were surveyed during the busiest 2 months of the season at 39 parks across the country. Approximately 91 per cent of the visitors reported that their reason for the park visit was to enjoy the "natural quiet." By way of comparison, approximately 93 per cent reported that the reason for their visit was to view the natural scenery.

Most of the current EAs and EISs that deal with noise and its effects on the parks approach it from the standpoint that annoyance effects of noise on visitors is the principal effect of noise that needs to be assessed. They then go on to try to apply the DNL metric and the annoyance curves from urban noise studies to demonstrate that there is very little reason to expect high levels of annoyance associated with the imposition of "a little more" noise and therefore the proposed action is acceptable. The NPS has not accepted this approach.

How does one monitor the soundscape of a park?

There is no one answer or simple answer. In addition, this is an area of acoustics where there is little experience. In a large sense, the NPS is writing the book. There are certain truisms that apply to everything the NPS has done to date.

There will never be enough data. No matter how long and in what manner one collects soundscape data, there will always be an element of uncertainty because the soundscape is dynamic. On the other hand, some data is infinitely better than none if there is an issue related to noise and, when that issue surfaces, it is often too late to collect the data you should have had. There is probably something like the classic 90:10 rule at work here – 90 per cent of what you need to know takes 10 per cent of the effort, the other 10 percent takes 90 per cent of the effort.

There are some basic principles that one should follow as part of a soundscape monitoring project.

Define goals: Are you trying to identify park-caused noise sources or to assess the soundscape of an entire park? What do you think will be done with the data? Is it being collected to address a particular issue on the horizon or as part of a long-term study? Is it likely to be needed for legal proceedings? How do the "desired future conditions" identified in the park's GMP relate to the objectives of the study? What are the known locations of elevated sound levels – rivers, roads, visitor parking areas, etc? Are there particular time of the day or seasons of the year that are of interest? Who is going to analyze the data and how?

Split the study onto rational chunks: A reconnaissance study – a few hours monitoring at times and places of interest -- can provide invaluable information on which to base a broader effort as well as providing training for park (or other) staff engaged in the process. If insect/animal vocalizations are likely to be a factor affecting sound levels, consult with park staff familiar with the insect/animal life. If wind in the trees is likely to be a consideration, consult the vegetation maps and look at met data. Identify obvious noise sources like rivers and streams, roads, or visitor centers and incorporate that knowledge in your plans.

Develop your study plan. Once you have collected and digested the results of the reconnaissance study, lay out your plans for a detailed study. How much data do you need (or can you afford to collect) given the purpose of the study? Where do you want to focus your effort? Were there unexplained anomalies in the reconnaissance data, e.g., was that prolonged elevation in L_{eq} levels due to insect activity or is there a freight train that passes by the park at 3 AM, that need further observation and documentation before you start?

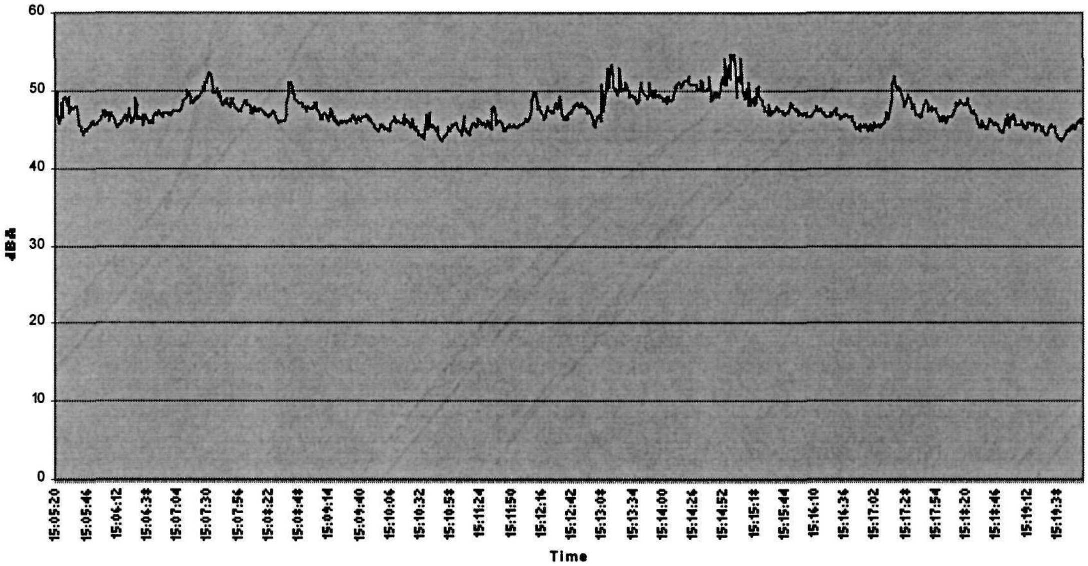
What sorts of instruments are needed? That again depends on the purpose of the study. For a simple assessment of park-caused noise you can probably use a meter from your local Radio Shack that costs less than $100. A hand-held, ANSI Type 2 meter such as the CEL 254 would cost you about $850 and can be used for basic short-term reconnaissance and assessment of baseline soundscape conditions. As you move up in sophistication, particularly for long-term unattended monitoring, the cost rises to perhaps $10,000 for each setup with attendant peripherals – logging ANSI Type 1 meters like the LD 824 or Norsonic 121, data storage, mics, preamps, calibrators, cabling, solar panels, batteries, environmental cases, etc. In any case, the biggest cost, whether monetized or not, will be labor.

What is actually being measured when you monitor? The more sophisticated Type 1 meters identified above are capable of measuring a number of parameters and presenting data in a variety of formats. The microphone/preamp provides the meter with the instantaneous raw data on the energy the mic is receiving and the meter assembles the data into user specified forms, codes it as a binary file, and records to internal memory. The manufacturers provide translation programs that read the binary files and output the data in a useable form, e.g., an ASCII file.

Trying to describe all of the options and their uses is beyond the scope of this paper and can really get confusing so let us focus on a few of forms of output data that are likely to be the principal interest of a park. Earlier I presented a sketch that showed two different weighting schemes and mentioned third octave data. Both the LD 824 and the Norsonic 121 are capable of producing records showing A-weighted, C-weighted, and 1/3 octave band data (and more) for each second of the monitoring period to the limit of the setup's storage capacity.

One useful and commonly used displays is that of 1 second, A-weighted L_{eq}s. Here is 15 minutes worth of data from Minute Man NHP.

15 Minutes of 1 second Leqs



This presents the continuous record of the park's soundscape on an A-weighted basis for that period of time. One can see how the sound levels varied in a manner similar to what the human ear would have received at that location. Although this time period is unrealistically short, I can also tell you the L_{90} (45), the L_{min} (43), L_{max} (55), and a variety of other things to meet the needs of DO 47 and to communicate with others. Since A-weighted data is the lingua franca of the acoustic community, the data are useful for assessing and defending the soundscape. In addition, the data storage requirements are minimal. Had I recorded only the A-weighted data, this 824 could have recorded about 40.5 hours of data before the data had to be downloaded or the 2MB memory capacity of the meter was reached.

I also recorded the C-weighted sound levels. If you'll recall the sketch above, C-weighting filters out less of the low frequency sound. If I were interested in the presence of such low frequency sounds in the soundscape, I could have (logarithmically) subtracted the A-weighted values from the C-weighted values, plotted those, and made a general assessment of the presence of mechanical or other low frequency noise during the recording period. The data storage requirements would have been about twice those for only A-weighted values but still modest.

In addition, I recorded the 1/3 octave data for the session. From those 33 bands of data I could have taken a detailed look at the amount of sound energy present in each band, reasonably assessed the presence of mechanical noise sources with some tonality, e.g., helicopters, and stayed up all night computing weird things like dB(Z) values. I would have also exhausted the storage capacity of the meter in a few hours.

Historically, most of the acoustic data collected in the parks (and elsewhere) was done using short-term, observer-based monitoring, i.e., an observer was present to document the changes in the acoustic environment for short (1 – 3 hour) periods on one or more days. The advantage of this approach, given the use of good monitoring protocols, is that there is generally good documentation of the sources of noise. The disadvantage is high cost and the fact that the periods sampled may not have been representative of anything other than those times on those days. The NPS has been moving toward long term (a week or more of continuous data collection) unattended soundscape monitoring supplemented by occasional observer visits to the monitoring sites to listen and observe what is going on from an acoustic sense. These longer term monitoring efforts are cheaper per megabyte of data and provide a much more complete acoustical record but impose additional burdens on the data collection systems in terms of ancillary data storage systems, power supplies and system protection.

How does one get started? One approach is to employ consultants to provide the instrumentation and collect the data. This has the benefit that it essentially a "turn key" operation. It has the disadvantage that consultants are quite expensive -- $1,000 to $1,500 per day plus per diem and travel. There is an ongoing discussion about ways that the NPS could purchase data as a commodity with significant reduction in data cost per MB but it is still too early to provide accurate estimates of cost or to assess the pros and cons of this approach. (The caveat on the high cost is "value for money." If the issue of interest is likely to end up in court, hire a consultant with good credentials.)

Who are some of these consultants? Here is a list of the companies that I have worked with on NPS soundscape studies. All of them do good work, all understand the NPS soundscape policies, and all seem to have an interest in the NPS soundscape issues. All of them are currently available to the parks under an existing indefinite quantity contract. Some have particular approaches that may or may not suit your circumstances. (The first hyperlink is the email address of the individual and the second is the company's web site.)

Gonzo Sanchez, SID, Inc.

Jim Foch, Foch Associates

Bill Bowlby, Bowlby & Associates

Micah Downing, Wyle Laboratories, Inc.

Nick Miller, HMMH, Inc.

In addition, there are hundreds of acoustic consultants whose particular skills might suit a particular need.

What about doing it ourselves? Another approach that would fit in with the overall I&M program is to purchase the necessary equipment and provide the essential training for I&M personnel within the various clusters. Funding is being sought for this sort of effort. Acoustic monitoring, particularly long term monitoring, is not a job requiring full time, on-site presence. Personnel visiting parks for biological data collection, for example, could deploy the monitoring equipment at the start of the visit and collect the equipment and the stored data at the end of their stay. This approach would significantly reduce the overall cost of data collection to the NPS and would have the additional benefit of providing a great deal of data in the early stages of a growing I&M program. The equipment cost per team would vary depending on the number of parks and the level of detail of the studies but $15,000 for equipment per team would produce a great deal of useful data in a year or two.

How and where does one set up the equipment? The NPS has been working to develop a manual that describes the way that data should be collected by (or for) the parks, and the way that the equipment should be set up. The process was delayed when the NPS and contractor personnel involved in its preparation hit some unexplored and unresolved technical issues. These are being addressed and I would expect that the manual would be available by the summer of 2003. The procedures do not differ markedly from those in ISO 1996 -- "Acoustics -- Description and Measurement of Environmental Noise." In any case, the "best practices" followed by acoustic consultants or the training that NPS personnel involved in data collection will need to receive should cover this issue.

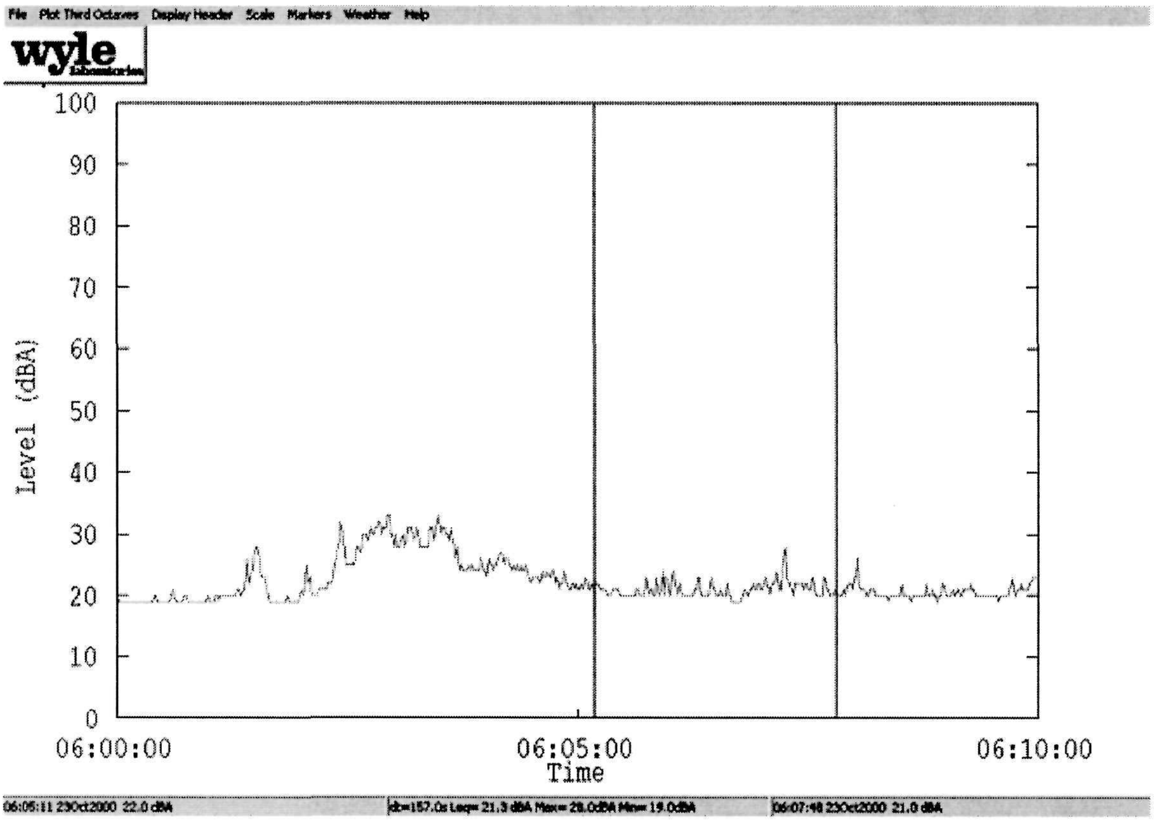
The matter of "where" is one that I will try to explore more fully in the presentation but a few general points can be made here. The first and most obvious is that the monitoring should be conducted in places consistent with your plan. If you are concerned about noise from fixed sources like a road, you need to place the meters where they can capture the noise of interest. If the goal is to monitor the overall soundscape, you will generally want to avoid known noise sources. For example, running water makes noise. You know that before you start. Other than perhaps collecting a bit of data to document the sound levels of a river, you would avoid river-noise influenced areas for soundscape monitoring. Why waste a meter and storage capacity by placing a meter next to a river for a month? On the other hand, if air tours are the issue, should you spend your time and effort monitoring the noise levels where they are now flying? Probably not.

One of the current technical issues has to do with the reality of hypothesized "acoustic zones." The logic for them is -- since vegetation affects all manner of acoustic effects, wind in the foliage, insects and other vocalizing critters, etc., it would seem reasonable to assume that one should base a sampling program on vegetative (or lack of vegetation) patterns – aim to have a meter in each of a park's dominant vegetative zones before the end of the sampling program. Unfortunately, other than gross differences in cover, e.g., trees versus barren ground (and then not always), our work to date does not seem to support this approach. While there hasn't been funding to allow for the controlled experiments needed to definitively address this issue, perhaps some of the ongoing and proposed soundscape monitoring projects can provide additional insight on this issue. My best advice at this point for a project to monitor a park's overall soundscape is to define your goals, do your reconnaissance studies, and set out the meters to get as broad a geographic coverage as you can with the available equipment and the knowledge gained from the reconnaissance work.

What other tools are available?

Beyond the uses that data has to a particular park, what happens to the data from all the parks? NRSS has been developing an inventory of all of the acoustic data that have been, are being, and will be collected in the parks. The database metadata are structured the same FGDC standards as other NPS I&M efforts. The collection will allow individual parks and researchers to view and analyze data for trends and to investigate hypotheses about the nature of soundscapes across the country. A park starting to monitor the soundscape might, for example, view the data from other parks with the same general characteristics – topographic, vegetative, etc. – to plan data collection locations or to develop estimates of sampling durations. Military or civilian personnel planning aircraft route changes or personnel considering highway changes will be able to access the data to obtain more realistic estimates of ambient conditions for preparation of environmental assessments. Researchers from CESUs and elsewhere could use the data to investigate long-term trends or to assess hypotheses like the reality of acoustical zoning a park or broader geographic area.

One of the ancillary benefits of the database is that the data will be stored in a common format. All of the data logging sound level meters save data in a (proprietary) binary form to reduce file size/data storage requirements. While this NPS standard format is basically being established to eliminate the complications of trying to deal with a number of different data structures, one of the things this allows is the development of viewer programs to allow humans to more easily visualize variations in time-series sound pressure data. Below is a screen shot showing 10 minutes of data from Zion NP. By panning the window forwards or backwards in time the user can quickly scan weeks or months worth of 1 second Leq data to identify time periods of interest or to identify intrusions.



The approaches above document the baseline soundscape conditions in a park and help identify intrusions to a park's soundscape but how would one assess a proposed change in conditions – a new highway, or an air tour flight track? The best way to do this is through mathematical modeling. The highway departments and aviation community have their own models and those models are also available to the NPS for a fee. The NPS has found problems with most of the commonly used noise models and all of these models were limited to a particular class of noise, e.g., aircraft, or highways, but not both. Recently the NPS decided to obtain its own noise model to replace the aging NODSS (National Overflight Decision Support System) model used for assessing air tours at Grand Canyon. After reviewing the options, we opted for a modification of a model based on a military noise model. This model, NMSIM (Noise Map Simulation) is based on the fundamental physics of noise transmission rather than empirical modeling and includes the ability to handle terrain features and a range of noise sources. In a recent field test of it, NODSS, and two versions of the Integrated Noise Model used by aviation interests, NMSIM demonstrated its superiority. The NPS version of NMSIM is now Windows-based, much more user friendly, and boasts an expanded noise library. It is presently in beta testing by an international group of acoustic experts and should be available to NPS personnel in about six months. The code for this model is open source and the US military has just announced plans for three-year effort to further enhance the model that should bring additional benefits to the NPS.

One additional and most useful tool is available to the parks. The battle to protect the soundscapes in the parks requires the NPS to effectively communicate its concerns to the public and decision makers. If you paid attention to the section on the fundamentals of sound at the start of this paper you can perhaps appreciate the high state of excitement in the audience as acoustic experts present their data on SEL levels and DNL values. The problem is that no one, including the experts can tell you what it means to experience a DNL value of 67. (In fact, other than reciting the definition of DNL, they can't even tell you what the value means. Ask one sometime.)

One of the tools that is part educational and part experiential is a multi-media, computer-based package called the Interactive Sound Information System (ISIS) that was developed originally for the Air Force and the FAA. The NPS has used a customized version of this package very successfully to carry its message about the impacts of proposed actions on the parks. Through its use the audience can be made to better understand what it actually means to have a 737 or F-16 passing over the visitor center or interpretive program 8 times an hour.