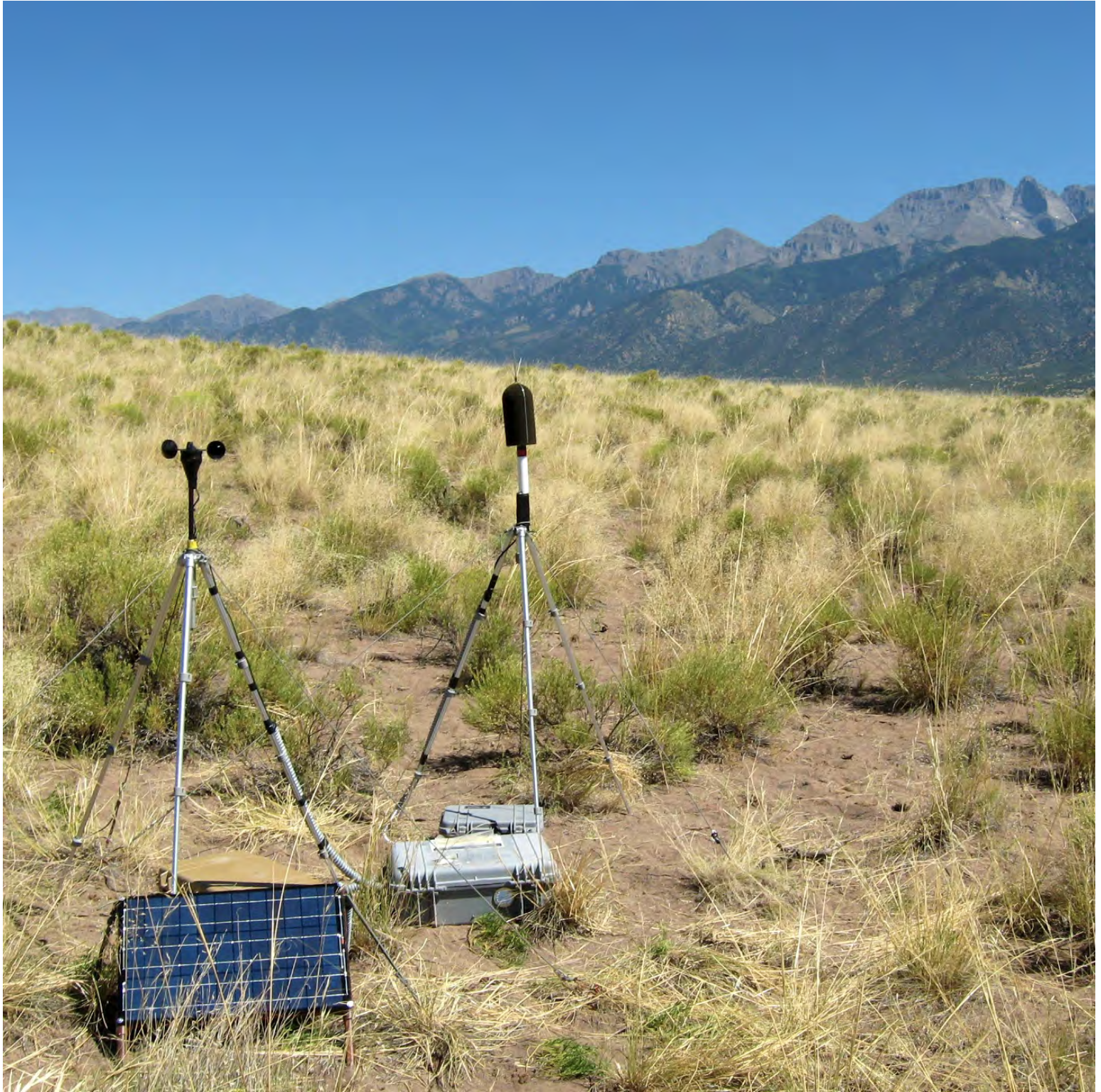




# Acoustical Monitoring *Training Manual*





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# Chapter 1

## Introduction

### 1.1 Goals of this Document

Through this standard operating procedure (SOP) document, the Natural Sounds and Night Skies Division (NSNSD) hopes to:

1. Increase understanding of the equipment and the training required to conduct acoustical monitoring.
2. Provide a reference and training manual to enable parks with available personnel and equipment to collect routine acoustical data.

This manual arose out of mounting requests for acoustical monitoring training in national parks.

### 1.2 Intent of Use

To get acquainted with the acoustical monitoring equipment and protocols the NSNSD suggests that you first go through this manual with all of the equipment on hand in an indoor environment where you can take your time exploring each section of the manual. Once you feel comfortable, this SOP should be taken into the field as a reference.

### 1.3 Background

The National Park Service has determined that natural sounds are valuable resources worthy of protection. Out of this ideal the NSNSD was born. The NSNSD works to protect, maintain, and restore acoustical environments throughout the National Park System. Its goal is to provide coordination, guidance, and a consistent approach to soundscape protection with respect to park resources and visitor use. The program helps provide national park managers with specialized resource management and policy expertise as well as technical assistance in the form of acoustical monitoring, data collection and analysis, and all aspects of park planning and compliance. Finally, NSNSD staff work in partnership with parks and other entities to further understanding of and inspire public appreciation for soundscapes throughout the national park system.

### 1.4 Acoustical Monitoring

Efforts to protect the acoustical environment in our national parks are driven by NPS management policies. Before any action can be taken, however, park planners must have reliable



data about a park's existing acoustical environment. Through monitoring efforts, parks can learn about the acoustical environment as a whole, discover desirable sounds, and identify sources that are inappropriate for a park setting. Information gathered can then be used to identify the potential impacts of non-natural sounds and proposed developments or actions that may affect the acoustical environment. Acoustical monitoring has been conducted in more than 70 parks since the division started in 2000. This monitoring has taken place in each region and in numerous park management zones, vegetation zones, and elevations.

## **1.5 Planning and Preparation**

Preparation for data collection includes identifying primary sampling areas, and defining the season and period of time for taking measurements. Each monitoring effort considers soundscape management objectives, as well as acoustically sensitive areas, such as endangered species habitat or cultural areas. In general, 25 days is the minimum recommended collection period to ensure statistical confidence and to capture the temporal variation for a summer or winter natural ambient measurement.

## **1.6 When to Measure**

Whenever possible, acoustical data is collected in all seasons. When not possible, technicians collect data during the high and low seasons for the activity of interest. This method helps to account for variables, such as weather and biological activity that differ among seasons. For example, air tour companies typically operate at high volume during the summer season. Thus, measurements are taken during both the summer and winter seasons.

## **1.7 Why Monitoring is Conducted**

Acoustical monitoring provides a baseline for understanding all components of the acoustical environment in a park, including sounds undetectable to the human ear and park-generated sounds. The highly sensitive equipment and expertise of the NSNSD acoustical monitoring team can provide park managers a more complete picture of the true acoustical environment. Data collected during monitoring can help shape park management plans, thus offering hope for a future where visitors can count on national parks to provide that simple yet increasingly elusive sense of solitude and connection to culture. Data collected during monitoring informs the decision-making process by providing metrics, reference standards, and thresholds for:

- Air Tour Management Plans
- Commercial Services Plans
- Soundscape Management Plans
- General Management Plans
- Transportation Management Plans
- Resource Management Plans
- Wilderness Management Plans
- Winter Use Plans

However, acoustic monitoring can also support:

- Biological studies (ex: peregrine falcon nesting patterns)

- Evaluations of internal park operations (ex: construction projects or grounds care)
- Impact analysis for specific sound sources (ex: snowmobiles, airboats, ORVs, or vehicles)
- Visitor Experience and Resource Protection (VERP) studies

## Chapter 2

# Site Selection

### 2.1 Developing Acoustic Zones

The primary purpose of conducting acoustical measurements in a park is to collect data that can describe existing and natural ambient conditions. This information can be used to evaluate the status of the acoustical environment, monitor compliance with management objectives, or assess potential impacts of proposed activities in and around parks. Site-specific sound level data can also be used to develop a set of acoustical maps that graphically display the park's acoustical resources. In most situations, the primary consideration in selecting measurement locations will be the acoustic zones of a park.

It is fair to assume that areas of like vegetation, land cover, topography, elevation, and climate contain similar animals, physical processes, and natural sound sources. As a result, we predict that these areas may have similar natural sound sources, sound levels, and propagation or attenuation properties. Most park units have identified and mapped primary vegetation and topographic types, so a review of these data is the first step in identifying the potential number and types of acoustic zones in a park unit. In parks where this sort of GIS product does not exist, acoustical technicians can query the [USGS seamless data warehouse](https://seamless.usgs.gov/)<sup>1</sup> for broad land cover information. Once the primary acoustic zones have been identified, measurement locations should be selected to ensure that the most prominent acoustic zones of the park are sampled.

Admittedly, the theory of comparable ambient conditions in comparable vegetation zones is a working hypothesis, and requires additional study by the NSNSD and its partners be fully understood. It is presently hypothesized that after a critical mass of baseline ambient sound level data has been collected, it will be statistically viable to generalize data measured in one park to regions possessing similar attributes in other parks. What is not currently known, however, is how many park measurement studies will be needed to achieve statistical reliability and scientific defensibility of ambient data as this type of effort has never been attempted before. Should the hypothesis be proven sound, it is anticipated that some baseline ambient sound level measurements will still be necessary in all parks (though the scope of such monitoring projects may be reduced).

Final measurement locations are chosen by passing potential sites through a screening process of site accessibility, equipment availability/capability, equipment security, and availability of personnel to deploy and service the equipment. Site accessibility is likely the most limiting factor in this list, but as acoustical measurement technology becomes smaller and lighter, personnel may be able to conduct measurements in previously inaccessible areas.

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<sup>1</sup><https://seamless.usgs.gov/>

## 2.2 Additional Considerations

In cases where using land cover to define acoustic zones is not a viable or appropriate solution, other techniques may be employed. Parks might also consider monitoring in:

- Park management zones where greater resource protection is needed.
- Specific sound-sensitive areas where sound sources of interest are known to exist.
- A grid formation, emulating the Inventory and Monitoring sampling techniques.

## 2.3 Site Selection for Sounds of Interest

Assessment of specific sounds of interest may require collection of acoustic data specific to the area and source of that sound. Although acoustical data for mechanized equipment (such as generators, motors, and vehicles) often exists, on-site verification may be needed to accurately model the potential impacts of these sources. When measuring specific sound sources, it may be necessary to gather more data than the standard 1-second decibel data. This additional data may include multiple dBA measurements per second from numerous locations around the source, observer logging, distance data for source to receptor, and others.

## 2.4 Site Selection Checklist

Earlier in this section, techniques for macro-level site selection were discussed. Use the bullet points below to determine the best site locations on a micro-level.

- Area should be representative of acoustical zones, management zones, or based on specific data collection goals.
- Area should have plenty of sunlight if solar panels will be used.
- Area should be protected from high winds (over 5 meters per second for prolonged periods of time).
- Avoid deploying the system near large reflective objects such as rock walls.
- Avoid deploying system close to constant noise sources (loud rivers, generators, etc.).
- A tree or unmovable rock is needed to secure the equipment pelican case with a chain and lock. Otherwise, the pelican cases can all be chained together.
- To avoid equipment-animal conflicts, the site should not be in an area of high livestock use/grazing, or in an area where wildlife (deer, elk, etc.) are known to congregate.

## Chapter 3

# Equipment

This chapter will discuss the function of various components of the acoustical monitoring station, why they are necessary, and where to find more information if needed.

As newer technologies develop (such as the advance of high density lithium batteries), the Natural Sounds and Night Skies Division will try to incorporate them into the existing monitoring setup to make the process easier and more efficient.

### 3.1 Larson Davis 831 Sound Level Meter

The Type-1 sound level meter (SLM) is the central part of the monitoring station. It is a powerful calibrated signal processing device, capable of analyzing incoming audio signals in real-time<sup>1</sup>, and deconstructing them into their individual frequencies. The Natural Sounds and Night Skies Division currently uses the Larson Davis 831 with the 2Gb memory upgrade, 1/3 octave filter, time history, and weather options installed. As it is a calibrated instrument, it should be sent back to Larson Davis every year to renew the certification. Park management plans can be subject to legal review, and the certification of calibration will help defend the validity of the measurements.

Often, when the unit is powered on, it will run through a memory self-check. This can delay the appearance of the Live screen by up to several minutes. If you believe your unit is no longer responding, even after waiting several minutes, you can perform a hard reset by sliding the small power switch at the bottom to the off position. Wait 30-60 seconds, then slide the switch to the on position. This may clear some settings, so verify your settings before performing a measurement.

The software embedded into the SLM is called the *firmware*. Every so often, Larson Davis will release a software update on their [support page](#)<sup>2</sup>. As these updates usually fix errors and bugs, it is recommended to use the latest firmware version<sup>3</sup>. Larson Davis provides [instructions on upgrading](#)<sup>4</sup> online.

Specific settings used in acoustical monitoring can be found in section [4.3.1](#). Refer to the [Larson Davis 831 User manual](#)<sup>5</sup> for a comprehensive instruction manual for the unit.

---

<sup>1</sup>This function is often abbreviated as RTA, or Real-Time Analyzer

<sup>2</sup>[http://larsondavis.com/Support/Model831\\_Support.htm](http://larsondavis.com/Support/Model831_Support.htm)

<sup>3</sup>As of 2011 November 01, the latest version is 2.101

<sup>4</sup>[http://larsondavis.com/Manuals\\_DataSheets\\_Brochures/README-Model831&LXT-UpgradeInstructions.pdf](http://larsondavis.com/Manuals_DataSheets_Brochures/README-Model831&LXT-UpgradeInstructions.pdf)

<sup>5</sup>[http://larsondavis.com/Manuals\\_DataSheets\\_Brochures/I831-01\(H\)Manual.pdf](http://larsondavis.com/Manuals_DataSheets_Brochures/I831-01(H)Manual.pdf)



Figure 3.1: Front view of the Larson Davis 831



Figure 3.2: Bottom view of the Larson Davis 831











Icon	Description
	<b>Softkeys:</b> The functions of these three keys will change depending on the mode and screen that the instrument is currently displaying. Their function will be shown on the LCD screen directly above.
	<b>Stop/Store Button:</b> Stop a measurement currently in progress. If unit is stopped already and is not set to autostore, pressing this button a second time will store the current measurement to a data file.
	<b>Run/Pause Button:</b> Start logging, or if currently logging, pause the measurement. Unlike stopping the instrument, this will keep data before and after the pause in the same data file.
	<b>Navigation Keys:</b> Used in moving around the menus
	<b>Enter Button:</b> Used to confirm a selection
	<b>Reset Button:</b> Reset the current measurement
	<b>On/Off Button:</b> Turn unit on or off
	<b>Tools Button:</b> Enter the tools menu, where settings and preferences can be changed

Table 3.1: Visual guide to the buttons on the face of the Larson Davis 831

### 3.2 Roland R-05 Digital Audio Recorder

While 1-second  $L_{eq}$  data can be used to identify some sources, they do not provide the same level of detail as continuous audio. Recordings made from the DAR can help technicians learn unknown sound sources, identify animal species, and provide useful interpretive material to the park.

As opposed to the laboratory quality sound level meter, most digital audio recorders are consumer grade and relatively inexpensive. As such, they will not be able to record sounds below a certain threshold. This limit is called the noise floor of the device — the point at which internal noise from the electronics of the recorder are greater than the signal coming in to be encoded.

For more comprehensive information, refer to the [Roland R-05 User Manual](#)<sup>6</sup>



Figure 3.3: Front view of the Roland R-05

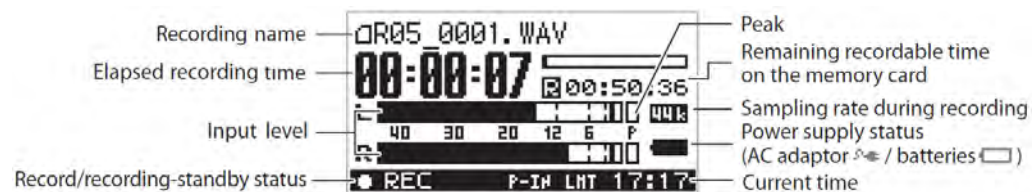


Figure 3.4: Recording screen on the Roland R-05

<sup>6</sup>[http://media.rolandus.com/manuals/R-05\\_OM.pdf](http://media.rolandus.com/manuals/R-05_OM.pdf)

Item	Description
Peak Indicator	Will become red when recording input level is too high.
Finder Button	Opens the file browser. Press again to exit.
Menu Button	Opens the settings menu. Press again to exit.
Rehearsal Button	Not used.
Speed Button	Not used.
Reverb Button	Not used.
A ◀▶ B Button	Not used.
Input [+][-]	Adjust the recording input level.
Vol [+][-]	Adjust the volume output to the headphones.
▶/	Starts/pauses playback of selected file. Also acts as up arrow in navigation.
■	Stops playback <b>or recording</b> of selected file. Also acts as down arrow in navigation.
◀◀	Rewind/skip track. Also acts as left arrow in navigation.
▶▶	Fast-Forward/skip track. Also acts as right arrow in navigation.
●	Start recording (first press enters standby mode, second press begins recording). Also acts as ENTER key in navigation.

Table 3.2: Guide to the face of the Roland R-05

Item	Description
Line-In	Jack to receive line-level audio signals from external sources.
Mic	Not used.
Power switch	Turns unit off and on by sliding down. Disables buttons (hold mode) by sliding to the up position.
DC in	3.2V DC power input, pin positive.
Phones	Headphone jack.
USB	Not used.
SDHC	SD card slot.
Mic Gain Switch	Not used.
Limiter Switch	Adjusts recording level to prevent clipping. Should be set to off.
Low Cut Switch	Cuts out low frequency sounds. Should be set to off.

Table 3.3: Guide to the sides and back of the Roland R-05

### 3.3 Meteorological Sensors

Although the measurement microphone is protected by a foam windscreen, high wind speeds ( $\geq 5\text{m/s}$ ) can create turbulence around the microphone, artificially inflating measured sound pressure levels and in extreme cases, causing distortion. When this occurs, the data cannot be used in the analysis for natural ambient.

The acoustical monitoring system uses a Davis anemometer to record second-by-second wind speeds, and integrates these readings directly into the sound pressure data. Wind direction is also recorded, and can be useful to study propagation of ground based sources, such as nearby parking lots or rivers. Temperature and humidity also influence the propagation of sound, the performance of the electronics and power supply, and the calibration of the components. These parameters are also recorded using a custom RH/T<sup>7</sup> sensor.



Figure 3.5: Relative humidity / temperature probe mounted on tripod with an anemometer

### 3.4 Power

The monitoring station has two devices that consume power: the sound level meter and the digital audio recorder. Two separate batteries are used; a 12V battery pack and a 3.2V battery. Two batteries are used since these two devices require different voltages, and by employing two power sources, electrical noise in the audio signal is minimized<sup>8</sup>.

The sound level meter is powered by the 12V battery pack, which is comprised of eight 3.2V 40Ah<sup>9</sup> LiFePO<sub>4</sub><sup>10</sup> ThunderSky™ batteries. They are connected on 4S2P configuration, meaning that four batteries are connected in series (thereby summing the individual voltages to yield 12.8V), and these two series-packs are connected in parallel (summing the charge capacity, or total Ah rating). The battery connector assembly provides a fuse for each of the two series-packs, and routes all the connections appropriately. Nothing more than plugging each cell into the connector is needed to configure the total pack.

<sup>7</sup>Relative Humidity and Temperature

<sup>8</sup>When two audio devices are connected to the same ground, as in the case with just one battery, there can be a mismatch in potentials, resulting in stray current on the audio line. This is known as a ground loop.

<sup>9</sup>Ah = Ampere-hour, a unit of electric charge. A 40Ah battery can supply 1A of current for 40 hours, or 0.25A for 160 hours.

<sup>10</sup>Lithium-Iron Phosphate

The audio recorder is powered by a 3.2V battery pack. Depending on the desired runtime, there may be just one of the ThunderSky™ batteries, or two connected in parallel (again, to increase the total charge, but remaining at 3.2V).

To prevent damage to the battery packs, individual cells should not be allowed to drain much below 2.6V. Luckily, the equipment used in the monitoring station will not run when the batteries are this low. However, the batteries should not be left in the field for more than a few days once discharged, and should be promptly charged when returned to the office.

All batteries are outfitted with Anderson Powerpole® connectors. These terminals prevent incorrect mating (i.e., red connected to black), making the connections simple and safe. Replacement 15A and 30A connectors can be ordered from [Powerwerx](#).

### 3.5 Interface Box

The interface box provides a simple way to connect all the pieces of the acoustical monitoring system together. It is powered from a 12V source, and powers the Larson Davis 831, , provides audio from the LD831 to the R-05, and incorporates meteorological measurements into the data files.

An external view is shown in figure 3.6(a), and a view of the circuit inside is shown in figure 3.6(b).



(a) Interface box

(b) Interface box circuit

Figure 3.6: Monitoring system interface box

### 3.6 Audibility Logger

In addition to the sound level data collected by the sound level meter, knowledge of the source, duration, and distribution of sound sources is useful when characterizing acoustical conditions in national parks. Thus, during sound-level data collection, periods of on-site listening may be conducted in order to discern the type, timing, and duration of different sound sources. The information collected during on-site listening serves as a ground truthing when acoustical conditions are analyzed later in the office environment.

The audibility logger is a handheld device (such as a personal digital assistant or small laptop) used to identify the begin and end times of all audible sound events. The information collected on the device can then be easily transferred to a database for processing and analysis.



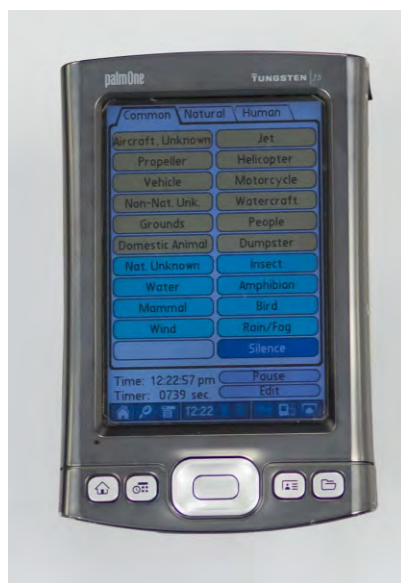


Figure 3.7: Palm Tungsten T5 running NPS Soundscape software

# Chapter 4

## Data Collection

### 4.1 Metadata and Visit Logs

Metadata is data that provides information about one or more other pieces of data, such as when, where, and with what instrumentation particular sound pressure level measurements were made. Metadata gives context and utility, and is critical for interpretation and organization of data.

The NSNSD has a standard site visit data sheet (appendix A) for deployments of sound monitoring equipment that specifies location and equipment related metadata. In addition, there is a visit log for recording site status during post-setup visits.

#### 4.1.1 Site Visit Data Sheet

This section provides guidelines for completing a site visit data sheet. Depending on the specific equipment configuration and intent of collection, some fields may be inapplicable. Please use the code NA (not applicable) for such fields. The top half of the data sheet contains fields for metadata that generally persists during the entire deployment. Each row of the bottom half (and subsequent pages if necessary) are for individual visits is for an individual visit to the site, including set up and tear down. For instructions on how to conduct a site visit, see section 4.6

#### General

1. Park: The four letter park code, usually generated by taking the first four letters of the name or first two of a two word name (e.g. GRCA)
2. Site ID: The three digit site number (e.g. 001)
3. Site Name: A representative name for the area based on the region, nearby geographical features, historical significance, etc. (e.g. Rippling Brook Canyon)
4. Investigator(s): Names of those involved in site setup and visitation.
5. Page: Indicate page number and existence of additional pages separated with a slash (e.g. 1/2 for page one of two).
6. Notes: This space is reserved for any peculiarities of the site or site setup outside of what is specified in this manual.

**Location**

1. Latitude: The site latitude, specifically the microphone location, in decimal degrees according to the NAD83 geodetic datum acquired via GPS.
2. Longitude: The site longitude, specifically the microphone location, in decimal degrees according to the NAD83 geodetic datum acquired via GPS.
3. Elevation: The site elevation, specifically the microphone location, in meters acquired via GPS.
4. Time Zone: Time zone indicating daylight savings time if appropriate (e.g. EST or EDT)

**Site characteristics**

1. Habitat: Choose one of the following that represents the habitat or biome within 1 km<sup>2</sup>.
  - (a) Tundra: A biome where the tree growth is hindered by low temperatures and short growing seasons. In tundra, the vegetation is composed of dwarf shrubs, sedges and grasses, mosses, and lichens. Scattered trees grow in some tundra. The ecotone (or ecological boundary region) between the tundra and the forest is known as the tree line or timberline.
  - (b) Taiga: Also known as the boreal forest, is a biome characterized by coniferous forests. Taiga is the world's largest terrestrial biome and covers: in North America most of inland Canada and Alaska as well as parts of the extreme northern continental United States. The term boreal forest is sometimes, particularly in Canada, used to refer to the more southerly part of the biome, while the term taiga is often used to describe the more barren areas of the northernmost part of the taiga approaching the tree line.
  - (c) Montane grasslands: The biome includes high altitude (montane, subalpine, and alpine) grasslands and shrublands around the world. Montane grasslands and shrublands located above the tree line are commonly known as alpine tundra, which occurs in mountain regions around the world. Below the tree line are subalpine and montane grasslands and shrublands. Stunted subalpine forests are known as krummholz, and occur just below the tree line, where harsh, windy conditions and poor soils create dwarfed and twisted forests of slow-growing trees.
  - (d) Temperate coniferous forest: A terrestrial biome found in temperate regions of the world with warm summers and cool winters and adequate rainfall to sustain a forest. In most temperate coniferous forests, evergreen conifers predominate, while some are a mix of conifers and broadleaf evergreen trees and/or broadleaf deciduous trees. Temperate evergreen forests are common in the coastal areas of regions that have mild winters and heavy rainfall, or inland in drier climates or mountain areas. Many species of trees inhabit these forests including cedar, cypress, douglas-fir, fir, juniper, kauri, pine, podocarpus, spruce, redwood and yew. The understory also contains a wide variety of herbaceous and shrub species.
  - (e) (Sub)Tropical coniferous forests: Tropical and subtropical coniferous forests are a forest biome. They are located in regions of semi-humid climate at tropical and subtropical latitudes. Most tropical and subtropical coniferous forest ecoregions are found in the Nearctic and Neotropic ecozones, from Mexico to Nicaragua and on the Greater Antilles, Bahamas, and Bermuda.

- (f) **Temperate Broadleaf/Mixed:** Mixed forests are a temperate and humid biome. The typical structure of these forests includes four layers. The upper most layer is the canopy which is composed of tall mature trees ranging from 33 to 66 m (100 to 200 feet) high. Below the canopy is the three-layered, shade tolerant understory which is roughly 9 to 15 m (30 to 50 feet) shorter than the canopy. The top layer of the understory is the sub-canopy which is composed of smaller mature trees, saplings, and suppressed juvenile canopy layer trees awaiting an opening in the canopy. Below the sub-canopy is the shrub layer, composed of low growing woody plants. Typically the lowest growing (and most diverse) layer is the ground cover or herbaceous layer.
- (g) **Mediterranean Forest:** Mediterranean forests, woodlands, and scrub is a temperate biome, characterized by dry summers and rainy winters. These regions are home to a tremendous diversity of habitats and species. Vegetation types can range from forests to woodlands, savannas, shrublands, and grasslands; “mosaic habitat” landscapes are common, where differing vegetation types are interleaved with one another in complex patterns created by variations in soil, topography, exposure to wind and sun, and fire history.
- (h) **(Sub) Tropical Moist Broadleaf:** Tropical and subtropical forest regions with lower rainfall are home to tropical and subtropical dry broadleaf forests and tropical and subtropical coniferous forests. Temperate rain forests also occur in certain humid temperate coastal regions. The biome includes several types of forests: Lowland equatorial evergreen rain forests, moist deciduous and semi-evergreen seasonal forests, Montane rain forests, and flooded forests.
- (i) **Temperate Grasslands:** Temperate grasslands is a terrestrial biome whose predominant vegetation consists of grasses and/or shrubs. This includes savannas and shrublands. The climate is temperate and semi-arid to semi-humid.
- (j) **(Sub) Tropical Grasslands:** Tropical and subtropical grasslands, savannas, and shrublands are a grassland terrestrial biome located in semi-arid to semi-humid climate regions of subtropical and tropical latitudes. Grasslands are dominated by grass and other herbaceous plants. Savannas are grasslands with scattered trees. Shrublands are dominated by woody or herbaceous shrubs. Rainfall in tropical and subtropical grasslands is between 450 and 1500 millimeters (18 to 60 inches) a year and can be highly seasonal, with the entire year’s rainfall sometimes occurring within a couple of weeks.
- (k) **Desert:** A desert is characterized by an extremely low amount of precipitation, less than enough to support growth of most plants. Deserts are defined as areas with an average annual precipitation of less than 250 millimetres (10 in) per year or as areas where more water is lost by evapotranspiration than falls as precipitation.
- (l) **Flooded Grasslands:** Flooded grasslands and savannas is a wet terrestrial biome. Its component ecoregions are generally located at subtropical and tropical latitudes, which are flooded seasonally or year-round. Flooded grasslands and savannas are characterized by wet conditions, warm temperatures, and nutrient rich soil.
- (m) **Riparian:** A riparian zone is the interface between land and a river or stream. The assortment of riparian zone trees varies from those of wetlands and typically consists of plants that either are emergent aquatic plants, or herbs, trees and shrubs that thrive in proximity to water.
- (n) **Wetlands:** A wetland is an area of land whose soil is saturated with moisture either permanently or seasonally. Such areas may also be covered partially or completely by shallow pools of water. Wetlands include swamps, marshes, and bogs, among others. The water found in wetlands can be saltwater, freshwater,

or brackish. Wetlands are considered the most biologically diverse of all ecosystems.

2. **Ground Porosity:** Along with flow resistivity, the ground porosity has a significant effect on the ground reflected sound field. Estimate the quality of the nearby ground from 1 (soft) to 5 (hard). The descriptions in parentheses (snow, grass, bare ground, talus, and pavement) are provided as guidelines only; for example the floor of an evergreen forest is likely to be similar to grass, water is similar to pavement, and bare ground packed with dust can be similar to pavement as well.
3. **Veg Cover:** Vegetation cover refers to the relative area occupied by the understory. Plants in the understory consist of a mixture of seedlings and saplings of canopy trees as well as shrubs, herbs, etc.
4. **Canopy Cover:** Canopy cover is the relative area not open to the sky due to leaves and branches of tall trees.
5. **Potential Srcs:** This section is for identification of any nearby acoustic sources that may dominate the soundscape during the measurement period. These may not be active during setup such as a road with no traffic, trail with no hikers, or a calm lake. Mechanical refers to miscellaneous machinery (e.g. generator, grounds care). Circle all that apply.
6. **Use:** Indicate the type of park management in which the site is located.

### Equipment

1. **Digital Audio Recorder (DAR):** list the make and model of the digital audio recorder (e.g. Roland R-05) as well as the serial number (EV33920).
2. **Sound Level Meter (SLM):** list the make and model of the sound level meter (e.g. Larson Davis 831) as well as the individual serial number (e.g. 1480).
3. **Microphone:** list the make and model of the microphone (e.g. PCB 377B20) as well as the individual serial number (e.g. 106638).
4. **Preamp:** list the make and model of the preamp (e.g. LD PRM902) as well as the individual serial number (e.g. 3582).
5. **Calibrator(s):** list the make and model of the calibrator (e.g. B&K 4231) as well as the individual serial number (e.g. 2122929). If the calibrator used during a site visit is different than used during setup, list it as well.

### Settings

1. **Audio Bitrate:** The data rate of the compressed audio recording in kilobits per second (kbps). File format is assumed MP3, indicate in notes if otherwise.
2. **Recorder Gain:** The gain, or input level, for the audio signal input to the digital audio recorder.
3. **SLM Gain:** The sound level meter preamp gain in dB (e.g. this is usually +20 dB for a Larson Davis 831 deployed for natural ambient monitoring).
4. **OBA Range:** This refers to the dynamic range of the SLM Octave Band Analyzer. Depending on the SLM, could be high, normal, or low.
5. **Noise Floor:** The wideband sound pressure level indicated by the sound level meter with dummy mic (dB).

6. Weather Station: Weather station components (e.g. anemometer) and manufacturer (e.g. Davis). Indicate NA if no weather station present.

#### Visit log

1. Date: Day, month and year of visit.
2. Arrive and Depart Time: Estimate of your arrival and departure to and from the site (roughly 50 meters from the microphone). Use GPS time in the same time zone as specified under 'Location'.
3. Voltage (SLM and DAR): Measurements of the DC voltage of the battery source for individual devices.
4. SLM Time Drift: Comparison of the time indicated on the SLM versus GPS time, relative to the GPS (e.g. if the GPS time is 12:00:00 when the SLM is 11:59:57 the SLM time drift is -00:00:03)
5. Clock Reset?: Indicate Y if the SLM clock is synchronized to GPS time. This requires momentarily stopping the recording and is not recommended to correct minor clock drift.
6. Cal. Level: Comparison of the sound pressure level indicated by the SLM to the level of the calibration tone, relative to the calibration tone level (e.g. if the SLM reads 94.3 dB and the calibrator emits a 94 dB tone, the Cal. Level is +0.3 dB). It is assumed that if a deviation greater than  $\pm 0.1$  dB is measured then the SLM was recalibrated.
7. Notes: Space for any additional information.

## 4.2 Equipment Setup

This section will walk you through the physical setup of the monitoring equipment hardware, as well as the interconnects between the various components. Some connectors are fragile, or must be inserted in a certain orientation. To prevent damage to any of the equipment, do not force any connections. Also keep in mind that this system will be exposed to the elements for almost 30 days, so make sure connections are solid, loose ends are secured (to prevent flapping in the wind), and no sensitive electronics are exposed.

### 4.2.1 Tripods and Cases

When setting up the tripods and cases, it is good practice to place the equipment and battery cases centrally, between the two tripods. Try to choose a level area for the cases. The tripods should be far enough from the cases to prevent noise from the anemometer being picked up by the microphone, but not so far as to have the location of the anemometer be dissimilar to the location of the microphone<sup>1</sup>. Take the length of the microphone and anemometer cables when choosing locations (usually 10-15 ft).

The microphone and anemometer should be placed at a height of roughly 60 inches above the ground. The environmental housing for the preamplifier is 10 inches long, so set the height of the microphone tripod to 50 inches above ground. For additional stability, one of the legs of the tripod for the anemometer should be facing due north, as the anemometer will be mounted over this leg. Using parachute cord (or similar strong, thin, and flexible cord) and tent stakes, create guy-lines from the center of the tripod *over* each leg. To ensure an adequate amount of tension in the line, use a taut-line hitch, or a line tensioning device, such as a ClamCheat<sup>®</sup> Line-Lok<sup>®</sup>.

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<sup>1</sup>The anemometer is used to estimate the wind speed moving over the microphone.

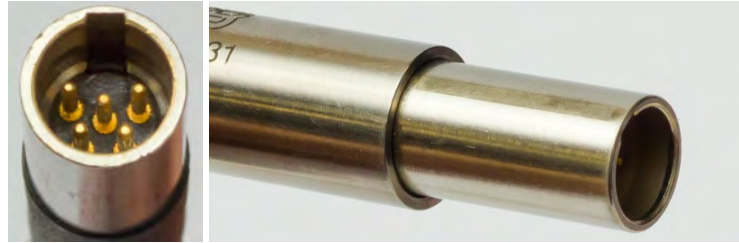


## 4.2.2 Microphone and Anemometer

### Microphone

Setting up the microphone requires attaching components in a certain order, as some ports allow the cable to pass through in only one way.

1. Unscrew bottom portion of the environmental microphone housing (smaller black portion)
2. Pass female end of microphone cable (end *without* black ferrite core on the cable) through the housing from the bottom
3. Reattach bottom portion of the environmental microphone housing, careful to keep cable in the small pass-through of the acrylic tube to prevent damage to the cable
4. Mount housing onto the tripod
5. Locate the grooved portion of the preamplifier (figure 4.1(a)). It is also marked with a faint matte line (figure 4.1(b)).
6. Connect the preamplifier to the cable, aligning the groove with the black release button on the cable (figure 4.1(c)).
7. Push the preamplifier down into the housing until it is fully seated (figure 4.1(d)).
8. If you do not need to calibrate the microphone, slide the bird spike and windscreen onto the housing, and secure with the black set screw. It should look similar to figure 4.2.



(a) Preamplifier groove

(b) Preamplifier line marking



(c) Aligning the preamplifier



(d) Seating the preamplifier

Figure 4.1: Setting up the environmental housing



Figure 4.2: Assembled microphone tripod

### Anemometer

The arm of the anemometer will be pointing due north (and directly over a tripod leg, if the tripod was aligned this way). If the mounting block is not attached to the anemometer, attach it now. Care should be used when inserting the arm into the socket as to not crimp the flat cable exiting the anemometer, and the socket may need to be pried open slightly. To secure the arm, thread the small machine bolt provided in the bag with the rest of the anemometer mounting hardware through the appropriate hole in the socket, and attach the matching nut. For convenience, NSNSD recommends using wingnuts instead of the supplied nuts on the U-bolts.

1. Insert U-bolts through the mounting block so that the threaded ends face the anemometer arm.
2. Thread the wingnuts onto the bolts, but do not tighten.
3. Slide anemometer over extended tripod center column. The larger post (or wind vane if assembled) should be on top. See figure 4.3(a).
4. Hand-tighten the lower U-bolt
5. Insert RH/T sensor arm between center column and upper U-bolt. Run cable through U-bolt. See figure 4.3(c) for a detailed view.
6. Hand-tighten the upper U-bolt.
7. Attach the wind cups to the lower post on the anemometer. Make sure they are pushed up as far as they can go. See figure 4.3(b).
8. Tighten the small black hex screw in the side of the wind cups.
9. Leave the wind vane off until calibration has been performed (see section 4.4.4).

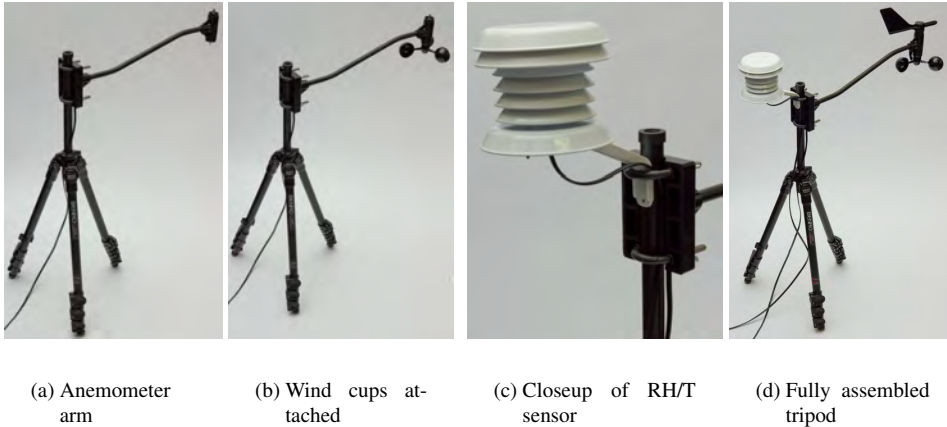


Figure 4.3: Setting up the weather sensors

### 4.2.3 Power

The eight  $\text{LiFePO}_4$  will be connected to the battery connector assembly to provide the 12V supply that the system requires. For safety reasons, make sure that the batteries are oriented in such a way that the terminals cannot come in contact with each other, or the assembly box.

1. Plug all 8 batteries into the bank connector (figure 4.4).
2. Make sure each battery bank is working:
  - (a) Disconnect any battery from one of the two banks.
  - (b) Ensure the voltage coming out of the assembly box is  $\geq 12.6\text{V}$ .
  - (c) Reconnect the battery.
  - (d) Disconnect any battery from the *other* bank.
  - (e) Ensure the voltage coming out of the assembly box is  $\geq 12.6\text{V}$ .
  - (f) Reconnect the battery.
3. Plug one end of an extension cable into the assembly box.
4. Carefully route the cable through the channel on the lip of the pelican case.
5. Close the lid.



Figure 4.4: Battery bank connector, a.k.a. “battery squid.”

#### 4.2.4 Larson Davis 831 and Roland R-05

Inside the equipment case are three important components: the Larson Davis 831, the Roland R-05, and the interface box. In addition, you should have the following cables:

- 3.5 mm stereo cable, male/male
- 2.5 mm stereo cable, male/male
- Larson davis data cable (one end is terminated with an RJ-45 jack, the other end is terminated with a Hirose connector)
- Interface power connector (one end is terminated with a black-tipped DC power barrel, the other end is terminated with a red and black Powerpole connector)
- Roland R-05 power connector (one end is terminated with a yellow-tipped DC power barrel, the other end is terminated with a red and black Powerpole connector)

##### Audio connections

There are three main audio paths: microphone to LD831, LD831 to interface box, and interface box to R-05. There is no specific order in which to connect the cables.

- Connect the 3.5 mm stereo cable to the interface box (figure 4.5(a)) and the *Line-In* port on the R-05 (figure 4.5(b))
- Connect the 2.5 mm stereo cable to the interface box (figure 4.6(a)) and the headset port on the LD831 (figure 4.6(b)). The LD831 port is recessed, so check to make sure the jack was plugged in all the way (you should feel a “click”).
- Connect the male end of the microphone cable to the top of the LD831 (figure 4.7)<sup>2</sup>. To release the cable, press the grey button (highlighted by the arrow) and pull the cable away from the LD831.



(a) Interface box



(b) Roland R-05

Figure 4.5: Audio connection between interface box and Roland R-05

<sup>2</sup>The connector has a specific alignment, and can only fit in one orientation: with the LD logo on the black plastic of the cable facing up.



(a) Interface box



(b) Larson Davis 831

Figure 4.6: Audio connection between interface box and LD831



Figure 4.7: Microphone cable connection to the LD831

### Data connections

There are three data connections: LD831 to interface box, RH/T sensor to interface box, and anemometer to interface box. There is no specific order in which to connect the cables. *Note: the LD831 data cable also provides power to the LD831.*

- Connect Larson Davis 831 data cable to the interface box, screw side up (it cannot fit any other orientation). See figure 4.8(a).
- Connect the RJ-45 end of the data cable into the “LD831” jack of the interface box. See figure 4.8(b).
- Plug the anemometer cable into “Wind” jack on the the black box, tab side facing up. See figure 4.9.
- Plug the RH/T sensor cable into “Temp” jack on the the black box, tab side facing up.

### Power connections

The interface box is powered by an external 12V supply, and provides power to the Larson Davis 831. The Roland R-05 is powered independently by a 3.2V supply.

- Plug the black-tipped DC barrel connector into the 12V jack on the interface box. See figure 4.10(a).





(a) Interface box



(b) Larson Davis 831

Figure 4.8: Data/power connection between interface box and LD831



Figure 4.9: Weather connection into the interface box

- Connect the powerpole connector from the previous step to the external **12V** battery pack.
- Plug the yellow-tipped DC barrel connector into the R-05. See figure 4.10(b).
- Connect the powerpole connector from the previous step to the single external **3.2V** battery.



(a) External power connection







(b) Power connection for the Roland R-05

Figure 4.10: Power connections

## 4.3 Instrument Settings

### 4.3.1 Larson Davis 831

1. Confirm that the small toggle switch on the bottom of the LD 831 is switched to Power On ().
2. Press and hold the power button () to turn on.
3. Remember to hit the STOP/STORE button () when you power on the LD 831. (It will automatically be running. This means that later you may find a very small file has been created.)
4. Format USB thumb drive if using one (otherwise continue to step 5).
  - (a) In the main screen, press the TOOLS button () and choose SYSTEM PROPERTIES.
  - (b) Select the PREFERENCES tab. (scroll using right soft key)
  - (c) Make sure the USB host port is turned on.
  - (d) Exit menu. (center soft key)
  - (e) Go back to the TOOLS menu and select SYSTEM UTILITIES.
  - (f) Select FORMAT USB. This takes about 45 seconds. *Be careful not to format anything else.*
5. When in the main screen, select the TOOLS button.
6. Select SYSTEM PROPERTIES.
 

*Used to identify and/or control functions of LD not related to sound measurement or calculations. Scroll through tabs using small soft keys directly below screen.*

  - (a) Select Device tab. *Used to enter information about the instrument.*
    - i. Name equipment with site name. (e.g., ARCH001 - same as in General Tab)
    - ii. Highlight the field to be changed, hit ENTER. Scroll up for letters, down for numbers and symbols.
  - (b) Select Time tab.
    - i. For precise time recording, sync the LD831 time with the GPS time.
    - ii. Highlight the field to be changed, hit ENTER. Use up and down buttons to change.
    - iii. Set LD831 time a few seconds ahead of GPS time, press ENTER, then prepare to press SET TIME exactly when the GPS time matches.
  - (c) Select Power tab. *Used to select power settings.*
    - i. Battery type: **NiMH**  
*Doesn't matter unless you are running the unit on AA batteries*
    - ii. Auto Off-Time: **Never**  
*Very important so that LD doesn't power down when you leave*
    - iii. Power save time: **10 min.**  
*This will turn the screen off after 10 minutes of no activity. The meter will still be running. To turn the screen back on, hit any button once.*
    - iv. Backlight time: **Does not matter.**
    - v. Backlight: **off**
    - vi. Ext Shutoff Voltage: **10.8**  
*Automatically shuts off LD when battery level gets too low.*

- (d) Select Preferences tab.  
*Used to configure certain instrument functions.*
    - i. Mic Corr: **off**  
*Applies a microphone correction if using a free-field mic or random incidence response mic.*
    - ii. Auto store: **store**  
*LD automatically saves a data file when STOP/STORE key is pressed.*
    - iii. Jack Function: **AC/DC**  
*Set to output signal from detector. \*Check this setting if Edirol isn't receiving audio input.*
    - iv. Reset Prompt: ☐  
*Box is not checked. User will not be prompted when the reset key is pressed.*
    - v. USB host port: **off**  
*This must be on if using USB drive for storage and not internal memory.*
  - (e) Select Localization tab.  
*Used to select formats for parameters which may vary from one country or region to another.*
    - i. Language: **English**
    - ii. Decimal symbol: **.** (**period**)
    - iii. Date: **y-m-d**
    - iv. Units: **SI**
  - (f) Select Options tab.  
*Used to enable/disable installed options on the LD.*
    - i. The following settings are **required** to be checked: 1/3 Octave, Time History, and Weather.
  - (g) When finished, hit CLOSE. If prompted, reply yes to save changes.
7. Select Setup Manager from TOOLS menu, press ENTER.  
*Allows user to create and store a number of user-defined measurement setups for easy recall, editing, and use.*
  8. Highlight LD NPS (a non-active profile) and hit MENU (right soft key).
    - (a) If there is a profile called LD NPS in the list, then skip to step 9.
    - (b) If there is not a profile called LD NPS, then create one.
      - i. Highlight LD default and hit MENU (right soft key)
      - ii. Scroll down to Save As, press ENTER.
      - iii. Rename folder NPS.
      - iv. Highlight the word default, press ENTER. Scroll down for upper case letters and blank space. Press ENTER, scroll down and press YES to save.
      - v. You should now have an Active profile, a default profile, a non-active NPS profile, and any other folders you have added in the past.
  9. Edit the LD NPS profile.
    - (a) Select LD NPS and hit MENU (right soft key).
    - (b) Scroll down to Edit, press ENTER.
    - (c) Page left to the General tab using the soft keys. (Used to enter a file name and a measurement description for the measurement being defined.)
      - i. Default data file = SiteName (e.g., ARCH001)

- (d) SLM Tab *Used to set parameters for the measurement of sound levels.*
- i. Frequency weighting: **A**  
*Choose either A, C, or Z frequency weighting: A weighting (dBA) adjusts the levels of a frequency spectrum in the same way the human ear does when exposed to low levels of sound. C weighting (dBC) adjusts the levels of a frequency spectrum in the same way the human ear does when exposed to high levels of sound. Z weighting does not adjust the levels of the spectrum. It has a passband from 10 Hz-20 kHz.*
  - ii. Detector: **Fast**  
*Speed at which the sound level meter converts the actual sound signal from the microphone to a signal that indicates amplitude.*
  - iii. Peak Weighting: **Z**  
*Measures peak sound level values using a user-selected frequency weighting.*
  - iv. Integration Method: **Linear**  
*Integrates only energy that occurs during a given period and does not exhibit the decay slope.*
  - v. +20 dB Gain: ☒  
*This increases the gain by 20 dB. When measuring low level sounds, the sound level may approach background noise level of the instrument.*
- (e) OBA Tab  
*Octave Band Analyzer: used to set the real-time octave frequency analysis.*
- i. OBA Range: **Low**  
*Low Range = -10-110dB, Normal range = 20-140 dB*
  - ii. Bandwidth: **1/3 Octave**  
*Choose which range of frequencies to use. 1/1 Octave: no splitting of octave bands, very little detail of frequency of sounds; 1/3 Octave: subdivides octave bands into 3 bands, finer frequency resolution.*
  - iii. Frequency Wt.: **Z**  
*Weighting filters in which the 1/1 or 1/3 octave frequency analysis modules process data.*
  - iv. Spectral Ln Mode: **Off**  
*Measures spectral Ln values; turn off to reduce memory use*
- (f) Control Tab  
*Used to set the mode of measurement timing and the storage of measurement history records.*
- i. Run mode: **continuous**  
*Select the mode of measurement duration. Continuous: measurements are taken continuously.*
  - ii. Auto store: **1/day**  
*Automatically stores daily measurement reports for 24-hour periods.*
  - iii. Time: **00.00.00**  
*Time at which daily measurement reports are stored, set to midnight.*
- (g) Time History Tab  
*Used to setup the timing and select the metrics that are stored in the time history*
- i. Enable Time History: ☒
  - ii. Period: **1 s**
  - iii. Time History Options  
*The acoustic and non acoustic metrics that are logged. Scroll down to the Time History Options box, press ENTER to cycle through options, use left and right to check and uncheck options. Only the following boxes should be checked:*

- ☒ LAeq  
*integrated A-weighted value evaluated for the time interval since the preceding sample*
- ☒ LCeq  
*integrated C-weighted value evaluated for the time interval since the preceding sample*
- ☒ LZeq  
*integrated Z-weighted value evaluated for the time interval since the preceding sample*
- ☒ OBA 1/3 Leq  
*Leq for 1/3 octave frequency bands*
- ☒ Wind speed
- ☒ Gust Dir.
- ☒ ADC1 Avg  
*external temperature field*
- ☒ ADC2 Avg  
*humidity field*
- ☒ External power
- ☒ Internal temp  
*internal temperature of the LD*

iv. Press ENTER.

(h) Weather Tab

*Scroll all the way to the right; Used to setup external transducers for the measurement of wind speed, wind direction, temperature and humidity*

- i. Select Weather-INT from dropdown menu.
- ii. From Settings drop down, select WIND
  - Scale: **1.0064**  
*Wind sensor scale factor for using Davis Anemometer with m/s*
  - Units: **m/s**  
*Meters per second*
  - Gust Dir: **Degrees**  
*Display wind direction in degrees*
  - Threshold: **5**
  - Excd. Level: **40**
  - Hysteresis: **10**
- iii. From Settings drop down, select Temperature
  - Scale: **204.8**  
*Range of values the sensor can detect*
  - Offset: **-60**  
*Adjusts lower limit of temperature sensor*
  - Units: **°C**
- iv. From Settings drop down, select Humidity
  - Scale: **216.25**  
*Range of values the sensor can detect*
  - Offset: **0**
  - Units: **mV**  
*Millivolts*
- v. Select the CLOSE soft key. If prompted, reply 'yes' to save changes.

10. Highlight the LD\_NPS profile, then select MENU by hitting the right soft key.

11. Select **SAVE AS** from menu (by pressing **ENTER**)
  - (a) Save file: **NPS**
  - (b) Select **YES** to save file.
  - (c) Overwrite file: **yes**
12. Highlight **LD\_NPS** profile, and select "menu" by hitting the right soft key.
13. Select load settings from menu (by pressing **Enter**)
  - (a) Apply changes: **Yes**
  - (b) May get a message saying reset required, select **Okay**
14. Close setup manager with middle soft key.
15. Close again to return to main menu.
16. Close again to close Control Panel and return to the live recording screen.
17. Check the anemometer wind direction calibration which you began in Section 2.
  - (a) When in the live recording screen, hit the up button 3 times to display meteorological information.
  - (b) Confirm that wind direction reports properly on the compass displayed on the LD831 screen by slowly rotating the wind vane. If not, adjust the silver dial beneath the vane as described in section 2.
  - (c) Confirm that when the anemometer cups are gently rotated, a non-zero wind speed is reported in meters/second.
  - (d) Hit the down button 3 times to display the live recording screen.

### 4.3.2 Edirol R-05

1. Make sure there is an SD card in the Edirol by opening the SD cover at the top of the Edirol.
2. See sections 4.2.3 and 4.2.4 for how to connect power and audio cables if you have not already done so.
3. Check sliding button settings on back of unit
  - Mic Gain: **N/A**  
*Setting not applicable for standard monitoring*
  - Limiter: **Off**  
*Suppresses noise by lowering the volume level when the sound input is too high. Keep off to prevent sounds from being altered*
  - Low Cut: **Off**  
*Cuts out the low frequency sounds, needs to be turned off to record the lower frequency range.*
4. Power on by sliding the power switch toward **POWER** for a few seconds (on right side of Edirol)
5. Check to make sure that SD card isn't full by pressing **FINDER** button once. The root directory and all file names present on the SD card will be displayed.
6. Navigate to Menu by pressing and holding **MENU** button.

- (a) Highlight Recorder Setup then press the red REC button.
  - Sample Rate: **44.1 kHz**
  - Rec Mode: **MP3-96Kbps**  
*Lower sound quality but smaller than WAV files and allows for longer recording time*
  - Pre-Rec: **Off**  
*Captures the two seconds of sound that precedes the moment the rec button is pressed*
  - File Name: **Date**  
*Sets how file names are assigned*
  - Auto Rec Start: **Off**  
*Recording starts automatically when a specified time has elapsed, or when the recording level exceeds a specified value*
  - Split Type: **256 Mb**  
*Specifies the size at which the files are split*
7. Navigate back to Menu by pressing MENU button.
  - (a) Highlight Display Setup then press the red REC button.
    - Contrast: **5**  
*Adjusts the contrast of characters in the display*
    - Backlight: **2**  
*Adjusts the brightness of the backlight*
    - Display timer: **2 sec**  
*Turns off display when no operations are performed after the set time*
    - Rec/Peak LED: **Power save**  
*Indicates if the REC and Peak LED indicator turn off with the display timer*
8. Navigate back to Menu by pressing MENU button.
  - (a) Highlight Power Manage then press the red REC button.
    - Auto power off: **Off**  
*Turns off power when no operation is performed in a set time*
    - Battery: **Alkaline**  
*Defines the battery type*
9. Navigate back to Menu by pressing MENU button.
  - (a) Highlight Date & Time then press the red REC button.
  - (b) Use the GPS time to adjust the time on the Edirol to the appropriate time and date. When the time and date on the GPS and Edirol match, press red REC button. Time on the Edirol will be updated.
10. Navigate back to Menu by pressing MENU button.
11. Press FINDER button once to display recording screen.
12. Press FINDER button once to display contents of SD card.
13. Create folder to save MP3 files in.
  - (a) Press REC button once and select option 2, make folder.
  - (b) To name folder, use up and down button to highlight New Folder.
  - (c) Press REC button and select option 4, Rename.



- (d) Up and down arrows will change the selected letter fields (holding them makes the character change faster)
  - (e) Rename the folder with site name (ie MORA005). Hit REC button to save new folder name.
14. Save MP3 files in new folder by selecting folder name and choose option 1 "select" by hitting the REC button.
15. Note: Files can also be created on an SD card using a PC by connecting the Edirol via a mini-USB or by using an SD card reader connected to a PC.

## 4.4 Calibration

One of the most important properties of a measurement device is sensitivity: the ratio of the output parameter to the quantity present in the environment. Calibration is a process to determine the sensitivity of a measurement device. This is often accomplished by a comparison between two measurements of the same quantity — one known with a higher degree of precision than the other. A calibration is performed:

- To ensure that measurements are correct
- To verify the stability of the measurement equipment, including equipment used to perform calibration
- To account for local measurement conditions (e.g., variations in ambient pressure and temperature)
- To prove that measurement methods and the equipment used are accurate. (e.g., to prove that a measurement complies with the requirements of national legislation, standard bodies, and customers)
- To ensure product quality
- To build confidence in measurement results

To calibrate sound level meters using a 1/2" microphone, the NSP uses Brüel & Kjær acoustical calibrator type 4231 (hereafter referred to as the calibrator) [figure:bk4231.jpg]. This device has a calibration accuracy  $\pm 0.2$  dB. Check to ensure the calibration of the calibrator itself is valid by inspecting the due date, usually located on the protective leather case. When a microphone is securely positioned in the calibrator cavity, the 1kHz tone emitted by the device will reach a sound pressure level of 94dB. Although the calibrator shields the microphone from some outside sound, perform the calibration in as calm an environment as possible (e.g. calm wind, absence of talking, etc.). It switches off automatically when removed from the microphone.

### 4.4.1 Larson Davis 831

Assuming the LD831 is on, stopped, and appropriate parameters have been set (section 4.3.1), follow these steps to calibrate:

- Hit the TOOLS button to open control panel.
- Navigate to the CALIBRATE icon using the arrow buttons and press ENTER.
- Ensure that calibrator field says 094.00 dB at 1000.0 Hz. Towards the bottom of the screen, there is a radio button that will activate this preset if necessary.
- Place the calibrator on microphone and turn on.

- Use the up and down arrows to select the CALIBRATE on screen button (a box will appear around the word 'Calibrate' when it is selected).
- Press ENTER to begin the calibration procedure. The current calibration level of the system as well as the offset is displayed. Log calibration results on site visit sheet.
- Respond YES to save results. If the conditions are not stable (heavy wind or loud external noise for example) the calibration may fail. Wait for calmer conditions and try again.
- Close the calibration tool by hitting the middle soft key.
- Close the control panel by hitting the middle soft key.

#### 4.4.2 Roland R-05

This Roland R-05 procedure assumes the digital audio recorder is paired with a sound level meter such as the Larson Davis 831 and is receiving an audio signal through the line-in jack.

- Place a calibrator on the sound level meter microphone; activate the calibrator.
- On the R-05, press REC to put the device in Standby mode.
- Adjust the input level using the + and - buttons on left side of R-05. The correct level should be two increments *below* the point at which the peak indicator level is illuminated (normal value is 20). If input level is outside normal range, refer to appendix [4.8.2](#).
- Press REC again to begin recording. Notice that recording time is advancing. Record 30 seconds of the 94dB calibration tone. Press stop to end recording.

#### 4.4.3 Noise Floor

Standard calibration verifies the values recorded are accurate, but it does not give a lower bound to the measurements. To do so, the inherent noise in the system must be measured, giving a value below which measurements are no longer valid. This noise floor is system specific, influenced by factors such as length of cables used, type of power supply, irregularities in the SLM and preamplifier, and any local electromagnetic interference (possibly due to power lines). Since these factors do not change during the course of monitoring, *this measurement only needs to be performed on initial setup at a site.*

- Verify the Larson Davis 831 is turned on, but not logging.
- *Carefully* unscrew the microphone capsule from the preamplifier by turning counter-clockwise (see figure [4.11\(a\)](#)).
- Screw the “dummy mic” onto the preamplifier (see figures [4.11\(b\)](#) and [4.11\(c\)](#)).
- Wait several seconds for the SLM to stabilize, and then read the  $L_{eq}$  reading from the main screen. Log this on the site visit data sheet.
- Record 30 seconds of audio on the R-05 with the dummy mic attached, to be able to differentiate silence in the field with the static of the system.
- Unscrew the dummy mic and replace with the microphone capsule.
- Check the calibration on the LD831 using the procedure from [4.4](#).



(a) Detaching the microphone capsule



(b) Dummy mic orientation



(c) Dummy mic connected

Figure 4.11: Attaching the dummy mic

#### 4.4.4 Anemometer: Wind Direction

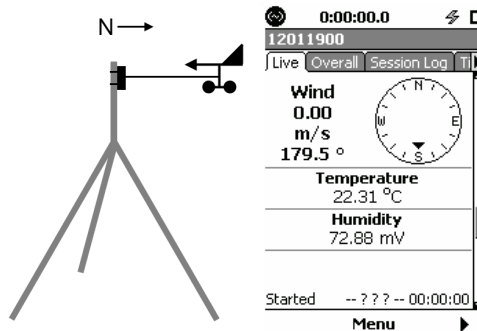
Ensure all physical connections between the anemometer/wind vane and LD831 are correct and the appropriate parameters are set (section 4.3). Note that the convention is that a north wind is one that blows from the north, and the vane will point in the direction the wind originates. To obtain an accurate reading, the wind vane must be located well above the ground and away from buildings, trees, and other objects which interfere with the true wind direction.

- Adjust the tripod such that the weather vane is level and the wind vane arm points to north.
- Remove the vane on the top of the anemometer to expose the vane shaft (figure 4.12(a)).
- Scroll up or down three times from the LD831 live tab to display the weather screen
- Twist the shaft so that LD831 compass reads south.

- Replace the vane so that the nose is pointing south and the tail points north (figure 4.12(b)).
- To confirm the orientation of the anemometer, check the LD831 compass. The compass should indicate the direction in which the wind is coming from (figure 4.12(a)).
- Rotate windcups and verify windspeed is being shown on LD831 screen under “Wind.”



(a) Wind vane shaft



(b) Proper orientation of the wind vane

(c) Larson Davis screen showing wind direction

Figure 4.12: Orienting the wind vane

## 4.5 Final Preparations

1. Check all cords to make sure they are adequately protected and taped down.
2. Check guy lines to make sure that tripods are secure.
3. Make sure all red/black power pole connections are inside a pelican case.
4. Confirm that SLM is running (a “play” symbol will be displayed), audio is being recorded (the clock on the R-05 is running and “Rec” is displayed in the lower-left corner of the display), and anemometer is functioning.
5. Confirm that “Hold” is switched **on** for the audio recorder.
6. Make an audio timestamp by clearly stating your name, location, site name, date, and current GPS time into the microphone. To aid in time-synchronization, it is useful to make an impulsive sound as a time marker (e.g., “When I clap my hands, the time will be 11:35:30.”)
7. Estimate time when you will be more than 50 yards away (5-10 minutes) from the site during your departure, and record on site visit data sheet.
8. Lock pelican case containing SLM to an immovable object, or lock battery cases and SLM case together.
9. If site is being deployed, take a few photographs to document the exact placement of equipment.
  - Position yourself in the center of the monitoring site.
  - Face north
  - Take one photo in each of the cardinal directions, in a clockwise manner.
  - If needed, take photos at the ordinal directions (NE, SE, etc.).
10. Leave.
11. If time allows, perform on-site listening session. See section 4.7, “On-Site Listening.”

## 4.6 Site Visits

At least one site visit (after set up) is recommended during the monitoring period. Most failures occur within the first 24 hours; if everything works well for a day it will likely work well for a month. Site visits are also an opportunity to retrieve data and conduct on-site listening sessions.

### 4.6.1 Site Visit Checklist

1. Record an audio timestamp: stand by the microphone and state aloud the site name and GPS time. When GPS clock displays those numbers, clap your hands once. In the notes field of the site visit data sheet, record when the timestamp was performed (e.g. TS = HH:MM:SS).
2. Estimate when you were 50 meters away and record the arrival time on the site visit data sheet.
3. Confirm that all equipment is connected, powered on and logging: the sound level meter, digital audio recorder, weather station, etc.

4. Check the power source(s) and record the DC voltage on the site visit data sheet. Do not disconnect the power to do this. It can be accomplished by touching the volt-meter leads to any parallel connection, such as a pigtail socket. The battery voltage is indicative of remaining battery capacity.
5. Check the SLM time drift and record this on the site visit data sheet. Compare the time indicated on the SLM versus GPS time, relative to the GPS (e.g. if the GPS time is 12:00:00 when the SLM is 11:59:57 the SLM time drift is -00:00:03)
6. On the site visit data sheet, indicate whether or not you have re-synchronized the SLM clock to GPS time. This requires momentarily stopping the recording and is not recommended to correct minor clock drift.
7. Remove windscreen from the microphone and check calibration of the SLM. If the measured level is within  $\pm 0.1$  dB no calibration is necessary. If the deviation is greater than  $\pm 0.1$  dB, calibrate the SLM (see section 4.4 for details). In either case, replace the windscreen and record the deviation under Cal. Level on the site visit data sheet.
8. Assuming the sound level meter is an LD831, check to ensure that files are being created daily at midnight. Navigate to the Data Explorer window. With weather information, files will be about 16 MB; without weather information, they should be about 14 MB each.
9. Use the notes field of the site visit data sheet to record any other information. Use additional lines if necessary.
10. Confirm that all cables are intact and connections are secure.
11. Remove dust and/or pollen from solar panels with a soft cloth and water if necessary.
12. Estimate the time when you will be more than 50 meters away (5-10 minutes) from the site and record this under depart time on the site visit data sheet.
13. Double check all the equipment one last time and then lock the cases.
14. Leave.

## 4.7 On-Site Listening

In addition to sound pressure level and audio data, knowledge of the type, context, duration, and distribution of sound sources is crucial for characterizing natural and non-natural acoustic conditions in national parks. This information can be acquired during periods of observer data collection called on-site listening. During an on-site listening session, one inconspicuously listens to the soundscape and takes note of all audible events as they occur. Investigators should have ‘normal’ hearing. Several hours of on-site listening (at least 2.5 percent of the site measurement duration) should be conducted throughout the monitoring period. It is desirable to conduct hour long sessions beginning on the hour, such as from 1000 or 1500, in order to facilitate matching the on-site listening data with hourly acoustic data (NPS/Volpe Acoustic Plan 2006). The following on-site listening procedure assumes use of a Palm PDA and NSP Soundscape V5 software.

### 4.7.1 How to Conduct an On-Site Listening Session

1. Arrive at the listening site a few minutes early. As you approach, and while listening, try to be as inconspicuous in sight and sound as possible. It is best not to alter natural processes such as animal vocalizations or attract the attention of curious humans while listening.

Note: For detailed instructions on how to download on-site listening data from PDA unit and query data, please contact Natural Sounds Program for a separate document, “Instructions for Using Soundscape for Palm V8.”

2. Find a comfortable place to sit, because you will have to sit there quietly for the next hour. Choose a spot at least 50 ft (15 m) from the acoustic monitor and in the same vegetation type as the acoustic monitor. Get settled-if you wish, eat or drink, and make any adjustments to clothing or gear that might make noise (e.g. snaps, zippers, velcro). Sit with the wind to your back. Avoid sitting near any large objects or topographical features that might alter the quality of sound reaching your ears.
3. Remove your hat if it covers your ears.
4. Listen for a few moments with the PDA turned off to acclimatize yourself to your surroundings. Make a mental catalog of the constant sounds you hear at the site (such as wind, water, or birds). These sounds will most likely be the first ones you select as you begin the listening session.
5. Turn the palm on and select the NPS Soundscape V8 software. Synchronize the Palm clock to the GPS time and fill out metadata information (name, park code, site name, etc.). Add any unusual sounds to the palm database. You will need to initiate the metadata process several minutes before the top of the hour so that you will be ready to start on time.
6. At the top of the hour, begin the session (if the on-site listening session is occurring in conjunction with an automated soundscape monitor).
7. As soon as you hear a sound, tap the corresponding button. When that sound is no longer audible, tap the button again. Multiple sounds may be audible at the same time, but you **MUST** be aware of when one sound obscures another. Just because you suspect that a sound is being generated does not mean you can hear it. Unselect a sound if it is being masked by another.
8. Certain sounds will be more difficult to log than others.
  - Birds** Often don't sing constantly, but produce sound at regular intervals. Try to get an idea of the interval of the birds you hear and turn the button off only when an interval is skipped. If the intervals are unclear or irregular, a good rule of thumb is to wait ten seconds after the last sound was made. If you still don't hear birdsong after ten seconds, turn the button off.
  - Aircraft** As they approach and retreat, the sound of aircraft tends to fade in and out. Don't be surprised if you stop hearing a jet and then hear it again almost immediately. Turn the button on and off as the sound fades and becomes audible.
  - Squirrels** Make sounds easily confused with birds. Familiarize yourself with the difference between these sounds before beginning on-site listening.
  - Artifacts** Artifacts are sounds that we create at the listening site that would not otherwise happen if we weren't there. This includes sounds like sneezing, or raindrops falling on a raincoat. Do not enter these noises.
  - Wind and Wind Induced Noise** - Before starting your session, understand the difference between these two terms. "Wind" describes the sound of wind turbulence while "wind induced noise" describes the sound of wind moving other objects to make noise (such as branches creaking or scraping against each other).
9. Document any information using the note feature that would make interpretation of the data easier, such as "I was interrupted by a hiker between X and Y times and was not logging accurately during that period." Use the note feature in PDA application before, during, or after session.
10. It is possible to conduct more than one session in a day, but to avoid compromising data with fatigue, take breaks between listening periods.

## 4.8 Data Retrieval



The components of an acoustical monitoring system save data in two ways, internally and on removable storage devices. This section will discuss the processes for retrieving data from each component, and preparing it for analysis.

### 4.8.1 Larson Davis 831

The LD831 is capable of storing up to 120 days of 1-second, 1/3 octave band sound pressure level files in its internal 2GB memory. However, to facilitate (and considerably speed up download times), you may choose to save files on a daily basis to a 2GB SanDisk thumb drive. Larson Davis recommends SanDisk brand USB drives, not exceeding 2GB in size.


#### USB storage option

Files will be saved to the external USB drive under an 831\_Data folder.

1. Stop the Larson Davis by hitting the STOP/STORE BUTTON once. This will create a partial file for the time between midnight today and now.
2. If the “Auto-Store” option was set to NONE or PROMPT, press the STOP/STORE button again. This instructs the LD831 to save the partial file to the thumb drive. The LD831 will display the USB copy indicator in the top left of the screen ()
3. Wait until the LD831 fully stores the partial file. The time required for this process is directly related to the time of day you are downloading. Later in the day, there will be more information to be stored, and this saving process will take longer. The save is complete when the meter displays the store icon ()

#### Internal storage option

Using the internal storage technique, daily sound pressure level files will be stored to the LD831's internal memory. To offload these data and begin processing, you must:

1. Stop the Larson Davis by hitting the STOP/STORE button once. This will create a partial file for the time between midnight today and now.
2. Press the STOP/STORE button again. This instructs the LD831 to save the partial file to the internal memory.
3. Insert 2GB SanDisk thumb drive into bottom of LD831.
4. Press the TOOLS button.
5. Select SYSTEM PROPERTIES, then select the PREFERENCES tab. Turn the USB port on.
6. Close the SYSTEM PROPERTIES screen.
7. Select DATA EXPLORER, then select MENU.
8. Select MOVE ALL TO USB. This takes 10 to 15 minutes per daily file. Before starting, be sure that you have both time and battery (or external power) to complete the USB download process.
9. Notice that the USB copy indicator in the top left of the screen is displayed () and that the light on the thumb drive is illuminated/flickering while the download is happening.

OPTIONAL: If you would like to continue monitoring without stopping the LD831, you can remove the full USB drive and replace it with an empty one without pausing or stopping the system. The LD831 only accesses the USB drive during download, which you have scheduled at a time when you will not service the site (such as 00:00:00).

NOTE: Once the data is on the thumb drive, it has been deleted from the LD831 unit. Perform backup storage as soon as possible.

TROUBLESHOOTING TIP: Don't see the Move All to USB option in the menu list? Try powering the LD831 down, then restarting while thumb drive is inserted into LD831.



### 4.8.2 Roland R-05

The Roland R-05 used in acoustical monitoring saves data files to secure digital high capacity (SDHC) cards. The quality of recording and size of the memory card will determine the number of files that can be stored. See table 4.1 for an overview of file quality vs. size.

To safely move MP3 files from recording device to permanent storage:

1. Press the stop button on the recording unit.
2. Remove the memory card.
3. Use a card reader to transfer raw MP3 files to permanent storage. Note that files may be named generically (R05\_0001, R05\_0002 etc). Ensure that the directory to which the raw files are saved does not contain any files that are similarly named, as this could result in an accidental erasure of data.
  - If the card reader does not recognize the memory card, make sure it is SDHC compatible.

Capacity of card	Recording quality			
	64kbps	96kbps	128kbps	WAV
8Gb	11.6 days	7.7 days	5.8 days	0.5 days
16Gb	23.1 days	15.4 days	11.6 days	1.0 days
32Gb	46.3 days	30.9 days	23.1 days	2.1 days

Table 4.1: Record time for various size cards and recording bitrates

# Chapter 5

## Data Analysis

### 5.1 Organization

Data organization is of great importance to the study and preservation of high-quality data. It also facilitates navigation through large sets of information. See the following sections for ways to effectively organize data for acoustical analysis.

#### 5.1.1 Directory Structure

Most of the programs offered in the Acoustical Monitoring Toolbox depend on a given directory structure to function properly. This is also the structure required for inclusion in the Natural Sounds Program's data archive.

Park

└ SITEID

└ SPL — *raw sound pressure level*

└ NVSPL — *hourly pressure level data converted into NPS/Volpe format*

└ AUDIO — *either WAV or MP3 samples*

└ PNG — *24 hour portable network graphic (.png) spectrograms*

└ Data — *Meteorological data, site photos, digitized site visit data sheets,  
94 dB and dummy microphone reference recordings*

#### 5.1.2 Digitizing Metadata

For long term data storage and analysis, it is necessary for field-based metadata to be transcribed into a digital format. For site visit data sheets, this can be done using either Microsoft Excel, or scanning. When complete, ensure that all entries are legible and correct. Save in the folder labeled DATA, introduced in section ???. You will refer to this information to determine what data to analyze and conversely, what data to omit. For photos and other miscellaneous forms of metadata, ensure that the file name includes the proper SITEID (e.g. PARK001), as well as any necessary descriptive information.

### 5.2 Data Preparation and Conversion

#### 5.2.1 Renaming LD831 Data Files

LD831 files are by default date-stamped folders, which usually<sup>1</sup> have a suffix of “.LD0,” and contain three binary files: OVERALL, SLOG, and THIST. In order to review sound pressure

<sup>1</sup>These folders can also have the suffix “.001,” “.002”, or “.RC0”.

level measurement results, you will need to convert these files using a two-step process within the Acoustic Monitoring Toolbox, starting with renaming the .LD0 files.

To rename LD831 files

1. Select LD831 Renamer from the Acoustic Monitoring Toolbox splash page.
2. Fill in site ID field with name of site (for instance, YOSE001).
3. FILE | OPEN DATA FOLDER
4. Select the folder containing .LD0 files. Now, the LD831 Rename program will read the time and date stamps from the binary files and create a number of daily SPL files.
5. Both the original name and the proposed new file name will be displayed.
6. Review the list of files displayed in the LD831 Rename window, and confirm that names and dates are appropriate. If they are not correct, you may select OPTIONS | ADJUST DATE STAMP, and enter begin time of the dataset manually.
7. When satisfied with naming scheme, click the RENAME button. A number of binary files with the following naming scheme will be saved in the same directory as the .LD0 files: SPL\_PARK001\_YYYY\_MM\_DD\_HHMMSS.831.

## 5.2.2 Converting LD831 Data Files

You will now use the .831 files you made in section ?? to create hourly NVSPL files. These are the building blocks of NPS acoustical analysis. With NVSPL files, you will be able to perform a number of tasks and analyses, including generation of spectrograms for each day of monitoring. Spectrograms are graphs which display time, sound pressure level, and frequency by day. They are visual representations of every sound that occurred.

To create NVSPL files:

1. Select the SPL2NV program from the Acoustic Monitoring Toolbox splash page.
2. Select FILE | CHOOSE SPL FOLDER or FILE | CHOOSE SPL FILES. Use the *folder* option when converting an entire site's worth of SPL files (or multiple sites). Use the *file* option when only converting one or two SPL files.
3. SPL file parser will automatically recognize SPL files and report the number in the FILES SELECTED field.
4. You may now choose where to save the NVSPL files by selecting FILE | ALT OUTPUT DIRECTORY. Alternatively, you may choose to accept the default output directory, which is the same folder as the .831 files.
5. Click the CONVERT FILES button to begin converting daily .831 files to hourly NVSPL files. This will take a few minutes per site. You may follow the progress of the conversion with the bar at the bottom of the screen.

## 5.2.3 Renaming Roland R-05 Files

As you may have discovered during the download process, raw MP3 files are generically named (R09\_0001.mp3, R09\_0002.mp3, etc), or by date/time (0526\_083526.mp3). In order to utilize these files properly during the analysis process, and preserve them for archival purposes, we will need to assign relevant site, date, and time information to each file.

To rename MP3 audio files:

1. Select the Audio Renamer program from the Acoustic Monitoring Toolbox splash screen.

2. Enter the name of the site in the SITE ID field (such as YOSE001).
3. Select the radio button corresponding to R-05 in the recorder model groupbox.
4. Select FILE | OPEN FILES, and navigate to the location of the audio files to be renamed.
5. The original file name and proposed file name will be displayed. If everything looks correct, based on the start time provided by an audible timestamp or the site visit datasheet, click the RENAME button.

If the timestamp in the filename looks incorrect:

- If the start time appears to be shifted by an hour or two due to a time zone difference, select the hour that recording started under OPTIONS | START HOUR ADJUSTMENT.
- If the start time appears totally incorrect (due to a recorder that does not timestamp correctly, or an incorrect time stamp at setup), select OTHER in the Recorder model groupbox. You must then provide the exact start date and time for the first file in order to proceed.
  - Recording gap is the time (in seconds) the recorder takes to close one finished recording and start the next. The default recording gap for the R-05 is 0 seconds.

NB: When using manual audio rename mode, the program assumes each file directly follows the previous. If any gap occurs during the monitoring period (due to a data download, power outage, etc.), you must run the rename program for each contiguous batch.

## 5.3 Sound Source Characterization

While sound pressure level measurements tell us how loud the acoustical environment is, and *suggest* what types of sources might be producing the existing sound levels (based on their frequency composition), the only way to be *sure* what sources are present is to review audio recordings. In this section, you will learn the steps required to create a complete inventory of audible sounds at a site. When this process is complete, you will be able to report what sounds were audible, how long they typically lasted, and how often they occurred. Because fully analyzing 30 days of continuous audio data would take far too long, NSNSD examines a subset of SPL and audio data. For each site, NSNSD staff suggests analyzing eight days of spectral data in order to identify durations of audible sound sources. Why analyze eight days? Air Tour Management Plan protocol states that at least 2.5% of continuous data should be analyzed to determine sound sources. Thus, for a 25 day monitoring period (600 hours), analysis must be performed for at least 15 hours. Using the 10 seconds every 2 minutes sub sampling scheme (which extracts 2 hours of audio for each full day of data), one would have to analyze 8 days (16 hours) to meet the 15 hour requirement. For continuity, when using SPL Annotation Tool to visually analyze data, the NSNSD suggests also examining 8 days.<sup>2</sup>

### 5.3.1 Tips for selecting days to listen

- Avoid days where the local measured wind speed exceeds 5 meters per second or 11 miles per hour. If no such days exist, try to select days where these wind speeds are exceeded infrequently.
- Use the wind plots generated by the toolbox to select appropriate days. Any hour where the top of the boxplot exceeds the threshold line will be excluded from data import.
- Avoid days that park staff or NSP staff visited the site. The sounds they made near the site are artifacts of the monitoring effort, and therefore, should not be catalogued.

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<sup>2</sup>See “National Park Service. 2005. Acoustic and Soundscape Studies in National Parks: Draft. Fort Collins, CO: NPS Natural Sounds Program” for further information.

- Avoid the first and last days of the monitoring period. These days are often missing one or more hours of data.
- Oftentimes, parks experience different levels of visitation on weekends and weekdays. Try to select a representative sample of each type for analysis (for instance, five weekdays, three weekend days).

### 5.3.2 Office Listening

Office listening is the act of listening to pre-recorded audio samples, and cataloging the presence of all audible sound sources. It is intended to replace the need for staff to listen for long periods of time in the field. Audio playback and data entry are handled by the Listening Center. The listener should wear headphones (preferably noise-cancelling) to maximize detection of quiet events. As stated above, we will select 8 days out of each dataset to analyze. You should have spectrograms, site visit data sheets, and NVSPL files with meteorological data at hand when you begin this process.

#### Preparing audio samples for listening

- Select the Audio Sampler button from the Acoustic Monitoring Toolbox.
- NSNSD standard sample scheme is 10 seconds of audio every 2 minutes, but you may adjust this if your monitoring protocol calls for something different.
- Select FILE | CHOOSE AUDIO DIRECTORY to select folder where audio files are stored.
- Select the check box beside the day(s) for which you wish to create audio subsamples.
- The audio sample files will be stored, by default, in your My Documents folder under ToolboxOutput\AudioSampler. If this is acceptable, click the SPLIT files button to begin the splitting process.
- To choose a different output directory, select FILE | CHOOSE OUTPUT DIRECTORY and choose a destination directory for the split files.
- Confirm that 720 .WAV files per day have been saved to the output directory you specified.

#### Analyzing audibility in Listening Center

The .WAV files can be played back by a number of audio editing programs, but the NSNSD has produced a custom program for listening, Listening Center.

1. Open Listening Center from the Acoustic Monitoring Toolbox
2. Select FILE | OPEN WAV FILES and choose the audio clip corresponding to the day to be analyzed. *Note: only the first wav file for each split day will be displayed.*
3. When prompted, select the location of NVSPL files for this site
4. The Listening Center window will be populated with two spectrograms
5. The first hour of the day will appear in a continuous spectrogram at the bottom of the screen
6. To begin listening for sound sources, click the Play button in the center of the screen. When audio files are playing, this same button is the Stop button.

7. To skip forward or backward to audio files, use the arrow buttons on either side of the Play button

There are two options for sound source entry:

#### 1. Quick Entry Mode

- In quick entry mode, 11 common sound sources are assigned to the number keypad
- To enter quick entry mode, check the box labeled `ENABLE BUTTON ENTRY`
- When a sound is audible, type the corresponding key. This will enter a record of the sound event into the active (orange) row in the source table
- If you hit the wrong key, you can remove a sound event record from the active row by typing the corresponding key again
- To advance to the next row, hit `ENTER` on the number keypad
- To assign different sounds to buttons, select `OPTIONS | REMAP SHORTCUT BUTTONS`
- In the button mapper window, use the dropdown menus to reassign sound sources to keys
- When finished reassigning buttons, select `OPTIONS | REFRESH SHORTCUT BUTTONS` to see changes

#### 2. Manual Entry Mode

- In manual entry mode, all possible sound codes are available. Select `HELP | SHOW SOURCE LIST` to see a complete list of available sources (`CTRL+?`)
- Use any number key on keyboard to enter values
- To advance to the next row, hit the `ENTER` key
- The row corresponding to the center spectrogram will be highlighted in orange.
- To jump to a particular audio clip, use the dropdown menu at the top of the window, or place your cursor on the row you wish to jump to in the sound source table and hit `CTRL-J`
- Listening center records are automatically saved in `MyDocuments\ToolboxOutput\ListeningCenter`. Filenames will be `LA_PARK000_YYYY_MM_DD_yourname.txt`

### Listening center display options

The Options menu holds a number of display options (color scale, resolution, screen size, etc.)

- To adjust size of Listening Center window, select `OPTIONS | LARGE SIZE, NORMAL SIZE, OR FULL SCREEN`
- To change the color scheme for the spectrograms, select the desired color scheme under `OPTIONS`
- To shift the color scale higher (generally useful for sites that are louder), click `OPTIONS | ADJUST COLORSCALE FOR LOUD SITES`
- To adjust spectral resolution, select `OPTIONS | FFT SIZE`. Increasing the FFT size yields increased frequency resolution but decreases the time resolution

### Tips for office listening

- While it may seem like a simple task, listening is a learned skill, and your accuracy will improve over time. Try a few practice sets before analyzing a dataset that you plan to report on.
- If you did not personally visit the site, review the on-site listening results to see what sounds the field technicians heard.
- Check the site visit data log and site photos to determine what sound sources you are likely to hear (ex: the site was 100m from a stream, or within hearing distance of a road).
- Use the spectral view to your advantage: you should start to notice that each sound has its own spectral “signature,” and you will be able to predict the sounds that will appear in the following clip, based on these visual cues.
- Focus your attention on the mid to lower frequencies to determine whether human caused sounds are present.
- Familiarize yourself with species common to this area or park. Generally, parks publish species lists on their websites under the Nature & Science link.
- To hear sounds of particular bird species, refer to the Cornell Lab of Ornithology’s [All About Birds website](http://www.allaboutbirds.org)<sup>3</sup>.
- To hear sounds of other species, try [Audubon Guides](http://www.audubonguides.com)<sup>4</sup>, or the [Western Soundscape Archive](http://www.westernsoundscape.org)<sup>5</sup>.

### 5.3.3 Visual Analysis

Office listening is an essential tool for calculation of percent time audible at sites where many noise sources occur at once (such as sites near roads or trails). However, at sites where anthropogenic noise is rarely audible (such as remote backcountry sites) the same results can be achieved much quicker through visual analysis of spectrograms. Spectrograms are plots, generated from calibrated sound pressure level data, which display sound level as a function of time and frequency. Most anthropogenic sounds have recognizable sound signatures. Thus, by plotting spectrograms for each site, analyzers can quickly examine many samples within the measurement period. The NSNSD has developed a user-friendly platform for examining spectrograms, called SPL annotation tool, or SPLAT. For every noise event, the user is able to record begin and end times, as well as the frequencies spanned, maximum sound pressure level, and sound exposure level (SEL). In datasets where continuous audio exists, the user can play back corresponding audio for events with questionable sound signatures.

The Natural Sounds Program suggests visually analyzing at least eight days of data, to remain consistent with office listening analysis. It is also recommended that one day of office listening be performed for the same site, prior to visual analysis, to help the analyzer become familiar with sounds likely to occur at the site. Guidance for selection of days to analyze is identical to that used for office listening. You should have spectrograms, site visit data sheets, and access to meteorological data at hand when you begin this process.

### Using SPLAT for source identification

1. Confirm that NVSPL files have been created for the day you would like to analyze. See section 5.2.2 for further instructions.

<sup>3</sup><http://www.allaboutbirds.org>

<sup>4</sup><http://www.audubonguides.com>

<sup>5</sup><http://www.westernsoundscape.org>

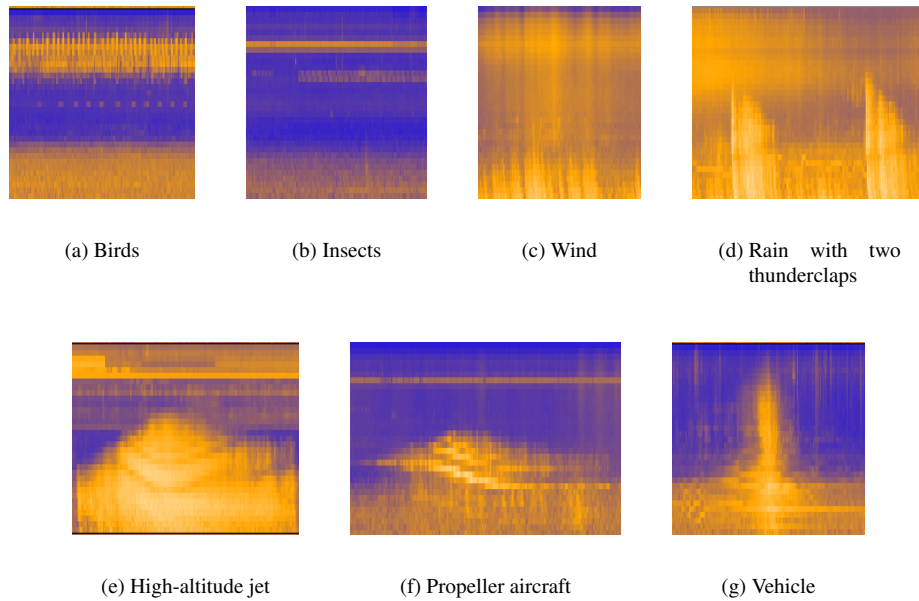




Figure 5.1: Examples of various sound sources as they would appear in spectrograms

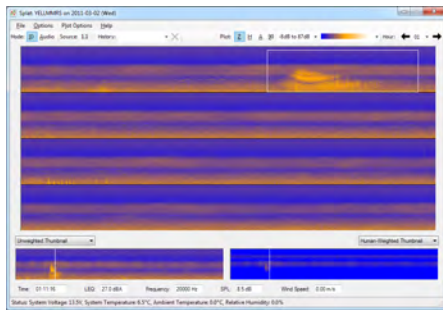
2. Open the Acoustic Monitoring Toolbox, then click on the SPLAT button.
3. Select FILE | OPEN and choose between two options: OPEN FULL DAY, or OPEN SINGLE NVSPL FILE. The open full day option will allow the user to open all 24 hours of the day at once. This option is only available for days where data started collection at the 00-hour (midnight). The other option, OPEN SINGLE NVSPL FILE, will open one hourly file at a time.
4. Navigate to the directory where NVSPL files are stored and select the desired day or hourly file.
5. Scan the spectrogram for instances of anthropogenic sound. Examples are given in figure 5.1.
6. When you have located an event, select the AUDIO mode from the toolbar. Draw a box around the event and click the extract icon (). This command will retrieve the corresponding audio from the continuous .mp3 files.
7. When SPLAT has successfully extracted the audio sample, the play icon will darken (). Click the play icon to listen to the sound.
8. When you have identified the sound source, select the ID mode from the toolbar.
9. Enter the corresponding source code (e.g. 1.1 for Jet) in the text box labeled Source. The complete list of sound sources and their codes can be found in Appendix B.
10. Click the START EDITS box to begin identifying events. This will allow you to draw boxes on the spectrogram.
11. Try to draw the boxes as tightly around the events as possible (both vertically and horizontally). Failure to do so could result in an over- or under-estimation of the percent time audible for this sound source. Refer to figures 5.2(a) and 5.2(b) for examples of poorly drawn and properly drawn boxes in SPLAT.

The time required to extract this .mp3 audio sample is directly related to the length of the box. If the source in question is very long, try selecting a shorter time period in the middle of the event.

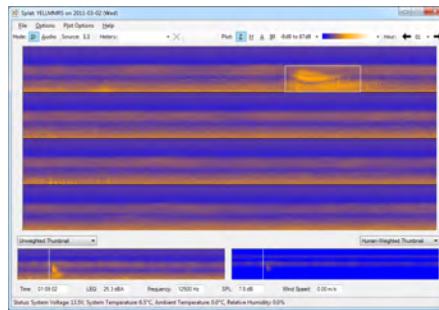
To draw a box spanning multiple rows, press and hold the SHIFT key before clicking the mouse button. Release the SHIFT key after drawing the box.



- If you are not certain where to draw the box, use the audio mode to determine when the event becomes audible, and when it is no longer audible.
12. Mark all occurrences of an event type. Each time you finish drawing a box, an event record is automatically saved under the filename SRCID\_PARK000.txt. The SRCID file will be located in your My Documents folder under ToolboxOutput\Splat. You may undo/delete any of the boxes by selecting the event in question from the History dropdown menu and clicking the red X (X).
  13. Repeat this routine for every anthropogenic source present in this hour. Then, proceed to the next hour.
  14. As you work through a day of spectrograms, you may encounter interesting sounds that you would like to permanently save. To do so:
    - (a) Extract the sound as usual, then either select FILE | SAVE UNCOMPRESSED AUDIO AS or select FILE | SAVE COMPRESSED AUDIO AS, then specify a file name.
    - (b) Select the directory you'd like to save the file in. By default, SPLAT appends the site name, date, and start time of the clip to the file name. It is recommended that you keep these associated with the audio sample for archival purposes, but add some sort of descriptive name before the first underscore (e.g. coyote\_DIN0001\_20100604\_011732).
  15. See section 5.4 for further instructions on processing the results of visual analysis.



(a) A poorly drawn source box in SPLAT



(b) A correctly drawn source box in SPLAT

Figure 5.2: Examples of source tagging in SPLAT

## 5.4 Producing Data Summaries and Metrics

It is possible to generate a suite of metrics immediately after retrieving data from the field, using Hourly Metrics, a program in the Acoustic Monitoring Toolbox. This report provides preliminary statistics about the acoustical environment at a site, and is often useful in situations where information is needed immediately. However, after a comprehensive sound source analysis is performed (through visual analysis or office listening), even more valuable statistics can be calculated, including hourly natural ambient estimates. This section will discuss both levels of metrics generation.

### 5.4.1 Generating Data Summary Files

1. Confirm that sound pressure level files have been converted to the NVSPL format before beginning.
2. Confirm that wind speed data has been incorporated into NVSPL files. Hourly metrics will exclude hours where wind speeds exceeded 5 meters/second more than 25% of the time.
3. Confirm that invalid hours (such as those that include site visits or acoustical vandalism) have been excluded from the dataset.
4. Open Acoustical Monitoring Toolbox and click on the Hourly Metrics button.
5. You will have two options for generating summary files. If you have only one site to process, you may select **FILE | OPEN NVSPL FILES**. However, if you would like to generate results from more than one site, you should select **FILE | OPEN NVSPL FOLDER**, which will search an upper level directory for all NVSPL files within all subfolders.
6. When a summary file is generated, it will be saved in `C:\MyDocuments\ToolboxOutput\HourlyMetrics` by default, but to specify a different directory, select **FILE | ALTERNATE OUTPUT DIRECTORY**.
7. Click the **CREATE SUMMARY** button to generate the summary file(s). This will create a large text file which incorporates all of the one-second sound pressure level measurements taken over the monitoring period, over all frequencies.
8. Progress will be indicated on the progress bar. It takes a few minutes to generate a summary file per 25 day monitoring period, but this time will vary depending on the computer that is performing the calculations.

### 5.4.2 Producing Metrics Without Sound Source Calculations

Immediately after data retrieval, it is possible to extract a number of useful metrics, including  $L_{10}$ ,  $L_{50}$ ,  $L_{90}$ , and percent time above certain thresholds, for various time periods. This does not require any data analysis, just the automated data summaries.

1. Select **FILE | OPEN SUMMARY FILES**. Navigate to the location of the summary files and click **OK**.
2. Select the radio button labeled **DON'T CALCULATE LNAT**.
3. The metrics file you are about to produce will provide statistics for day and night time categories. By default, day is defined as 7am to 7pm, and night is defined as 7pm to 7am. To alter these time parameters, check the box labeled **ADJUST DEFAULT TIME PARAMETERS**. At this point, you may also adjust seasonal parameters.
4. Click the **CALCULATE METRICS** button.
5. When a metrics file is generated, it will be saved in the same directory as the summary file.

### 5.4.3 Producing Metrics With Sound Source Calculations

After thorough sound source audibility analysis, it is possible to create a metrics file which reports the hourly natural ambient sound levels. Natural ambient is defined as the sound level which might have existed in the absence of anthropogenic sounds, at a given site. The 2006 NPS management policies state that the natural ambient is the baseline level and the standard against which current conditions in an acoustical environment will be measured and evaluated.

The analysis requires at least eight days of hourly sound source audibility results, from either NPS method. The analysis data can be read from a TAB delimited file (referred to as the PA file) or directly from the Excel or SPLAT SRCID files.

The PA file is usually used when results are pulled from non-standard formats, such as older reports. It must be named PA\_PARK.txt, where PARK is the 4-letter park code used in the summary and NVSPL files. Each season of each site has two rows: a total human caused audibility (TOT), and an audibility for a particular source of interest (SOI). Each row contains (in this order): sitename, the first three letters of the analysis season, either “TOT” or “SOI”, and 24 mean hourly percent time audible results. An example of this file is shown in table 5.1.

SITE	SEASON	SRC	00h	01h	...	23h
PARK001	SUM	TOT	9.6	6.5	...	27.2
PARK001	SUM	SOI	3.2	6.5	...	18.8
PARK001	WIN	TOT	5.0	7.2	...	11.7
PARK001	WIN	SOI	1.1	7.1	...	11.5
PARK002	SPR	TOT	12.4	5.2	...	7.3
PARK002	SPR	SOI	8.9	4.5	...	7.2
PARK002	FAL	TOT	0.0	1.8	...	33.5
PARK002	FAL	SOI	0.0	1.6	...	29.8

Table 5.1: Format of the PA file. Note that the seasons are abbreviated to their first three letters.

1. Select FILE | OPEN SUMMARY FILES. Navigate to the location of the summary files and click OK.
2. If you are using a PA file, select the radio button labeled USE PERCENT TIME AUDIBLE FILE. Otherwise,
3. Select the radio button labeled USE EXCEL AUDIBILITY AND SPLAT SRCID FILES. Hourly Metrics can read the Excel spreadsheets and SRCID files directly and extract the needed percent time audibility information.
4. In the Source of Interest groupbox, enter the name of the source being analyzed. If using the Excel or SRCID files directly,
  - If you want to use a specific source (such as Jet), select SPECIFIC.
  - If you want to use a categorical source (such as Aircraft), select GENERAL.
  - Enter the source ID code corresponding to the source of interest.
5. The metrics file you are about to produce will provide statistics for day and night time categories. By default, day is defined as 7am to 7pm, and night is defined as 7pm to 7am. To alter these time parameters, check the box labeled ADJUST DEFAULT TIME PARAMETERS. At this point, you may also adjust seasonal parameters.
6. Click the CALCULATE METRICS button.

7. When a metrics file is generated, it will be saved in the same directory as the summary file.

### 5.4.4 Creating Graphics

Once created, the metrics file can also be used to generate graphical representations of acoustical conditions. The Natural Sounds Program uses an open-source, statistical computing program called “R” to produce graphics. This program can be obtained at <http://www.r-project.org/>. The NSNSD has written a script (usually called `graphsYYMMDD.r`) that will query the metrics file and produce a graph for SPL vs. frequency, SPL vs. hour, percent time audible vs. hour, as well as a three axis contour graph showing time and frequency on the x and y axes, with color showing intensity (in dBA). The NSNSD periodically updates this script. Email [SoundscapeSupport@nps.gov](mailto:SoundscapeSupport@nps.gov) to request the latest version.

1. Open R.
2. Select FILE | OPEN SCRIPT
3. Navigate to location of `graphsYYMMDD.r` and click open
4. To customize your graphs, refer to the lines of the script between Begin User Settings and End User Settings. Use “T,” or true, to turn a function on, use “F,” false, to turn a function off.

**TitlesOnPlots** Add a title to the plot. If the plot will be self-standing, it is suggested that you turn the titles on. However, if the plot will be incorporated into a report, convention states that the title of the plot be in the caption, and not on the plot itself.

**plotHRDBA** Plot a graph of median dBA vs. hour measurements for L10, L50, and L90 over the course of the monitoring period. If you specified a `PA_PARK.txt` file when you created the `Metrics.txt` file, `Lnat` will also be displayed on this plot. [INS Rhourplot.png]

**PlotTRUNCDBA** Plot a graph of median dBA vs. hour measurements for L10, L50, and L90 over the course of the monitoring period, for only the frequencies between 20Hz and 1250Hz. Using this truncated frequency range, instead of the full spectrum, focuses attention on the frequencies where transportation noise tends to reside. If you specified a `PA_PARK.txt` file when you created the `Metrics.txt` file, `Lnat` will also be displayed on this plot. [INS Rtruncplot.png]

**PlotFREQDB** Plot a graph of dBA vs. frequency from 12.5 Hz to 20 kHz for L10, L50, and L90 for daytime (7am-7pm) and nighttime (7pm-7am) periods. If you specified a `PA_PARK.txt` file when you created the `Metrics.txt` file, `Lnat` for daytime and nighttime will also be displayed on this plot. [INS Rfreqplot\_1.png]

**PlotCONTOUR** Plot a contour plot which shows dBA for all frequencies and all hours over the course of the monitoring period. [INS Rcontour.png]

**PlotPA** Plot an hourly bar graph of audibility for all anthropogenic noise and all aircraft noise. This plot should ONLY be turned on (T) if you specified a `PA_PARK.txt` file when you created the `Metrics.txt` file.

**numAnalyzedDays** References the analysis you did to generate percent time audible statistics. Enter the number of days you analyzed. It will usually be 8.

**pngWidth and pngHeight** Set the dimensions of the plots. You will not need to change these unless the plots are intended for use other than reports.

**yMaxHr and yMaxHz** Set the maximum y-axis value for the dBA vs. hour plot and the dBA vs. frequency plot, respectively. While the script will find the optimal values for each graph, you may need to adjust these values if you want to present a number of graphs together (with identical axes).

- yMinHr and yMinHz** determine the minimum-y axis value for the dba vs. hour plot and the dBA vs. frequency plot, respectively. While the script will find the optimal values for each graph, you may need to adjust these values if you want to present a number of graphs together (with identical axes).
5. Confirm that the T and F values are as you desire in the user settings section of the script.
  6. Select EDIT | RUN ALL
  7. Navigate to the location you specified in the OutDir line to view the plots.

## 5.5 Processing On-site Listening

On-site listening results are an essential part of acoustical analysis. On-site listening takes full advantage of human binaural hearing capabilities, allows the listener to accurately identify the origin and directionality of a sound source, and most closely matches the experience of park visitors. For these reasons, on-site listening is an excellent tool for off-site listening quality assurance and development of site-specific audibility inventories. Furthermore, because of its simple design, on-site listening is an excellent way to involve interested volunteers or partners in acoustical monitoring. However, it should also be noted that logistical constraints often limit the number or distribution of listening sessions. Thus, off-site listening sessions, which sample over many days and many hours, are more likely to give a complete picture of common sound sources, durations, and patterns than on-site listening sessions. To process on-site listening data, you will need a copy of Microsoft Access and a copy of the database called `soundscape.mdb`. Contact [SoundscapeSupport@nps.gov](mailto:SoundscapeSupport@nps.gov) to request the latest version of this database.

### Importing on-site listening data

Save session data from all previously logged sessions to the external SD card in your logging device. The data should be saved in two text files, `session.txt` and `sounddata.txt`

1. To do so on the Palm devices commonly used by the NSP:
  - Open the Soundscape program on the Palm.
  - Click the SAVE SESSION DATA button. A dialog box should appear stating "Data were saved on the card. Filename: 'Session.txt' and 'SoundData.txt'"
    - Note: The session and sound data will now be saved on the external card as well as the PDA file system, but will remain on the PDA. Be sure to manually delete the internal files later to prevent repetitive imports into the database.
2. Move these two files to a location on your PC using an SD card reader
3. Open the Microsoft Access database, `soundscape.mdb`
4. Select the IMPORT FROM PALM DATA CARD button on the main form [INS Import-FromPalmMemoryCard.png]
5. When prompted, select 2 files - `Session.txt` and `SoundData.txt`, then click IMPORT
6. Confirm that all sessions are displayed in the main form [INS AccessMainForm.png]

**Processing audibility reports for on-site listening data**

1. In the Main Form, manually check the boxes next to the sessions you wish to process.
  - You may also select sessions based on date range, time range, park code, or site name by clicking on the REPORT SESSION SELECTION button in the Main Form.
  - When you have adequately defined parameters, click UPDATE, and the qualifying sessions will be automatically selected. This function is particularly useful for large datasets when manual selection proves to be too time consuming.
  - To clear report marks, click the CLEAR REPORT CHECKMARKS button in the Main Form.
2. Click on AUDIBILITY REPORT button, then click the CALC NEW REPORT button.
3. You will be prompted to confirm that at least one session has been selected for analysis. Click YES.
4. You will be prompted to enter an optional description of the report. If you are analyzing all sessions performed at a particular site, an appropriate name might be "SITE001 Summary."
5. Before the report is displayed, you must decide whether to display the session details (the author, date, length of the sessions included in the report). To show details, reply no to the dialogue box. To hide details reply yes to the dialogue box.
6. To save the report elsewhere (as an Excel, text, or Word file), refer to the data tab and follow prompts. [INS ExportAccessReport.png]

**Interpreting the audibility report**

As you learned in previous sections, the audibility report is an automatically-generated table. It details the results of a given number of attended listening sessions. If you chose to include session details when generating the report, it will begin with a number of informational fields for each session. This detail section will include:

**Duration as seconds** The composite length of all sessions presented in the report, in seconds.

**Duration as minutes** The composite length of all sessions presented in the report, in minutes.

**AudRptID** A unique number assigned to the report to differentiate it from others in the database.

**Session ID** The unique number assigned to each session to differentiate it from others in the database.

**Name, Address, Phone** Information about the person who performed the session. Address and phone of users are optional, and can be entered in the database.

**Site** The site where the session was performed. Is often in PARK001 format.

**Subsite ID** Optional site descriptor field.

**Date** The date the session was performed.

**Start Time** Time when the listening session started.

**End Time** Time when the listening session ended.

**Wind** Optional field to describe wind conditions (light, moderate) at the time of the session

**Weather** Optional field to describe the weather (sunny, overcast, foggy) at the time of the session.

**Park** Park where the session was performed.

**Time Group** Optional field to describe the time category (day, night, morning, afternoon) during which the session was performed.

**Palm ID** The serial number of the device on which session was recorded. This number is automatically conveyed when the results are moved to the database.

**Comments** Any notes the user entered at the beginning of the session will be displayed in this section.

Sound source audibility results are listed below the session detail section. This section reports various metrics about audible sound sources. This table indicates which sounds one is likely to hear at or near the site on a given day. The fields in this section can be interpreted as follows:

**Sound ID** The numerical ID for the detected sounds (e.g. 1.1).

**Sound Source Description** A textual description of the detected sounds(e.g. Jet).

**PA** The percent of time that each source was audible during the period of measurement.

**Max Event** The maximum length of an event (in seconds) for the sound source.

**Mean Event** The mean length of an event (in seconds) for the sound source.

**Min Event** The minimum length of an event (in seconds) for the sound source.

**SD event** The standard deviation among event lengths.

**Count** The number of times that each sound source was audible.

**Noise Free Interval** A metric describing the length of time between extrinsic or human-caused events.

## 5.6 Reporting

Acoustical monitoring results have little impact if they are not properly presented. Acoustical reports are excellent mediums for delivering concise results to many different audiences. The NSNSD produces two acoustical reports per monitoring effort. The first report type is a snapshot of results, which uses automatically generated metrics to present findings quickly. Snapshot reports also function well as trip reports, and should be produced as soon as possible after monitoring is complete. The second and final report type is a more thorough examination of the acoustical conditions at the site. It reports upon audible sound sources, as determined by personnel, and allows the author to elaborate on the effects of sound sources of interest. These reports follow the traditional model for scientific reports, and generally include an executive summary, introduction, methods, results, and conclusion.

### 5.6.1 Snapshot Report

This report is a quick way to return a great deal of information. The purpose of the report is to provide insight into the acoustical conditions at the monitored sites in cases where information is urgently required. Try to keep snapshot report as succinct as possible, and reserve long explanations for the full acoustical report. See below for an explanation of suggested sections.

- Background Information
  - Answer who, what, where, when, in reference to data collection.
  - Explain the purpose of the study.
  - Insert table describing study area including site name, location, dates, nearby vegetation, elevation, and coordinates.
- Metrics
  - Define the metrics you will use to characterize the sites. These may include percent time above certain sound levels, or levels exceeded x percent of the time.
  - You may wish to place your measurements into perspective by explaining the meaning of decibel, or by including common interpretations of sound levels (eg 10 dBA as measured in HALE is similar to human breathing at 3m).
  - Insert relevant graphics such as day and night decibel levels for 33 1/3 octave bands. Instructions for creating this and other figures can be found in [REF] section 5.4 Producing Metrics and Data Summaries
- Discussion/Conclusion
  - Summarize information covered in the report with a concise
- Literature Cited
  - List any sources you cited in the report. See the NRPM website for formatting guidance.
- Contact information
  - List the contact information for the author of the report.

### 5.6.2 Final Report

As the culmination of a lengthy data collection period, this report should fully explore the reasons for initiating the study, the methods used, the results, and the conclusions drawn. Keep in mind that this report may be retrieved or queried many years from now. Make sure that you provide adequate background information about the location of your objectives, sites, methods, and results. In addition, consider your audience carefully when providing explanations. Will this report be distributed to the public? Will your audience have enough acoustical knowledge to interpret the results as stated? See below for an explanation of suggested sections.

- Table of Contents, Table of Figures, Table of Tables
  - Use Microsoft Word styles and the automatic table generation functions to simplify this section so that changes to the order of items will seamlessly and automatically be reflected.
- Executive Summary



- This section should stand alone as a summary of the most important points covered in the report. After reading this section, the reader should know why the study was initiated, how it was conducted, and what the findings were without reading the body of the report.
  - It should combine at least some aspects of each subsequent section.
  - It may be helpful to write this section last.
- Introduction
  - Provide a complete review of background history for the study.
  - Provide a few key points about why your park is interested in monitoring sound.
  - List known Park Service directives for managing sound.
  - Place this study in larger context of resource management, acoustic monitoring, biologic monitoring etc.
- Study Area
  - Note how many acoustical monitoring stations were deployed, and for how long.
  - Provide related information about the park where data was collected (location, visitation numbers).
  - Insert a table of acoustical monitoring sites including site name, location, latitude, longitude, elevation, and dominant vegetation type.
    - \* If you determined acoustic zones based on management zones, note which zone each site was intended to represent.
  - Include a site photo showing equipment set up and locale.
  - Include a site map, placing sites in larger context of park boundaries.
- Methods
  - Thorough description of equipment used and metrics collected
  - Explanation of methods for off-site listening and on-site listening
  - Explanation of methods for calculating metrics such as natural ambient
- Results
- Discussion
- Literature Cited
- Glossary of Acoustical Terms

Formatting guidance for full acoustical reports was established by the National Park Service Graphic Identity Program. Specific guidance can be obtained from the National Park Service Natural Resource Publications Management (NRPM) website. When the report is complete, the author should also refer to this website for peer review guidance. After the peer review process is complete, the report can be uploaded into the NRInfo document storage and retrieval system.

### 5.6.3 Web Resources

Natural Resources Publications Management Resources (NRTR/NRR/NRDS):

<http://www.nature.nps.gov/publications/NRPM/>

NRTR templates:

<http://www.nature.nps.gov/publications/NRPM/NRRNRTR.cfm>

Instructions to Authors version 3.1:

[http://www.nature.nps.gov/publications/nrpm/assets/docs/Instructions\\_to\\_Authors\\_v3.1.pdf](http://www.nature.nps.gov/publications/nrpm/assets/docs/Instructions_to_Authors_v3.1.pdf)

<http://www.nature.nps.gov/publications/NRPM/Hints.cfm#guides>

List of reports in the NRTR series

<http://www.nature.nps.gov/publications/nrpm/nrtr.cfm#2010>

NR Info Portal (where you can search for reports)

<https://nrinfo.nps.gov/Home.mvc><https://nrinfo.nps.gov/Home.mvc>

### 5.6.4 Example Reports

Bryce Canyon National Park Acoustic Monitoring Report 2009-2010

[https://nrinfo.nps.gov/Reference.mvc/DownloadDigitalFile?code=423975&file=BRCA\\_Acoustic\\_Report\\_2011\\_final.pdf](https://nrinfo.nps.gov/Reference.mvc/DownloadDigitalFile?code=423975&file=BRCA_Acoustic_Report_2011_final.pdf)

Zion National Park: Acoustical monitoring summary report

[https://nrinfo.nps.gov/Reference.mvc/DownloadDigitalFile?code=423936&file=ZION\\_Soundscape\\_NRTR\\_2011-420.pdf](https://nrinfo.nps.gov/Reference.mvc/DownloadDigitalFile?code=423936&file=ZION_Soundscape_NRTR_2011-420.pdf)

# Chapter 6

## Software

### 6.1 Adobe Audition

Adobe Audition is a powerful multitrack audio recording, mixing, editing, and mastering application. It can be used for audio playback, adjusting audio levels, eliminating noise and hiss, mixing and combining clips, and many other features. Audio files can be displayed as waveforms, as shown in figure 6.1, or in a spectral decomposition, as shown in figure 6.2. The waveform view is useful for analyzing the absolute level of the file, where peaks above the top or bottom line indicate clipped samples. The spectral view (usually shown on a logarithmic scale) indicates the relative sound levels contributed by each frequency. This view is useful when analyzing recorded audio data, as sounds often have unique visual signatures. It can read/write MP3, WAV, and WMA files, as well as many other audio formats. More information can be found on the Adobe Audition website:

<http://www.adobe.com/products/audition/>

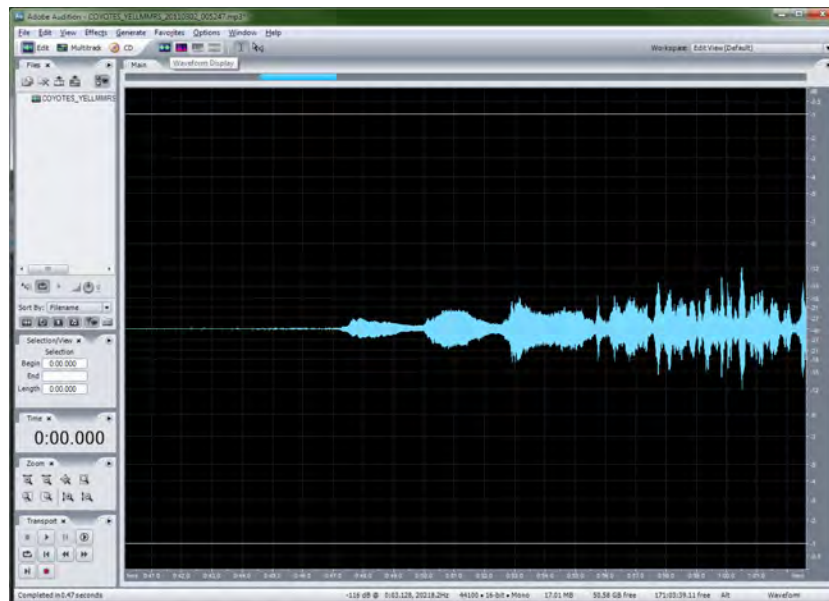


Figure 6.1: Screenshot of Adobe Audition 3.0 in waveform view

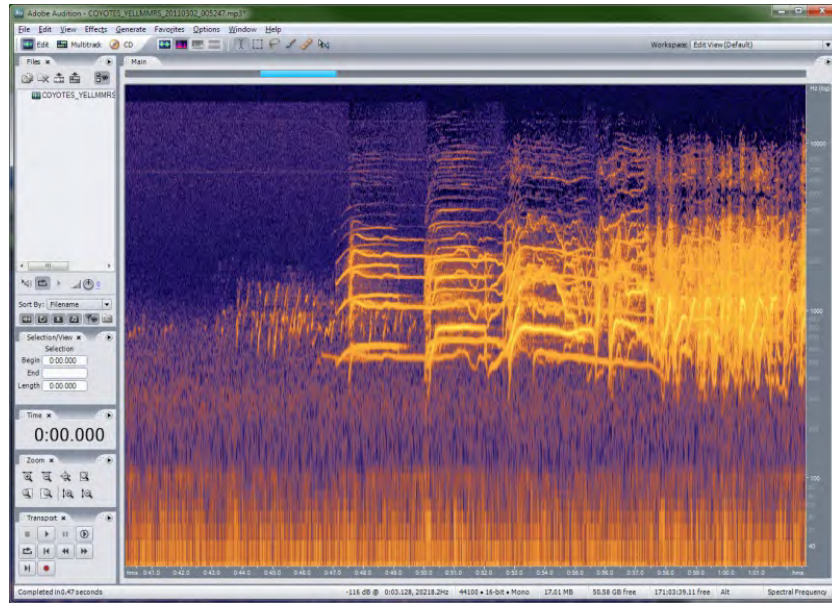


Figure 6.2: Screenshot of Adobe Audition 3.0 in spectral view

## 6.2 R

R is a free, open-source statistical computing environment widely used within the scientific community. Being open-source, there are thousands of developers and hundreds of add-on packages, covering almost every mathematical need. It is heavily used by the NPS for climate change analysis.

Similar to Matlab, R is an interpretive programming environment, meaning that code and scripts do not get compiled into machine code beforehand. This has the cost of being a little slower than compiled languages such as FORTRAN and C, but allows for greater flexibility in debugging and modification, since one can run small sections of code at a time. Scripts written in R usually have the .R extension, and can be opened in Notepad (although Notepad++ is highly recommended). Common coding practices usually put documentation and any user-modifiable variables at the very top of the script.

R has both a 64-bit mode and a 32-bit mode, and both modes are available in the same install package: <http://cran.stat.ucla.edu/bin/windows/base/R-3.0.0-win.exe>. This version is compatible with Windows XP, Vista, or Windows 7. For more information, visit <http://www.r-project.org>

## 6.3 Acoustic Monitoring Toolbox

The toolbox is a collection of several Park Service created programs to aid in the collection, conversion, and analysis of acoustical monitoring data. Most of the utilities create their log files or output in the My Documents/ToolboxOutput folder. If Portable mode is checked, then all output will be redirected to a ToolboxOutput folder in the same directory as the AMT.exe file.

It is currently maintained by Damon Joyce in the NSNSD office in Fort Collins, Colorado, and be downloaded from the Natural Sounds [FTP site](http://ftp.den.nps.gov/incoming/Natural_Sounds/Software/)<sup>1</sup>. The complete AMT folder should be downloaded, which contains several subfolders and files needed to run.

<sup>1</sup>[http://ftp.den.nps.gov/incoming/Natural\\_Sounds/Software/](http://ftp.den.nps.gov/incoming/Natural_Sounds/Software/)

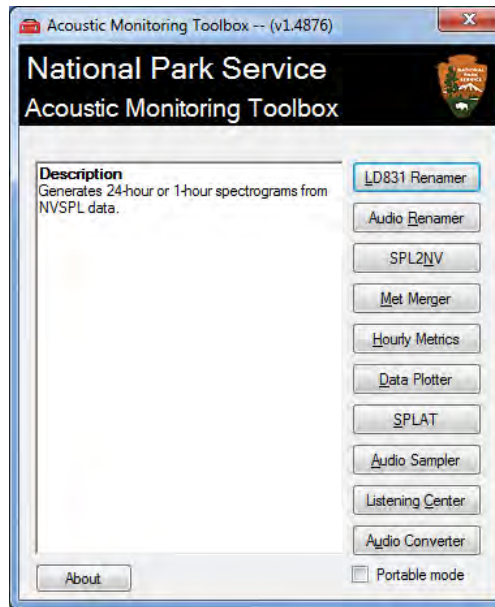


Figure 6.3: Screenshot of the Acoustic Monitoring Toolbox

### 6.3.1 Audio Renamer

Most digital recorders use an incremental naming convention, with little to no information about the file itself (i.e., REC\_0001.mp3). For organization and identification purposes, the filename should contain the site name, and the date and time the recording was started. The NPS uses the format SITE\_YYYYMMDD\_hhmmss.mp3.

#### Usage

1. In the Site ID box, provide the site name for the monitoring location (e.g., GRCA001).  
*Note: The site name must be alphanumeric only, no special characters or spaces may be used.*
2. In the Recorder Model group box, select the radio button corresponding to the field recorder used.
  - If selecting OTHER under recorder model, the program will give you manual control over the start time of the first recording. Subsequent files will be named based on start time and the sum of the recording length of the previous files (plus the recording gap). All files renamed
3. Select the files to be renamed by clicking FILE | OPEN FILES.
4. If the timestamp looks correct, click RENAME.

#### Options

**Start Hour Adjustment** If the timestamp is off by a few hours (verified from site logs), select the start hour of the *first recording*

#### Parameters

**Recording gap** The length of time the recorder takes to close one file and start the next. Only used in OTHER mode.

**Recording start time** The time the first recording was started, in YYYY-MM-DD HH:mm:ss (where HH is 24 hour format). Only used in OTHER mode.

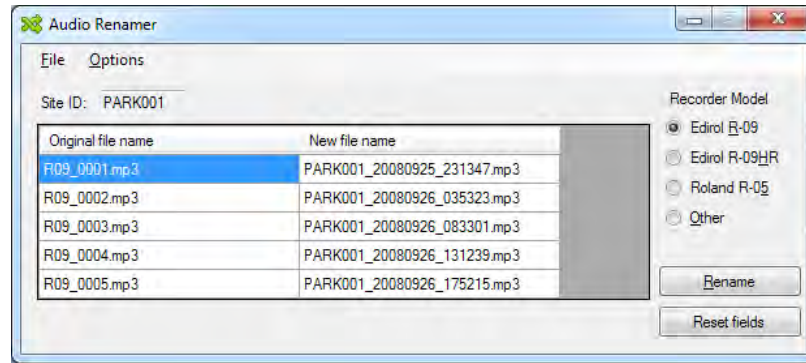


Figure 6.4: Screenshot of Audio Renamer

### 6.3.2 Audio Sampler

Audio Sampler was designed to take a day's worth of MP3 audio, and split it into sampled chunks to aid in listening-based analysis. By default, the program will split over the full range of the day, although a smaller range may be selected. *Note: MP3 files must be named using NPS protocol (SITE\_ YYYYMMDD\_ hhmmss. mp3, using the time the recording was started)*

#### Usage

1. Select the folder containing the audio to be split by clicking FILE | CHOOSE AUDIO DIRECTORY
2. Select the days of audio to split by checking the appropriate boxes
3. Enter in the parameters for your sampling scheme
4. Select the time range over which to sample
5. Select any options you may need
6. If desired, change the location where the split files will be saved by clicking FILE | CHOOSE OUTPUT DIRECTORY. Otherwise, split files will be placed in MyDocuments\ToolboxOutput\AudioSampler.
7. Click SPLIT FILES to begin the process.

#### Options

**File | Choose Output Directory** By default, files will be created in the application directory

**Mono Sampling (R Chan)** Extract right channel only and create a mono WAV file

**Mono Sampling (L Chan)** Extract left channel only and create a mono WAV file

**Stereo Sampling** Extract both channels of MP3 file to a stereo WAV file

**Split to MP3** Split files directly to MP3 instead of uncompressing to WAV

**Beep on Completion** Audible alert when processing is completed

## Parameters

**Sample length** Length of each audio sample to produce (in seconds)

**Sample interval** Temporal spacing between samples (in minutes)

**Sample time range** Choose the start and end hours for the portion of the day to sample

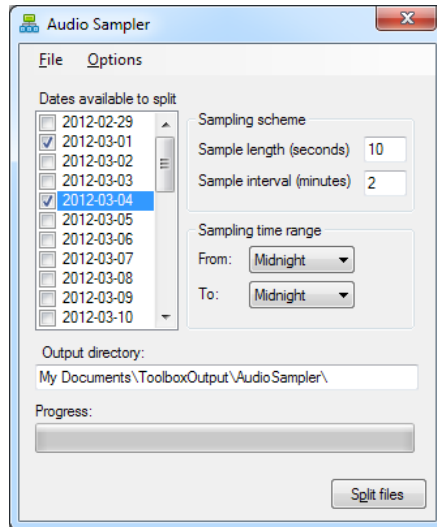


Figure 6.5: Screenshot of Audio Sampler

### 6.3.3 Data Plotter

This utility a few common plots from the NVSPL files: spectrograms, wind plots, and an SPL histogram.

Spectrograms are 24-hour graphics from hourly NVSPL files, and provide a visual display of a site. The data is presented as twelve two-hour rows, with a log-scaled y-axis labelled at 40, 400, and 4000 Hz. Cooler colors on the z-axis represent lower sound levels, while warmer colors correspond to higher levels. One hour graphs can also be created for more detailed study.

An example spectrogram is shown in figure 6.7

Wind plots are produced for each day, and are box and whisker plots, with the 90th percentile and 10th percentile at the extreme ends of the whiskers, and the 75th and 25th percentile at the extreme ends of the boxes. NPS protocol states that when 25% of the hour exceeds a certain wind threshold, it will not be imported. Visually, this means that when the top of the box touches or exceeds the threshold line, it will be excluded from analysis.

A wind rose is also produced as a site summary, if wind direction was incorporated into the monitoring protocol. The length of the segment represents the percent of time the wind was blowing from a given direction, and the color corresponds to the average wind speed.

Examples of the wind plots are shown in figures 6.8 and 6.9.

## Usage

1. Select either DAILY or HOURLY spectrograms under PLOTTING MODE.
2. Select one or more plot types under PLOT TYPES.

**Flat weighted** Applies no correction to the 1/3 octave data.

**Human weighted** Plots values relative to the threshold of human hearing.

**A weighted** Applies the ANSI standard A-weighting curve.

3. Select one of the color schemes (the NSNSD default is Blue–Orange–White).
4. If plotting daily files:
  - (a) Select the folder containing NVSPL files using FILE | OPEN FILES(S).
  - (b) In the textbox, check the dates to be plotted, or check SELECT ALL underneath the textbox.
5. If plotting hourly files:
  - (a) Select the NVSPL files you would like to plot using FILE | OPEN FILES(S).
6. Click START to begin processing.

### Options

**Beep on Completion** Audible alert when processing is completed.

**Plot Wind Speed** Overplot the wind speed as a line graph on the spectrograms. Any speed over 5 m/s will be displayed in green.

**File | Alternate Output Directory** By default, files will be created in the MyDocuments/ToolboxOutput/AudioSampler directory.

**High range** Lower bound of color scale will be shifted from -8dB to 4dB, and upper bound will be shifted from 87dB to 121dB.

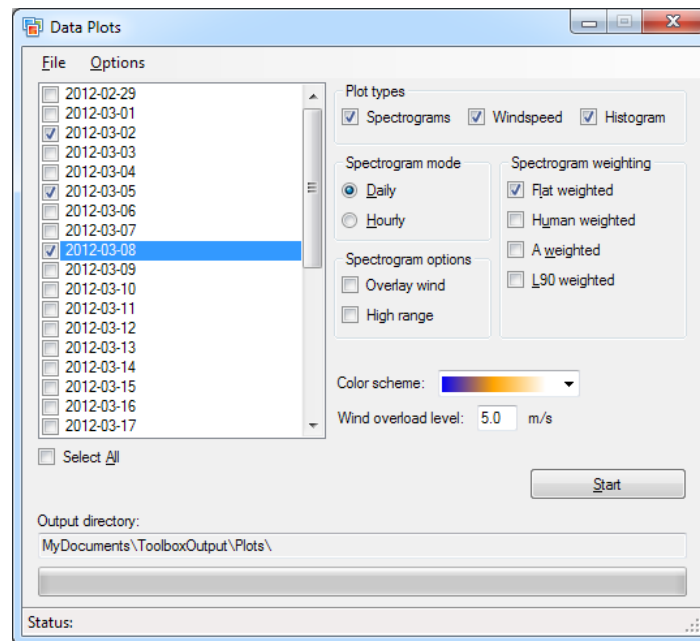


Figure 6.6: Screenshot of the Spectrogram utility



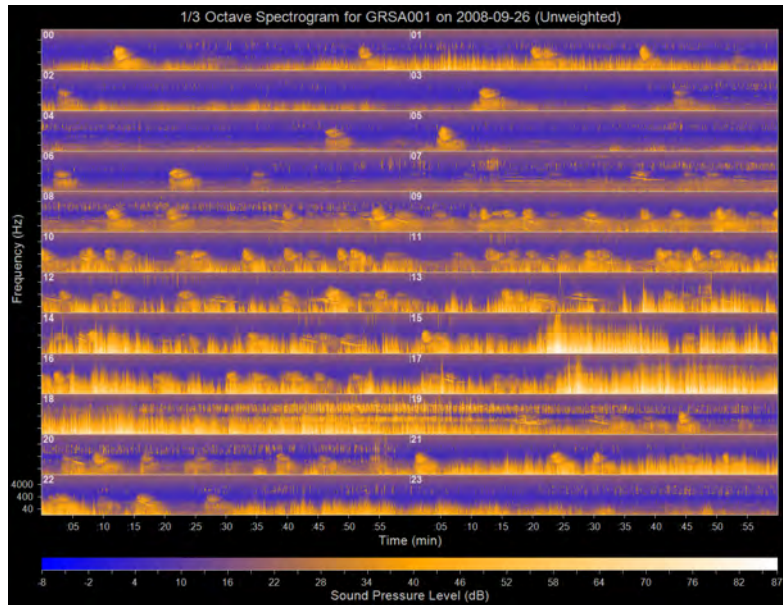


Figure 6.7: Spectrogram from Great Sand Dunes National Park and Preserve

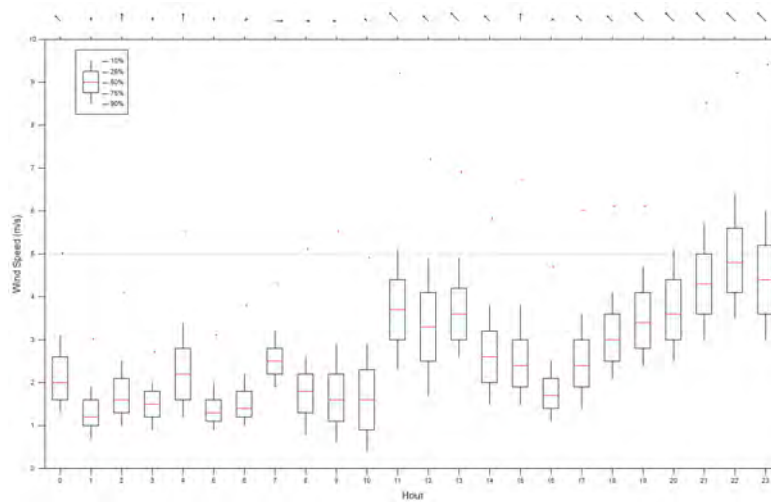


Figure 6.8: Daily wind plot from Petroglyph National Monument

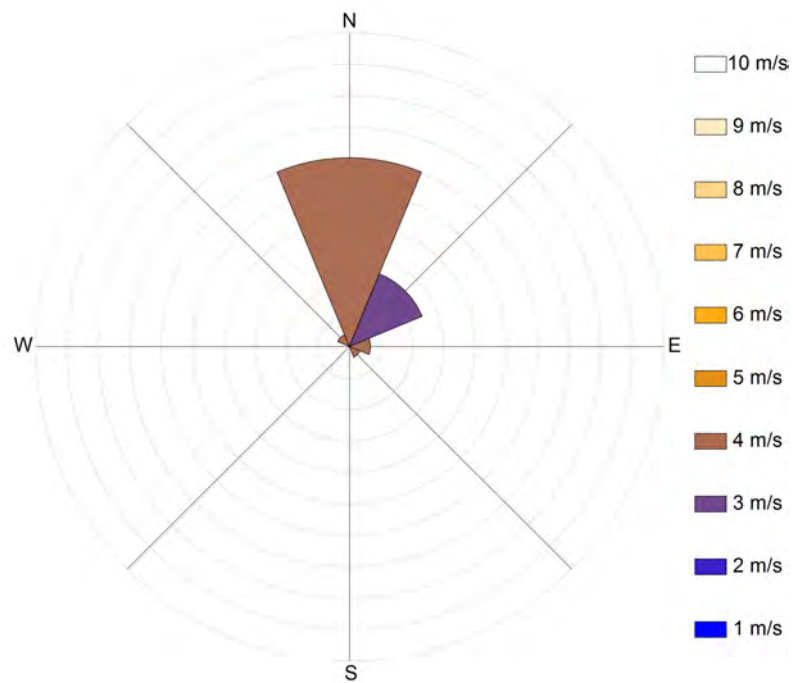


Figure 6.9: Site wind rose from Petroglyph National Monument

### 6.3.4 Hourly Metrics

**Summary Creation** This section will create a summary file from NVSPL files for a monitoring location. Each 1-hour file will be summarized in the file as one line containing  $L_{\min}$ ,  $L_{01-99}$ , and  $L_{\max}$  for each 1/3 octave band and the wideband  $L_{\text{eq}}$ . The number of seconds above various metrics will also be reported. When wind speed data are present in the NVSPL files, Hourly Metrics will not process any data points over 5 m/s. Any hour missing 25% or more of data will not be processed.

**Metric Calculation** This section will take the summary files from the previous step and create a human readable file with the following metrics:

- SPL (Full and Truncated) vs. Hour
- SPL vs. Frequency
- Nighttime Exceedence (%)
- Daytime Exceedence (%)
- Nighttime Ambient (Full and Truncated)
- Daytime Ambient (Full and Truncated)
- SPL vs. Hour vs. Frequency

This can be done with or without percent time audible values by hour. Without the PA values, the  $L_{\text{NAT}}$  columns will simply be left blank.

#### Usage

- Summary Creation
  1. Select NVSPL files to be summarized by either
    - (a) Selecting individual files using FILE | OPEN NVSPL FILES.
    - (b) Selecting an NVSPL folder by using FILE | OPEN NVSPL FOLDER.
  2. Click CREATE SUMMARY to start processing.
- Metric Calculation
  1. Select FILE | OPEN SUMMARY FILES. Navigate to the location of the summary files and click OK.
  2. If you are using a PA file<sup>2</sup>, select the radio button labelled USE PERCENT TIME AUDIBLE FILE. Otherwise,
  3. Select the radio button labelled USE EXCEL AUDIBILITY AND SPLAT SRCID FILES. Hourly Metrics can read the Excel spreadsheets and SRCID files directly and extract the needed percent time audibility information.
  4. In the Source of Interest groupbox, enter the name of the source being analyzed. If using the Excel or SRCID files directly,
    - If you want to use a specific source (such as Jet), select SPECIFIC.
    - If you want to use a categorical source (such as Aircraft), select GENERAL.
    - Enter the source ID code corresponding to the source of interest.
  5. The metrics file you are about to produce will provide statistics for day and night time categories. By default, day is defined as 7am to 7pm, and night is defined as 7pm to 7am. To alter these time parameters, check the box labelled ADJUST DEFAULT TIME PARAMETERS. At this point, you may also adjust seasonal parameters.

<sup>2</sup>For the format of the PA file, refer to table 5.1

6. Click the **CALCULATE METRICS** button.
7. When a metrics file is generated, it will be saved in the same directory as the summary file.

### Options

**Alternate Output Directory** By default, the summary file will be created in the same directory as the Toolbox. Use this option to change the destination

**Beep on Completion** Audible alert when processing is completed

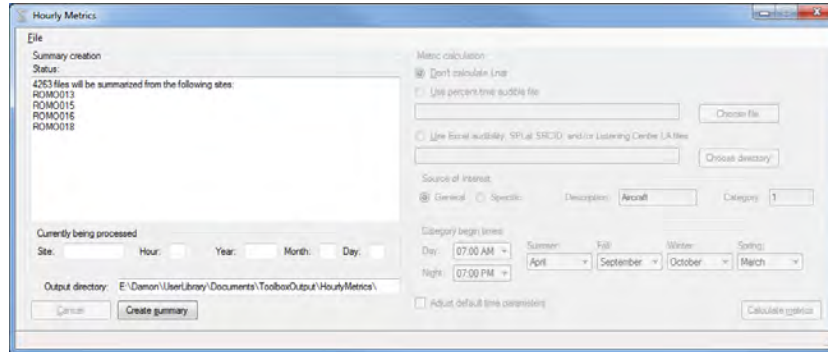


Figure 6.10: Screenshot of Hourly Metrics in Summary Mode

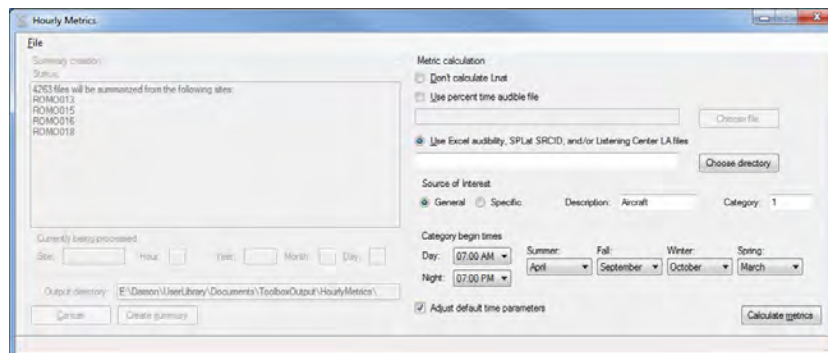


Figure 6.11: Screenshot of Hourly Metrics in Metrics Mode

### 6.3.5 LD831 Renamer

The Larson Davis 831 Sound Level Meter has the ability to save time history data to an external flash drive. When doing so, it actually creates folders with file extensions rather than single binary files. To facilitate data organization, this utility extracts, concatenates, and renames the three binary data files within each data folder.

#### Usage

1. In the Site ID box, provide the site name for the monitoring location (e.g., YOSE001).  
*Note: The site name must be alphanumeric only, no special characters or spaces may be used.*

2. Choose the folder containing the Larson Davis data folders (i.e., 831\_Data) by selecting FILE | OPEN DATA FOLDER. Do not select the individual data folders (usually a folder ending in .LD0)
3. If the new filenames look correct, click RENAME. Files will be created in the folder selected in the previous step.

### Options

**Adjust Date Stamp** If the time was not correctly set on the LD831, this option will allow changes to the timestamp.

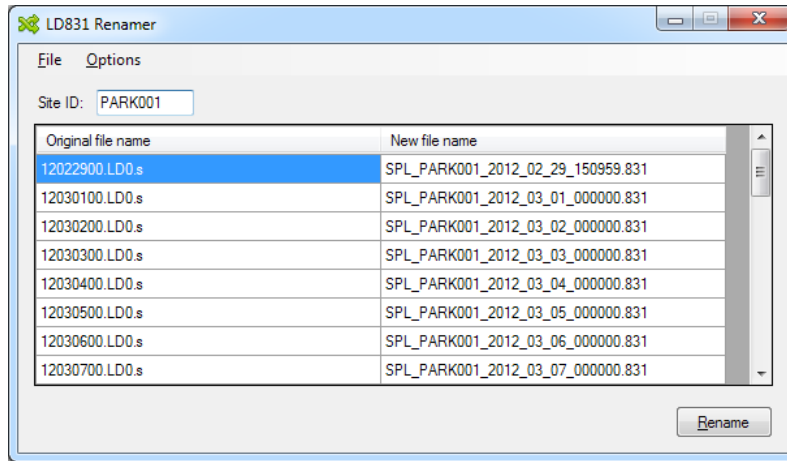


Figure 6.12: Screenshot of LD831 Renamer

## 6.3.6 Met Merger

In the case when weather data was logged with a separate device, this utility will merge the data with the Park Service NVSPL file format. This program will merge data collected from either a HOBO Microstation or the CV3 utility. The HOBO files can either be the raw binary file (\*.dtf) when using the standard anemometer as the only sensor, or CSV files with YASML headers exported using Hoboware Pro.

### Usage

1. *Note: This program requires a specific folder structure.* There must be a folder named DATA in the same directory as the folder containing the NVSPL files. This DATA folder must contain the HOBO dtf file(s) or the CV3 files.
2. Select the folder containing the NVSPL files to be merged by using FILE | CHOOSE NVSPL FILES.
3. Click MERGE to begin processing

### Options

**Hobo Data Files** Merge wind speed data from files originating from a Hobo Microstation

**CV3 Data Files** Merge wind speed data from files originating from CV3 utility

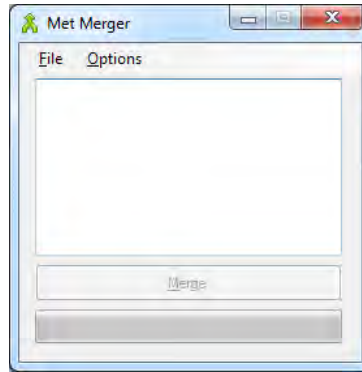


Figure 6.13: Screenshot of Met Merger

### 6.3.7 SPL2NV

The NPS Natural Sounds Program uses an hourly comma separated value (CSV) file to store sound pressure level data. This utility will convert from the following formats into the NVSPL file format:

- Spectra files
- SndMon files
- Gnat files
- LD831 USB drive files
- LD831 exported CSV files
- Volpe text and binary files
- Wyle .zwc files

#### Usage

1. Choose the SPL files to process by either
  - (a) Selecting individual files using FILE | CHOOSE SPL FILES.
  - (b) Selecting a folder to recursively process using FILE | CHOOSE SPL FOLDER.
2. By default, NVSPL files will be created in an NVSPL folder in the directory containing the raw SPL files. If desired, choose an alternate output directory using FILE | ALTERNATE OUTPUT DIRECTORY.
3. Click CONVERT FILES to start processing.

#### Options

**Adjustments** *Reserved for future use*

**Beep on Completion** Audible alert when processing is completed

**Create Site Folders** Useful for recursive processing of multiple sites, will put NVSPL files into individual site folders in selected folder

**Exclude Binary Files** Exclude binary files in recursive selection

**Exclude Text Files** Exclude text files in recursive selection

**Search for Wind Speed** If weather data is present in the Data folder, it will be merged with the output file. Refer to the instructions for “Met Merger” for more information.

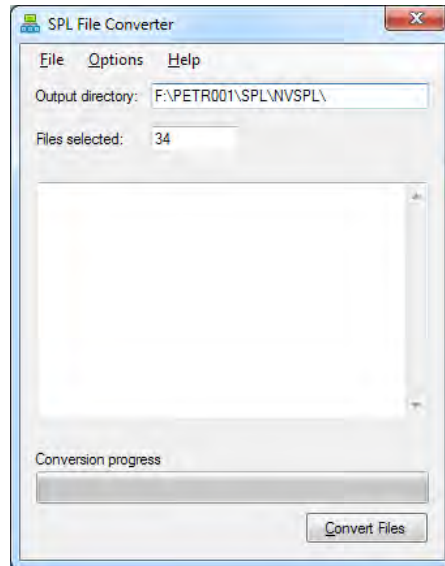


Figure 6.14: Screenshot of SPL2NV

### 6.3.8 SPLAT

NPS protocol for determining the natural ambient level is to first determine the percent time audible for human sources for each hour. This is done by using SPLAT<sup>3</sup> for simple sites, or listening to audio for more sonically complex sites. SPLAT produces an annotation file for each site analyzed, with the following tab-delimited data: Event date, hour, start second, length, source code, lower frequency range, upper frequency range, maximum SPL, SEL<sup>4</sup>, username of technician tagging, and timestamp of when event was tagged.






For unknown sound signatures, SPLAT can extract and play back audio clips for identification purposes. *Note: SPLAT requires a specific folder structure. NVSPL files must be in an NVSPL directory, with no subdirectories. MP3 files must be named using NPS naming convention, and placed in an AUDIO folder alongside the NVSPL folder.*

#### Usage

1. Select NVSPL files by selecting either FILE | OPEN SINGLE NVSPL FILE or FILE | OPEN FULL DAY.
2. Select either ID or AUDIO under the MODE section of the toolbar. If audio files are present, SPLAT will automatically enter audio mode; otherwise ID mode will be selected.
  - ID Mode
    - (a) Either type the source ID code for the source type (jet, helicopter, etc.) you wish to tag, or select from the source dropdown list if the SIMPLE ID TAGGING option has been enabled.

<sup>3</sup>Sound Pressure Annotation Tool

<sup>4</sup>Sound Exposure Level, see Glossary

- (b) Draw a box around the source, trying to include obvious boundaries (both in time and frequency).
  - (c) You can now enter a new source ID and start tagging again.
  - (d) To delete a tag, select the event from the HISTORY dropdown. The selected tag will flash on the main screen. If this was the tag you wanted to delete, press the delete icon (✗)
- Audio Mode
    - (a) Draw a box around the sound of interest.
    - (b) Click the extract icon () to pull audio out of the larger source MP3.
    - (c) Click the play icon () to begin playback. The main display will be replaced by either the audio waveform () , a detailed spectrogram () , or a zoomed in display of the SPL data () . You can switch between modes by selecting the appropriate icon, or you can switch back to the main screen by clicking the currently highlighted icon.
    - (d) If the audio and SPL are not lining up, you can manually enter the offset in the toolbar, or you can use the following visual method:
      - i. Select a segment of audio longer than the suspected offset. Try to choose a segment with a distinct and brief audio event.
      - ii. Extract the audio.
      - iii. Enter the Detailed view and left-click on the event you will try to synchronize.
      - iv. Enter the Spectrogram view and left-click on the corresponding event. An offset will be calculated and entered into the toolbar for you. The next time you extract audio, the offset will be applied.
    - (e) Audio can be saved by selecting the appropriate option under FILE.
    - (f) The additional audio displays can be saved by selecting the appropriate option under FILE.

In Spectrogram and Detailed view, when right-clicking on the display, a crosshair with a fixed time location will appear. By moving the mouse up and down while holding down the right mouse button, you can view frequency information. This is useful for finding harmonics.

- 3. Full hour thumbnails are displayed at the bottom. The view type can be selected in the drop down above the thumbnail.
- 4. If present, system voltage, system temperature, ambient temperature, and relative humidity will be displayed in the status bar.
- 5. Various metrics relating to the cursor position will be displayed below the hour thumbnails.

## File

**Open Single NVSPL File** Choose a single NVSPL file to analyze. If other files from the same day as the selected file are present, the PREVIOUS or NEXT buttons will become active.

**Open Full Day** Choose a single day from the NVSPL files by displaying only the midnight hours. You can cycle through the hours by using either the PREVIOUS or NEXT buttons or the NAVIGATION dropdown.

**Save Uncompressed Audio As** Save the extracted audio clip to a WAV file. The timestamp for the file will be provided in the default filename.

**Save Compressed Audio As** Save the extracted audio clip to an MP3 file. The timestamp for the file will be provided in the default filename.

**Save Waveform As** Save the waveform display to a PNG file.



**Save Spectrogram As** Save the spectrogram display to a PNG file.

**Save Detailed View As** Save the detailed view display to a PNG file.

### Process SRCID Files

#### Options

**Audio on R Channel** Use the R channel for audio extraction (default)

**Normalize Audio** Scale the volume of the audio so the loudest portion of the clip is at 80%

**View Audio Spectrogram** View secondary audio displays when playing back audio

**Linear Scale** Use a linear scale for the audio spectrogram rather than a logarithmic scale

**Simple ID Tagging** Select common sources from a dropdown list instead of manually typing in the sound source code

**Replot** Refresh the screen

#### Plot Options

*Note: Some of the combinations of options may extend the borders of the program window beyond the screen resolution, and as such may not be available*

**2 Line Plot** Split the hour into two 30-minute lines

**3 Line Plot** Split the hour into three 20-minute lines

**4 Line Plot** Split the hour into four 15-minute lines

**Y-scaling** Use either 3, 5, 7, 9 , or 13 vertical pixels for each frequency bin

**Unweighted Plot** Display the spectrogram with no correction

**Human-weighted Plot** Display the spectrogram relative to the human threshold of hearing

**A-weighted Plot** Display the A-weighted spectrogram

#### Toolbar

**Range** Adjust the SPL range. This affects the color mapping.

- Low: -8dB to 87dB
- High: 4dB to 121dB
- Dynamic: uses the lowest and highest SPL values from the current hour

**Weighting** Same as under "Plot Options"

**Color Scale** Change the color scale of all plots. Audio may need to be re-extracted for changes to take effect.

**Hour** Navigate through the available hours in the current day.

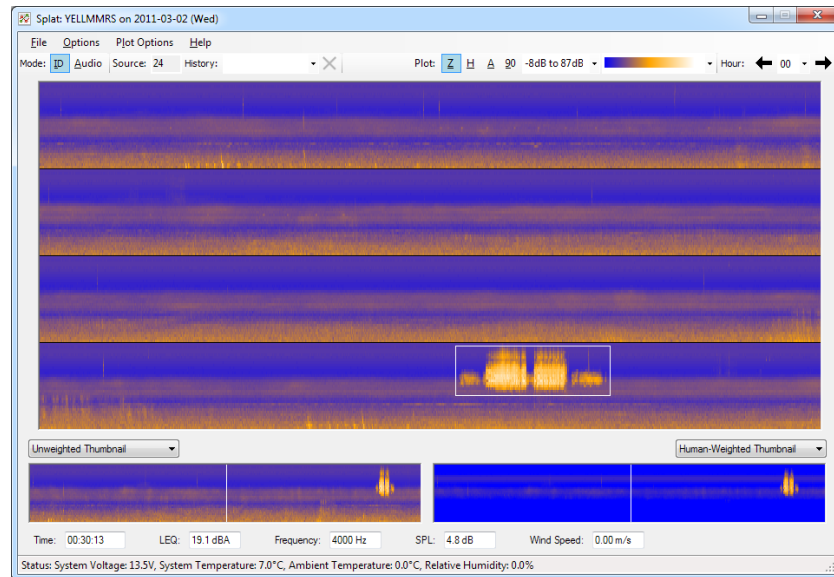


Figure 6.15: Screenshot of SPLAT

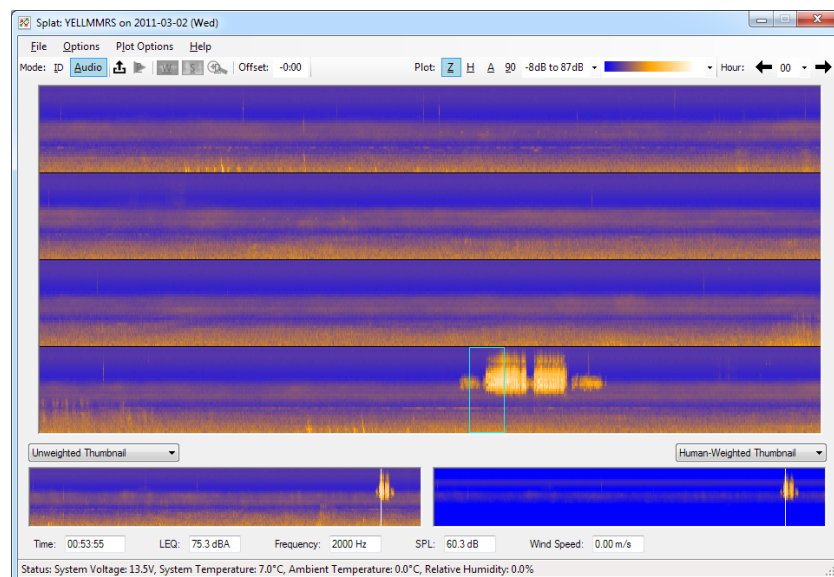


Figure 6.16: Screenshot of SPLAT in Audio Mode

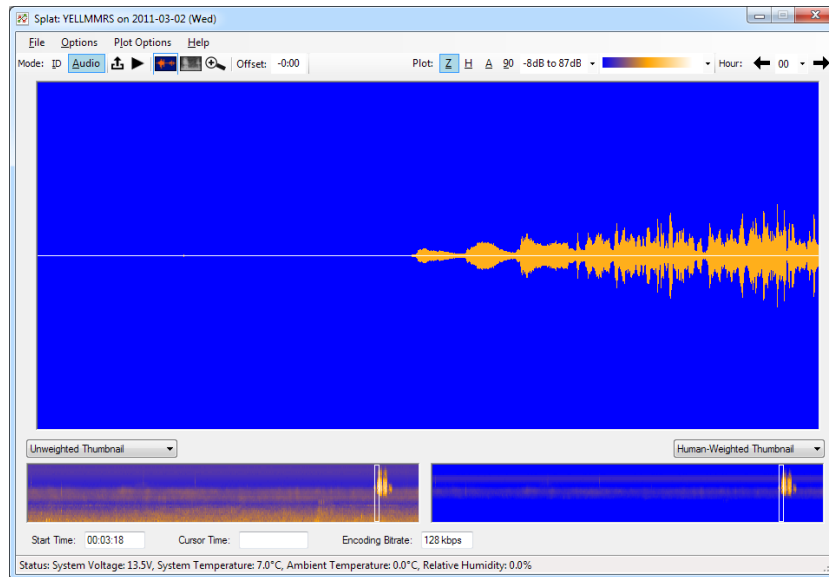


Figure 6.17: Screenshot of SPLAT

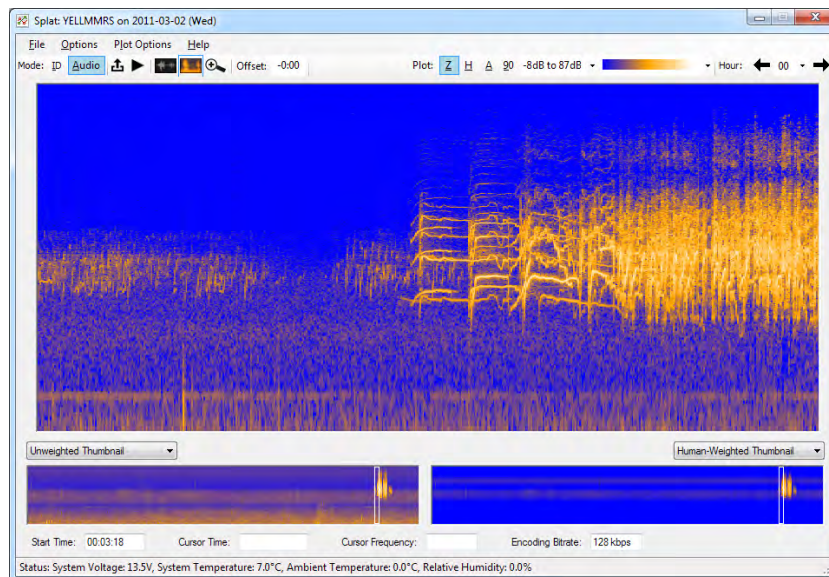


Figure 6.18: Screenshot of SPLAT in Audio Mode

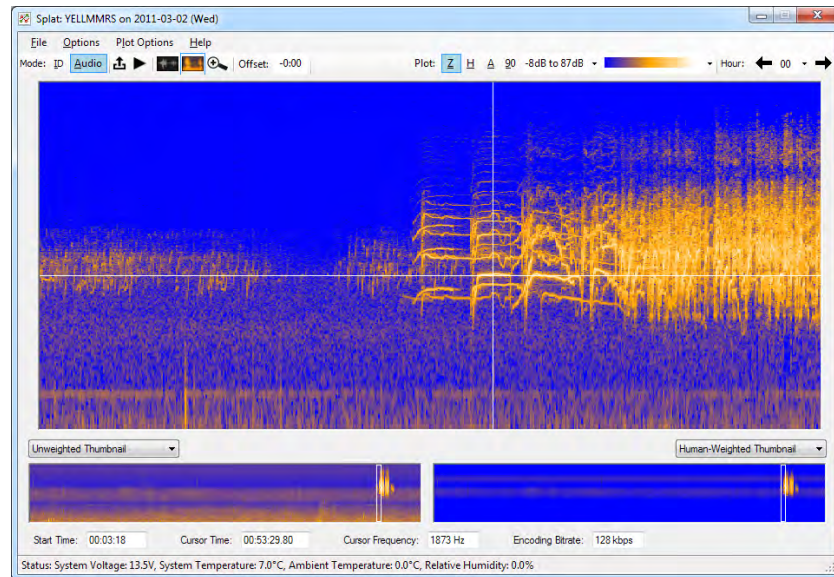


Figure 6.19: Screenshot of SPLAT in Audio Mode

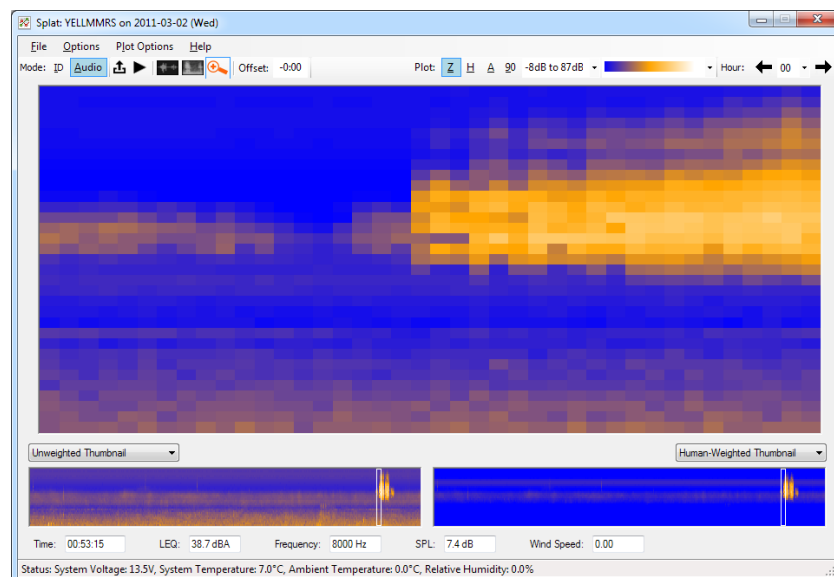


Figure 6.20: Screenshot of SPLAT

## **Appendix A**

# **Site Visit Data Sheet**

A printable copy of the SVDS main page and overflow page are included on the following pages.

## Acoustical Monitoring Site Visit Sheet

Park	Site ID	Site Name		Investigator(s)	Page ____/____
Deployment Date <small>YYYY-MM-DD</small>			Retrieval Date <small>YYYY-MM-DD</small>		
Site Notes <small>describe physical <b>characteristics</b> of the site, e.g., "100m from trail"</small>					
Deployment Notes <small>describe <b>conditions</b> during the deployment, e.g., "Construction in parking lot"</small>					
Latitude <small>decimal degrees, xx.xxxxx</small>		Longitude <small>decimal degrees, -xxx.xxxxx</small>		Elevation <small>meters</small>	
Site Characteristics					
<b>Habitat</b>					
Tundra		Tiaga		Montane grasslands	
(Sub)Tropical Coniferous Forest		Temperate Broadleaf/Mixed		Temperate Coniferous Forest	
(Sub)Tropical Dry Broadleaf		Mediterranean Forests		(Sub)Tropical Moist Broadleaf	
Temperate Grasslands		(Sub)Tropical Grasslands		Desert	
Flooded Grasslands		Riparian		Wetlands	
				Coastal	
<b>Use type</b>	Admin/Developed	Backcountry	Frontcountry	Traffic corridor	
<b>Vegetation cover</b>	0-25%	25-50%	50-75%	75-100%	
<b>Canopy cover</b>	0-25%	25-50%	50-75%	75-100%	
<b>Ground porosity</b>	1 (snow)	2 (grass)	3 (bare ground)	4 (talus)	5 (pavement)
<b>Potential sources</b>	Mechanical	Rail	Road	Trail	Water
Equipment					
<b>Digital Audio Recorder</b>		<b>Sound Level Meter</b>		<b>Microphone</b>	
Model		Model		Model	
Serial		Serial		Serial	
Settings					
Audio Bitrate	DAR Input Level	SLM Gain	OBA Range	Noise Floor	Weather Station
					Misc.
Data Types Collected					
1/3 Octave LEQ	A-wt SPL	C-wt SPL	Z-wt SPL	Continuous audio	
Wind speed	Wind dir.	Humidity	Ext. Temperature	Segmented audio	

# Acoustical Monitoring Site Visit Sheet

Site ID	Deployment Date <span style="float: right;">YYYY-MM-DD</span>							Page ____/____	
<b>Site Visits</b>									
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		
Date (YYYY-MM-DD)	Arrive Time (24hr time)	Depart Time (24hr time)	Volt. (DAR)	Voltage (SLM)	SLM time diff from GPS	Cal. Lvl (dB)	Clock Reset?	Data Xfer?	SYS ERR?
							Y/N	Y/N	Y/N
Visit Notes					Visitors		Calibrator S/N		

# Appendix B

## Sound Source Codes

### B.1 Human Caused

#### 1 Aircraft

##### 1.1 Jet

- 1.11 Jet, Air Tour*
- 1.12 Jet, Commercial*
- 1.13 Jet, G/A*
- 1.14 Jet, Military*

##### 1.2 Prop

- 1.21 Prop, Air Tour*
- 1.22 Prop, Commercial*
- 1.23 Prop, G/A*
- 1.24 Prop, Military*
- 1.25 Prop, Ultralight*

##### 1.3 Helicopter

- 1.31 Helicopter, Air Tour*
- 1.32 Helicopter, Commercial*
- 1.33 Helicopter, G/A*
- 1.34 Helicopter, Military*

#### 2 Vehicles

##### 2.1 Automobile (car, van, light truck)

##### 2.2 Motorcycle

##### 2.3 Bus (vehicle with capacity > 9 people)

##### 2.4 Truck (6+ tires)

- 2.41 Truck Medium (2 ax 6 tire, 10K-26K lbs)*
- 2.42 Truck Heavy (3+ ax 6+ tire, >26K lbs)*

##### 2.5 Heavy Equipment

##### 2.6 Rotary Snow Plow

##### 2.7 Other Snow Plow

##### 2.8 RV

###### *2.81 RV < 20 ft*

###### *2.82 RV > 20 ft*

##### 2.9 ATV

##### 2.11 Farm Equipment

##### 2.12 Alarm, Horn

##### 2.13 Door

##### 2.14 Brakes

##### 2.15 Rumble Strip

#### 3 Watercraft

##### 3.1 Outboard

###### *3.11 Outboard 2-stroke*

###### *3.12 Outboard 4-stroke*

###### *3.13 Outboard Jet Drive*

##### 3.2 Inboard

###### *3.21 Inboard 2-stroke*

###### *3.22 Inboard 4-stroke*

###### *3.23 Inboard Jet Drive*

##### 3.3 Jet Ski (PWC)

###### *3.31 Jet Ski 2-stroke*

###### *3.32 Jet Ski 4-stroke*

##### 3.4 Pontoon Boat/Houseboat

###### *3.41 Pontoon Boat/Houseboat 2-stroke*

###### *3.42 Pontoon Boat/Houseboat 4-stroke*

##### 3.5 Motorized Raft

###### *3.51 Motorized Raft 2-stroke*

###### *3.52 Motorized Raft 4-stroke*

##### 3.6 Non-motorized Craft

##### 3.7 Sail Boat



3.8 Boat Wake (on shore)	11 Construction
3.9 Air Boat	19 Non-natural Other
4 Over-snow Vehicles	19.1 Wind-induced Non-natural
4.1 Snowmobile	20 Non-natural Unknown
4.11 <i>Snowmobile 2-stroke</i>	
4.12 <i>Snowmobile 4-stroke</i>	
4.2 Snowcoach	
4.3 Snowmobile or Snowcoach	
4.4 Snow Groomer	
4.5 Snowplane	
5 Trains	
5.1 Train Rumble	
5.2 Train Whistle	
6 Motors	
6.1 Generator	
6.2 Pump	
6.3 Ice Auger	
7 Grounds Care	
7.1 Lawnmower	
7.2 Leaf Blower	
7.3 Sprinkler	
7.4 Dumpster / Trashcan	
8 People	
8.1 Voices	
8.2 Walking	
8.3 Skiing	
8.4 Portable Audio Devices	
8.5 Gunshot	
8.6 Using Boardwalk	
8.7 Bicycling	
8.8 Segway	
9 Domestic animals	
9.1 Dog	
9.2 Cow	
9.3 Horse	
10 Buildings	
10.1 Utilities (HVAC, Alarm, etc.)	
10.2 Door	
	<b>B.2 Natural</b>
	21 Wind
	21.1 Wind, Light (not mask most other sounds)
	21.2 Wind, Strong (masks most other sounds)
	22 Water
	22.1 Rain, Fog Drip
	22.2 Flowing Water
	22.21 <i>Flowing Water, Rapids</i>
	22.22 <i>Flowing Water, Ripples</i>
	22.3 Snowfall
	22.4 Waterfall
	22.5 Waves (natural)
	23 Thunder
	24 Mammals
	24.1 Squirrel
	24.2 Chipmunk
	24.3 Coyote
	24.4 Wolf
	24.5 Elk
	25 Birds
	25.1 Raven
	25.2 Canada Goose
	25.3 Duck
	25.4 Gray Jay
	25.5 Magpie
	25.6 Chickadee
	26 Reptiles
	27 Amphibians
	28 Insects
	29 Animals

30 Geothermal / Mass Movement

30.1 Aval./Rockslide

30.2 Geyser/thermal Activity

39 Natural Other

39.1 Wind-induced Natural

40 Natural Unknown

**B.3 Other**

0 No Sound Audible

41 Artifacts

41.1 Wind distortion

41.2 Static/interference–quiet

41.3 Static/interference–loud

41.4 Precipitation

41.5 Field Personnel

99 Unknown

# Appendix C

## Troubleshooting

### C.0.1 Roland R-05 not receiving audio

- Confirm that the R-05 is on.
- Confirm that the LD831 is on.
- Make sure that stereo cable is plugged into “Line In” jack on R-05, **not** “Mic” jack.
- Check all audio cables between LD831 and R-05 for proper placement and confirm that all jacks are free of dirt and dust.
- Confirm that LD831jack function (located in System properties preferences tab) is set to AC/DC.
- Ensure that microphone is properly connected to LD831.

### C.0.2 Wind speed is not being recorded on LD831

- Ensure that weather option is enabled on the LD831.
- Unplug and re-plug all cables between anemometer and LD831.
- Confirm that anemometer cups are properly seated by loosening the tension screw, removing cups, then re-attaching cups.
- Restart the LD831.

### C.0.3 Temperature is not being recorded on LD831

- Ensure that weather option is enabled on the LD831.
- Unplug and re-plug all cables between temp/humid sensor and LD831.
- Restart the LD831.

### C.0.4 No LD831 files on thumb drive at site visit

- Confirm that the LD831 was turned on and running prior to site visit.
- If LD831 had trouble saving to the thumb drive (due to corrupt files or transfer error), it may have saved to the internal memory of the LD831. Check the LD Data Explorer screen for these files.
- Before re-deploying these components, ensure that “USB Host Port” option is set to “On” and “USB Storage” is set to “Auto” in System properties, Preferences tab on the LD831.

**C.0.5 LD831 not calibrating properly**

- Ensure that calibrator is on during calibration procedure.
- Ensure that calibrator is set to proper level (likely 94 dB), and that settings on LD831 match that level (94 dB at 1000 Hz).
- Ensure that mic and calibrator are properly shielded from wind gusts during calibration.
- Ensure that microphone and preamp are properly attached to LD831 (and each other), and that the O-ring between preamp and mic is properly seated..

**C.0.6 LD831 won't turn on**

- Try to isolate the problem by providing an alternative power supply (4 AA batteries). If LD831 turns on, troubleshoot power cable or batteries.
- Confirm that sliding power switch on the bottom of the LD831 is set to the "On" position.
- Make sure LD831 power cable (which extends from bottom of LD831 to black box) is properly attached.
- If you have an extra power cable, try installing it.
- Ensure that you have provided adequate power supply (check battery levels with voltmeter).

**C.0.7 R-05 won't turn on**

- Ensure that "hold" is not switched to the on position.
- Try to isolate the problem by providing an alternative power supply (2 AA batteries). If R-05 turns on, troubleshoot power cable or batteries.
- Ensure that you have provided adequate power supply (check battery levels with voltmeter).
- Ensure that R-05 power cable (which extends from the side of the unit) is properly attached.
- If you have an extra power cable, try installing it.

**C.0.8 R-05 not responding to key presses**

- If the R-05 is on, but not responding to key presses, ensure that the "hold" switch (colocated with the power switch) is off.

**C.0.9 Input level for Roland R-05 is outside normal range**

When running a calibration procedure, the LD831 turns the +20 dB gain off. Some versions of LD831 firmware incorrectly cause the gain to remain off until the LD831 starts actively logging. In these cases, when the user adjusts the input level on the DAR, the input level must be very high to reach a peak level. Check LD831 firmware (TOOLS | ABOUT | FIRMWARE REV.)

- Firmware version < 2.1

- Field workaround: run the LD831 (Run/Pause button) during R-05 input level calibration procedure. The LD831 will properly apply the 20 dB gain, and input level should be within normal range. If peak level is lower than normal range, ensure that LIMITER or AUTO GAIN CORRECTION (AGC) is set to off on R-05.
- Office solution: upgrade unit to firmware version 2.1 or later.

#### **C.0.10 LD831 displays a blank screen**

- If the LD831 is on but the screen is blank, power save mode may be enabled. The screen will turn off after a prescribed amount of time. Press any button once to temporarily turn display back on.

#### **C.0.11 LD831 is turned off at site visit**

- Ensure that power save mode is not enabled by pressing any button once.
- If screen does not turn on, check power source with a voltmeter.
- LD831 can be powered in numerous ways, but when powered off LiFePo<sub>4</sub> batteries, the voltage must be between 14.0V and 10.8V.

#### **C.0.12 Calibrator won't turn on**

- Check battery level.

# Appendix D

## Definitions

**Acoustical Environment** The actual physical sound resources, regardless of audibility, at a particular location.

**Alerting distance** The maximum distance at which a signal can be perceived. Alerting distance is pertinent in biological contexts where sounds are monitored to detect potential threats.

**Amplitude** The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

**Atmospheric absorption** The part of transmission loss caused by conversion of acoustic energy into other forms of energy. Absorption coefficients increase with increasing frequency, and range from a few dB to hundreds of dB per kilometer within the spectrum of human audibility.

**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, the masking effects of other sound sources, and by the frequency content and amplitude of the sound.

**A-weighted sound pressure level in decibels (dB(A) or dBA)** A frequency-based methodology used to account for changes in human hearing sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 and 6.3 kHz, in an effort to simulate the relative response of the human ear. Technically speaking, A-weighted decibels are defined as ten times the logarithm to the base ten of the ratio of A-weighted squared sound pressure to the squared reference sound pressure of 20  $\mu$ Pa, the squared sound pressure being obtained with fast (F) (125ms) exponentially weighted time averaging. Alternatively, slow (S) (1000ms) exponentially weighted time averaging may be specified.

**Decibel** Decibel is abbreviated dB, and is a logarithmic unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level, when no ambiguity results from so doing. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. The formula for computing decibels is:  
$$L_{dB} = 10 \log_{10} \left( \frac{P_1}{P_0} \right)$$

**Diel** A 24-hour period usually consisting of a day and the adjoining night.

**Extrinsic Sound** Any sound not forming an essential part of the park unit, or a sound originating from outside the park boundary (also see Intrinsic Sound).

**Frequency** Frequency equals the speed of sound divided by wavelength, and can be expressed in cycles per second, or Hertz (Hz). For a function periodic in time, the frequency is the reciprocal of the period, where the period is the smallest increment of an independent variable for which a function repeats itself (also see Hertz).

**Ground attenuation** The part of transmission loss caused by interaction of the propagating sound with the ground.

**Hearing Range (frequency)** By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20,000Hz.

**Hertz (Hz)** A measure of frequency, or the number of pressure variations per second. A person with normal hearing can hear between 20 Hz and 20,000Hz. KiloHertz (kHz) equals 1,000 Hz.

**Intrinsic sound** A sound which belongs to a park by its very nature, based on the park unit purposes, values, and establishing legislation. The term “intrinsic sounds” is perhaps a more accurate way to describe “natural sounds” in the context of parks where cultural and historic sounds are part of the acoustic environment (also see Extrinsic Sound).

**Listening area** The area of a circle whose radius is the alerting distance. Listening area is the same as the ‘active space’ of a vocalization, with a listener replacing the signaler as the focus, and is pertinent for organisms that are searching for sounds.

**Listening Horizon** The range or limit of one’s hearing capabilities. Just as smog limits the visual horizon, so noise limits the acoustic horizon.

**L<sub>eq</sub>** Energy Equivalent Sound Level. The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period.

**L<sub>x</sub> (Percentile -Exceeded Sound Level)** The A-weighted sound level equal to or exceeded by a fluctuating sound level  $x$  percent of a stated time period. For example, the symbol  $L_{(10)}$  represents that sound level which is exceeded 10 percent of the stated time period.<sup>1</sup>

**Masking (of a sound)** Interference with the detection of a sound due to the presence of another sound. More specifically, the number of decibels (dB) by which the intensity level of sound A must be raised above its threshold of audibility to be heard in the presence of a second sound, B. Sound A and sound B may be identical or may differ in frequency, complexity, or time.

**Noise-Free Interval** The period of time between noise events (not silence).

**Noise** Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds<sup>2</sup>.

**Noticeable** A signal that attracts the attention of an organism whose focus is elsewhere.

**Off-site Listening** The systematic identification of sound sources using digital recordings previously collected in the field.

**Percent Time Audible** The percent of time that a time-varying sound level may be detected in the presence of ambient sound as audible by the human ear.

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<sup>1</sup>Hobbs & Downing 2003. Wyle Report WR 03-08.

<sup>2</sup>McGraw Hill Dictionary of Scientific and Technical Terms, online <http://www.accessscience.com/index.aspx>

**Spectrum, power spectrum and spectral profile** The distribution of acoustic energy in relation to frequency. In graphical presentations, the spectrum is often plotted as sound intensity against sound frequency.

**Spectrum, 1/3 octave** Acoustic intensity measurements in a sequence of spectral bands that span 1/3 octave. The International Standards Organization defines 1/3rd octave bands used by most sound level meters (ISO 266, 1975). 1/3rd octave frequency bands approximate the auditory filter widths of the human peripheral auditory system.

**Sound pressure level** Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20  $\mu\text{Pa}$ , the threshold of human hearing.  $SPL = 10\log_{10}(\frac{p^2}{p_{ref}^2})$ , where  $p^2$  = time-mean-square sound pressure and  $p_{ref}^2$  = squared reference sound pressure of 20  $\mu\text{Pa}$ .

**Spreading loss** More rigorously termed divergence loss. The portion of transmission loss attributed to the divergence of sound energy, in accordance with the geometry of environmental sound propagation. Spherical spreading losses in dB equal  $20\log_{10}(\frac{R}{R_0})$ , and result when the surface of the acoustic wavefront increases with the square of distance from the source.



# Appendix E

## Equipment Checklist

### 1. Equipment Pelican case

- ☐ Larson-Davis 831
- ☐ USB flash drive (2Gb Sandisk)
- ☐ Edirol
- ☐ SD card
- ☐ Interface box
- ☐ Site data sheet

### 2. Microphone

- ☐ Mic Capsule
- ☐ Preamp
- ☐ Bird Spike/Windscreen
- ☐ Clear environmental shroud tubing

### 3. Weather

- ☐ Davis Anemometer
- ☐ Humidity/Temperature sensor
- ☐ Radiation shield
- ☐ Mounting hardware (bolts, etc.)

### 4. Power

- ☐ Pelican case
- ☐ 40Ah 3.2V LiFePO4 batteries (8)
- ☐ 60Ah 3.2V LiFePO4 batteries (2)
- ☐ Power junction box

### 5. Cables

- ☐ 3.5mm audio cable (standard headphone jack size)
- ☐ 2.5mm audio cable (smaller jack)
- ☐ LD 831 interface cable (ethernet version)

- ☐ Interface box power cable (2.1mm x 5.5mm DC power barrel)
- ☐ LD 831 microphone cable
- ☐ Extension cords

### 6. Field Bag

- ☐ Compass
- ☐ Calibrator
- ☐ Dummy Mic
- ☐ Leatherman
- ☐ Spare batteries (4 AA, 2 AAA)
- ☐ Black electrical tape
- ☐ Voltmeter
- ☐ Desiccants
- ☐ GPS unit
- ☐ Black permanent marker
- ☐ Camera
- ☐ Extra SD card
- ☐ Extra power pole connectors
- ☐ Headphones
- ☐ Lighter
- ☐ Pencil
- ☐ Flashlight

### 7. System Hardware

- ☐ Tripods, one with a mounting screw for mic (2)
- ☐ Chains
- ☐ Locks (for pelican case and for locking the heavy chain)
- ☐ Stakes (at least 8 per system)
- ☐ Parachute cord, 6-10' (8)

- ☐ Palms for attended listening
- 8. Miscellaneous/Back-up/Repair
  - ☐ Camera charger
  - ☐ Palm charger
  - ☐ Crimper
  - ☐ Extra power cubes
  - ☐ Extra SD cards
  - ☐ Extra site visit data sheets
  - ☐ Name tags
  - ☐ Velcro ties
  - ☐ Trekking poles
  - ☐ SOP
  - ☐ SPOT Satellite Messenger

# Appendix F

## Specifications

### F.1 Power consumption

Item	Voltage (V)	Current (mA)	Power (W)
Larson Davis 831	12.0V	83.0	1.00
Roland R-05	3.2V	65.6	0.21

Table F.1: Power consumption of monitoring system

### F.2 Larson Davis 831 measurement ranges

		Gain	
		0 dB	20 dB
Measurement range	A	28-140 dB	24.9-120 dB
	C	29-140 dB	27-120 dB
	Z	35-140 dB	34-120 dB
Noise floor	A	18 dB	17 dB
	C	18 dB	17 dB
	Z	23 dB	21 dB
Linearity range	A	24-140 dB	19-120 dB
	C	25-140 dB	23-120 dB
	Z	32-140 dB	32-120 dB

Table F.2: Measurement ranges of monitoring system

## Appendix G

### Contact Info

Name	Title	Phone Number
Karen Kovacs Treviño	Division Chief	(970) 225-3563
Tech Support		SoundscapeSupport@nps.gov
Jessica Briggs	Acoustic Technician	(970) 225-3577
Kurt Fristrup, Ph.D.	Scientist	(970) 267-2102
Damon Joyce	Physical Scientist	(970) 267-2116
Cecilia Leumas	Acoustic Technician	(970) 225-3531
Emma Lynch	Acoustic Specialist	(970) 267-2104
Lelaina Marin	Planner	(970) 225-3552
Vicki McCusker	Planner	(970) 267-2117
Scott McFarland	Acoustic Technician	(970) 267-2107
Dan Mennitt, Ph.D.	Acoustic Technician	(970) 267-2114
Misty Nelson	Acoustic Technician	(970) 225-3520
Randy Stanley	Acoustic Specialist	(970) 267-2194
Frank Turina, Ph.D.	Planner	(970) 225-3530