Recommendations:

1- Sound levels and audibility from motorized oversnow vehicles should be reduced.

Although substantial improvements have been made by the switch from 2-stroke to 4-stroke snowmobiles and by the guiding requirement, the WUP L_{max} sound levels and audibility thresholds are being exceeded at developed areas and travel corridors. Improvements to snowcoach sound emissions should be made, especially to the older and louder Bombardier snowcoaches. Phasing out 2-stroke snowmobiles used by employees, contractors, and concessionaires would reduce the sound levels and audibility of those user groups. Minimizing administrative OSV use at all times, especially during the night, would minimize impacts to the natural soundscape.

Sound levels and audibility from motorized oversnow vehicles also can be reduced by lowering travel speeds. With reduced speed, visitors would experience lower OSV sound levels and percent time audible, especially in popular areas such as near thermal features and around Old Faithful. Decreasing the speed limit on all roads would reduce oversnow vehicle impacts on the natural soundscape and would have the added benefit of encouraging sightseeing while traveling. Reducing unnecessary idling and rapid acceleration, and other driver behavior modifications would also minimize sound impacts from oversnow vehicles. Reducing the total number and reducing single OSVs operating on YNP roads would also minimize their impact to natural soundscapes. Soundscape awareness training should be developed and presented to operators of motorized oversnow vehicles. The NPS should work with manufacturers, equipment operators, and concessionaires to reduce further sound levels of oversnow vehicles.

2- Audibility and sound level metrics standards and thresholds should continue to be used for impact definitions in planning documents.

The ability to determine if the acoustic impacts of winter oversnow use are meeting the management objectives require defined quantitative acoustical standards and thresholds. Acoustical monitoring and the understanding of natural soundscapes in parks are rapidly improving. The requirements for specific impact definitions and associated standards parallel these changes. It is essential to use easily understood, and more importantly, measurable and meaningful standards and thresholds. New metrics that may better address impacts from OSV sounds should be pursued.

3- Continue to monitor both audibility and sound levels.

The combination of sound level and audibility data gathered for this study provides useful acoustical information about YNP's soundscapes and the level of impact from oversnow vehicles. Collecting audibility data and identifying sources of sounds is important to characterize natural soundscapes and the non-natural acoustical impacts. Evaluating oversnow impacts on the natural soundscape requires sound source identification. In addition to information on audibility, the sound level of intruding non-natural sounds is an important aspect of soundscape monitoring. Collecting continuous 1/3 octave band frequency sound levels allows all standard acoustical metrics to be calculated. Collecting acoustical data provides the means to validate results from computer acoustical modeling.

4- Conduct acoustical experiments to fill in gaps to better understand the impacts of oversnow vehicles on the natural soundscape.

YNP can better manage the impacts of oversnow vehicles on the natural soundscape with answers to specific questions such as how group size and type of oversnow vehicle affects sound levels and audibility, what is the distance to limits of audibility in different habitat types (acoustic zones) and weather conditions, the effects of road surface on sound levels and audibility, how speed influences percent time audible and sound levels, and other currently unanswered questions. Acoustic computer modeling can begin to answer some of these questions but needs to be validated by actual field data collection. Studies are ongoing that provide information to better understand the relationship between oversnow vehicle numbers and their impact on the natural soundscape.

5- Increase the number of sampling locations and sample duration, and continue sampling beyond the winter season.

The representativeness of the acoustical dataset will improve as the number of sampling locations is increased within and among management zones. A full range of locations provides a more comprehensive evaluation of YNP's natural soundscape and the impacts from oversnow vehicles. The need for additional sites should be tempered by the disadvantages of short data collection periods. That is, because of the soundscapes inherent variability, it is usually preferable to gather multiple weeks of data at one location rather than shorter duration periods at multiple locations. Data collected during non-winter seasons allow comparisons to other seasons and provides additional information of YNP's natural and non-natural soundscapes. Year-round data collection started during the spring of 2005 and should be continued.

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Appendix A: Instrument and Setup Protocol

AC Output Weighting
For digital recordings using the AC output of the SLM, the AC output weighting shall be set to Flat, with appropriate gain setting for SLM or recording device in use

Attended Data Logging
Observers will conduct attended data logging approximately 50 m (150 feet) from the sound level meter, microphone, and/or tape recorder to ensure that field personnel can move about and conduct whispered conversations without influencing the measured sound. Observations during attended logging will be recorded on a standardized NPS data sheet.

Bird Spike
Spikes made of wire or hard plastic which prevents birds from perching on microphones and windscreens shall be used.

Cables and Wiring
All cables and wiring shall be secured to prevent any sound which might be created in windy conditions (due to wiring hitting other objects).

Calibrator
A calibrator whose performance is essentially independent of off-reference atmospheric conditions (such as the B & K Model 4231) is to be used.

Instrument Clocks
All clocks associated with the sound measurement effort shall be coordinated with GPS (Global Positioning System) time. This includes sound level meters, data loggers (notebook computer, Personal Digital Assistant-PDA), and all digital watches used during data logging. For long-term measurements, all clocks will be synchronized with GPS time at the beginning of the measurement period, and time differences with GPS time will be noted at the end of the measurement period. Acoustic data collected during the measurement period will be adjusted to correspond with GPS time.

Microphone type
A Type 1 random incidence microphone is recommended for acoustic measurements in wilderness settings. Microphones can be either polarized or pre-polarized.

Monitor Location
The microphone/pre-amplifier/windscreen shall be placed in a location representative of the habitat/acoustic zone under study. The microphone diaphragm should be placed 1.1 m to 1.5 m above the ground surface and

oriented vertically (microphone grid facing the sky).

Solar Panels
All solar panels should be placed in a location with as little shading as possible and at least .3 m (12 inches) above the ground.

Sound Level Meter
Sound level meters shall be Type I or better and should perform true numeric integration and averaging in accordance with ANSI S1.4-1983.

Time Weighting
Sound level meters shall be set to fast exponential time weighting.

Windscreen
Windscreens which are effectively acoustically transparent (less than +/- 0.5 dB effect over the frequency span of interest) shall be used.

Appendix B: Glossary of Acoustic Terms

Acoustics
The science of sound.

Ambient Sound, Existing
All sounds in a given area (includes all natural and all non-natural (human-caused) sounds).

Ambient Sound, Natural
The natural sound conditions found in a given area, including all sounds of nature. The natural ambient sound level of a park is comprised of the natural sound conditions which exist in the absence of mechanical, electrical, and other non-natural sounds. Some generally unobtrusive non-natural sounds (talking quietly, walking) may be part of the natural soundscape, but not those generated by mechanical, electrical, or motorized means. Natural ambient sounds are actually composed of many natural sounds, near and far, which often are heard as a composite, not individually. In an acoustic environment subjected to high levels of non-natural sounds, natural sounds may be masked. Natural ambient sound is considered synonymous with the term “natural quiet,” although “natural ambient sound is more appropriate because nature is not always quiet.

Ambient Sound, Non-natural
Ambient sounds attributable to non-natural sources (mechanical, electrical, and other non-natural sources). In a national park setting, these sounds may be associated with activities that are essential to the park's purpose, they may be a by-product of park management activities, or they may come from outside the park.

Appropriate Sounds
Sound conditions defined as appropriate for an area in national parks, such as a specific management zone. Other appropriate sounds, not natural in origin, are those types of sounds which are generated by activities directly related to the purposes of a park, including resource protection, maintenance, and visitor services. Natural sounds are not only appropriate, but are part of the park’s resource base to be protected and enjoyed by the visiting public.

Appropriate Sound Level
Appropriate sound levels in a given area of a park are determined based on mandates in the Organic Act, establishment legislation, or other laws pertinent to the specific purposes and values associated with the park. This determination takes the form of management zone objectives for soundscape, as well as measurable indicators and standards for sound.

Attenuation
The reduction of sound intensity by various means (e.g., air, humidity and porous materials).

Area of Audibility
The area within which a specific sound or sounds is audible.

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

Decibel
A logarithmic measure of any measured physical quantity and commonly used in the measurement of sound. The decibel provides the possibility of representing a large span of signal levels in a simple manner as opposed to using the basic unit Pascal. The difference between the sound pressure for silence versus a loud sound is a factor of 1,000,000:1 or more, therefore it is less cumbersome to use a small range of equivalent values: 0 to 130 decibels. See also, Sound Level.

Doubling of Sound Pressure = 6 dB
Doubling of Sound Power = 3 dB
Doubling of Perceived Sound Level = 10 dB (approximately)

Doppler Effect (or Shift)
The apparent upward shift in frequency of a sound as a noise source approaches the receiver or the apparent downward shift when the noise source recedes.

Energy Equivalent Sound Level (L_{eq}**)**
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_{eq} depends heavily on the loudest periods of a time-varying sound. L_{eq} of an intruding source by itself, though, is inadequate for fully characterizing the intrusiveness of the source. Research has shown that judgments of the effects of intrusions in park environments depend not only upon the amplitude of the intrusion, but also upon the sound level of the "background," in this case, the sound level of the non-intruding sources, usually the natural ambient sound levels. L_{eq} must be used carefully in quantifying natural ambient sound levels because occasional loud sound levels (gusts of wind, birds, insects) may heavily influence (increase) its value, even though the sound levels are typically lower.

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

Hearing Range (human)
An average healthy young person can hear frequencies from approximately 20 Hz to 20000 Hz, and sound pressure levels from 0 dB to 130 dB or more (threshold of pain). The smallest perceptible change is 1 dB.

Impact
For environmental analysis, an impact is defined as a change at a receptor that is caused by a stimulus, or an action. In accordance with the CEQ regulations (40 CFR 1500-1508), direct and indirect impacts (environmental consequences) are to be described in an environmental document by assessing their type, magnitude, intensity, and duration. The significance of an impact is to be determined specifically in view of criteria provided in 40 CFR 1508.27, based on the outcome of these assessments. An assessment will take account of the short or long term nature of the impact, the extent to which it is either beneficial or adverse, whether it is irreversible or irretrievable, and, finally, its geographic and societal extent. Lastly, a resource impact is put in the context of all other past, present or reasonably foreseeable actions which affect the same resource, and its contribution to the total cumulative effect is to be disclosed. Under CEQ regulations, the term “impact” is synonymous with “effect” (40 CFR 1508.8).

Loudness
The subjective judgment of intensity of a sound by humans. Loudness depends upon the sound pressure and frequency of the stimulus. Loudness was defined by Fletcher and Munson (1933) as a physiological description of the magnitude of an auditory sensation.

Masking
The process by which the threshold of audibility for a sound is raised by the presence of another (masking) sound. A masking noise is one that renders inaudible or unintelligible another sound that is also present.

Noise
Traditionally, noise has been defined as unwanted, undesired, or unpleasant sound. This makes noise a subjective term. Sounds that may be unwanted and undesired by some may be wanted and desirable by others. Noise is sound, as defined in this document: a pressure variation, etc. In order to keep terms used in soundscape management as non-subjective as possible, sounds should be classified as either appropriate or inappropriate, rather than as “noise.” or “sound.” The appropriateness of any sound in a given area of a park will depend on a variety of factors, including the management objectives of that area.

Noise-free Interval
The period of elapsed time between human-caused sounds. The length of the continuous period of time during which only natural sounds are audible. Though

little research has been conducted to relate how this measure correlates with ecological functioning, visitor judgments or with common experiences in park settings, it should provide a reasonable measure of the existence and availability of periods with only natural sounds. It is also a metric that requires no acoustics knowledge to be meaningful.

Octave
The interval between two frequencies having a ration of 2 to 1. For acoustic measurements, the octaves start a 1000 Hz center frequency and go up or down from that point, at the 2:1 ratio. From 1000 Hz, the next filter's center frequency is 2000 Hz, the next is 4000 Hz, etc., or 500 Hz, 250 Hz, etc. Octave filtering is usually referred to as the class of octave filters typically 1, 3 or 12, thus creating full octaves, one-third octaves, or one-twelve octaves.

Octave Band
The segment of the frequency spectrum centered on an octave center frequency bounded by the midpoint between the next lower and higher octave.

Percent Exceedance (L_x)
These metrics are the sound levels (L), in decibels, exceeded *x* percent of the time. The L_{50} value represents the sound level exceed 50 percent of the measurement period. L_{50} is the same as the median. The L_{90} value represents the sound level exceeded 90 percent of the time during the measurement period. L_{50} and L_{90} are useful measures of the natural sounds because in park situations, away from developed areas, they are less likely to be affected by non-natural sounds. Put another way, non-natural sounds in many park areas are likely to affect the measured sound levels for less than 50% of the time, and almost certainly for less than 90% of the time. L_{50} is used when there is high probability that no non-natural sounds affect the measurements. L_{90} is used when human-produced sounds are present much of the time during measurements. Common sounds that could be present for more than 50% of the time include road traffic sounds and, in some areas, high altitude jet aircraft.

Percent Time Above Natural Ambient
The amount of time that sound levels from non-natural sound(s) are greater than sound levels of natural ambient sound levels in a given area. This measure is not specific to the hearing ability of a given animal, but a measure of when and how long non-natural sound levels exceed natural ambient sound levels.

Percent Time Audible
The amount of time that various sounds are audible to animals, including humans, with normal hearing (hearing ability varies among animals). A specific sound may be below the natural ambient sound level, but still be audible to some animals. This information is essential for measuring and monitoring non-natural sounds in national parks. These data can be collected by either a trained observer

(attended logging) or by making high-quality digital recordings (for later playback). Percent Time Audible is useful because it is a measure that is understandable without any acoustics knowledge. It is a metric that correlates well with park visitor judgments of annoyance and with visitor reports of interference from certain sound sources with the sounds of nature.

Spectrum (Frequency Spectrum)
The amplitude of sound at various frequencies. It is given by a set of numbers that describe the amplitude at each frequency or band of frequencies.

Sound
A wave motion in air, water, or other media. It is the rapid oscillatory compressional changes in a medium that propagate to distant points. It is characterized by changes in density, pressure, motion, and temperature as well as other physical properties. Not all rapid changes in the medium are sound (such as wind distortion on a microphone diaphragm).

Sound Impacts
Sound impacts are effects on a receptor caused by the physical attributes of sound emissions. In national parks, non-natural sounds cause physical changes in the soundscape that can be detected and measured. The fact that a sound can be measured does not equate immediately to whether the impact of that sound is adverse, inconsequential, or beneficial, or whether there are adverse secondary impacts on wildlife, cultural values, or visitors. Levels of impact and impact significance are policy determinations.

Soundscape
Soundscape refers to the total acoustic environment associated with a given area. In a national park setting, soundscapes can be composed of natural sounds, or it can be composed of both natural and non-natural sounds.

Soundscape, Natural
Natural soundscapes consist of sounds associated with nature: wind, water flow, rain, surf, wildlife, thermal activity, lava flows, or other sounds not generated by non-natural means.

Sound Level
The *weighted* sound pressure level obtained by frequency weighting, generally A-weighting (dBA).

Sound Level Floor (Noise Floor)
The lowest amplitude measurable by sound monitoring equipment. Most commercially available sound level meters and microphones can detect sound levels down to about 15 to 20 dBA; however, there are microphones capable of measuring sound levels below 0 dBA.

Sound Pressure Level (SPL)
The logarithmic form of sound pressure. In air, 20 times the logarithm (to the base 10) of the ratio of the actual sound pressure to a reference sound pressure (which is 20 micropascals, and by convention has been selected to be equal to the assumed threshold of human hearing). It is also expressed by attachment of the word decibel to the number.

Windscreen
A porous device used to cover the microphone of a sound level measurement system. Windscreens are designed to minimize the effects of wind disturbance on the sound levels being measured while minimizing the attenuation of the signal.

These definitions were derived from several sources, including:

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Appendix C. Acoustic standards and thresholds in previous winter use plans

Table C-1. Management zones and soundscape thresholds in 2000 Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr. Memorial Parkway Final Environmental Impact Statement Winter Use Plan.

Zone	Management Zone	Maximum Audibility[1] of motorized sound during the hours of 8 am-4 pm
1	Destination or Support Area	Audibility: NTE 50% (anywhere within area boundary)
2	Plowed Road (within 100 feet (30 m) either side of road)	Audibility: NTE 50% at 100 feet (30 m)
3	Groomed Motorized Route Clean and Quiet (within 100 feet (30 m) either side route)	Audibility: NTE 50% at 100 feet (30 m)
4	Groomed Motorized Route (within 100 feet (30 m) either side route)	Audibility: NTE 50% at 100 feet (30 m)
5	Groomed Motorized Trail Clean and Quiet (within 100 feet (30 m) either side of trail)	Audibility: NTE 25% at 100 feet (30 m)
6	Groomed Motorized Trail (within 100 feet (30 m) either side of trail)	Audibility: NTE 25% at 100 feet (30 m)
7	Ungroomed Motorized Trail (within 100 feet (30 m) either side of trail)	Audibility: NTE 25% at 100 feet (30 m)
8	Groomed Non-motorized Trail	Audibility: NTE 10% at 500 feet (152 m)
9	Ungroomed Non-motorized Trail or Area	Audibility: NTE 10% at 500 feet (152 m)
10	Backcountry non-motor trail or area	Audibility: NTE 10% at 500 feet (152 m) Audibility: NTE 0% at 1000 feet (305 m)

[1] Audibility- the ability of a person with normal hearing to hear a given sound

Table C-2. Management zones and soundscape thresholds in 2003 Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr. Memorial Parkway Final Supplemental Environmental Impact Statement Winter Use Plan.

Zone	Management Zone	Maximum Audibility[1], Max. dBA[2], and Hourly L_{eq}[3] of oversnow vehicle sounds during hours of 8 am-4 pm
1	Destination or Support Area (anywhere within area boundary)	Audibility: NTE[4] 50% dBA: NTE 70 dBA L_{eq}: NTE 45dBA
2	Plowed Road (within 100 feet (30 m) either side of road)	Audibility: NTE 50% dBA: NTE 70 dBA L_{eq}: NTE 45 dBA
3	Groomed Motorized Route (within 100 feet (30 m) either side route)	Audibility: NTE 50% dBA: NTE 70 dBA L_{eq}: NTE 45 dBA
4	Groomed Motorized Trail (within 100 feet (30 m) either side route)	Audibility: NTE 50% dBA: NTE 70 dBA L_{eq}: NTE 45 dBA
5	Ungroomed Motorized Trail or Area (within 100 feet (30 m) either side of trail)	Audibility: NTE 50% dBA: NTE 70 dBA L_{eq}: NTE 45 dBA
6	Groomed Non-motorized Trail (within 100 feet (30 m) either side of trail)	Audibility: NTE 25% dBA: NTE 70 dBA L_{eq}: NTE 45 dBA
7	Ungroomed Nonmotorized Trail or Area (within 100 feet (30 m) either side of trail)	Audibility: NTE 20% dBA: NTE Lnat[5] - 6 dBA L_{eq}: NTE to Lnat
8	Backcountry Nonmotorized Area (anywhere within area >1,000 feet (301 m) from motorized area)	Audibility: NTE 20% dBA: NTE Lnat - 6 dBA L_{eq}: NTE to Lnat
9	Sensitive Area (no winter use)	

[1] Audibility- the ability of a person with normal hearing to hear a given sound
[2] dBA- weighted sound level in decibels
[3] L_{eq} - 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.
[4] NTE- not to exceed
[5] Lnat- The natural sound conditions found in a given area, including only sounds of nature.

Table C-3. Impact definitions for the natural soundscape in the 2004 Temporary Winter Use Plans (WUP) Environmental Assessment. Also see Appendix C.

Impact Category Definition[1]	Management Area	Audibility[2, 3]	Maximum Sound Level[3,4]
No Effect An action that does not affect the natural soundscape or the potential for its enjoyment.	Na	Na	Na
Adverse Negligible Effect An action that may affect the natural soundscape or potential for its enjoyment, but with infrequent occurrence and only for short duration at low sound levels. At this impact level, unique soundscape characteristics (such as bubbling hot springs or geysers are rarely affected).	Developed	Sound created by action is audible < 25%	Maximum sound level created by action is < 45 dBA
	Travel Corridor	<5%	< 40dBA
	Backcountry	<5%	<40 dBA
Adverse Minor Effect An action that may affect the natural soundscape or potential for its enjoyment.	Developed	>25% <45%	<60 dBA
	Travel Corridor	>15% <25%	<60 dBA
	Backcountry	>5% <10%	<40 dBA
Adverse Moderate Effect An action that may affect the natural soundscape or potential for its enjoyment.	Developed	>45% <75%	<70 dBA
	Travel Corridor	>25% <50%	<70 dBA
	Backcountry	>10% <20%	<45 dBA
Adverse Major Effect An action with an easily recognizable adverse effect on the natural soundscape and potential for its enjoyment.	Developed	>75%	>70 dBA
	Travel Corridor	>50%	>70 dBA
	Backcountry	>20%	>45 dBA

[1]Thresholds are calculated using the period 8 am-4 pm. Measurements are at 100 feet (30 m) from sound source in developed areas and travel corridors.
[2]Audibility is the ability of humans with normal hearing to hear a certain sound.
[3]To remain within impact category listed audibility and maximum sound level thresholds shall not be violated more than 15% of the measurement days.
[4]Typical natural soundscape sound levels on a calm winter day can range from 0-30 dBA. Snowmobile best available technology (BAT) sound level requirements of 73 dBA measured at 50 feet (15 m) is roughly equivalent to 67 dBA at 100 feet. The maximum sound level for all non-natural sounds in national parks other than OSVs and motorboats is 60 dBA [36 CFR (2.12) (a)(1)(i)].

Appendix D. Visualizations of sound levels

The NPS Natural Sound Program in Ft. Collins, CO developed a technique for plotting each of the 33 one-third octave band frequency decibel levels for each second of the day (ex. Fig. D-1). The major sources of sound at each monitoring location can be “seen” in these visualizations. Viewing the pictures in color is essential. Each figure is one day, 24 hours from midnight to midnight. Each row contains two hours starting with the first hours of the day, labeled with white two digit numbers. The site and date is the title on top. The sound frequency is plotted on a logarithmic scale as indicated in the left margin. The right margin contains the decibel range and associated colors. Brighter colors indicate higher sound levels; deep blue is the quietest. Maroon diagonal lines indicate times of sample recordings and wind is indicated by the occasional erratic white lines. Not only can specific sound sources be identified from these visualizations, but patterns and the variability in number, timing, and sources of sounds can be seen.

Figures D-1-D-5 show example days from five monitoring sites. Determining the common sound sources signatures from the 1/3 octave band frequencies is not difficult, but takes a bit of experience. A brief introduction follows. Oversnow vehicle signatures are narrow yellow marks that extend from high to low frequency. Louder sounds are brighter yellow as shown in hour 10 in Fig. D-1. Snow groomers are the brighter broader marks with the extended light blue trails before and after in hours 18 and 23 (Fig. D-1). During the hours 00, 12, 13, 17, 18, 19, 23 and others, a jet appears as a slanting haystack (caused by the Doppler effect of decreasing frequency as the jet travels away from the monitoring location) (Fig. D-1). Starting during the 21 hour popping sounds from trees is clearly seen in the frequent vertical light blue lines.

Building utility sounds and wind create the extensive pale blue and horizontal light blue lines at Old Faithful Weather Station (Fig. D-2). The sounds of riffles on the Madison River are shown especially during the early morning and late evening hours (Fig. D-3). Aircraft and wind gusts are the main “visible” sounds at Delacy Creek Trail (Fig. D-4) and at Mary Mountain 8K (Fig. D-5). Mary Mountain 8K has the addition of sounds from the Nez Perce Creek (Fig. D-5). The Doppler Effect is also evident with propeller planes (double declining lines) during the 14 hour (Fig. D-4).

Figures D-7 and D-8 compare the sound levels during Saturday of Presidents Day Weekend at Madison Junction 2.3 during 2003 (1,679 snowmobiles during Saturday and Sunday) and 2008 (768 snowmobiles during Saturday and Sunday). One can readily see the yellow spikes of OSVs passing the monitoring site beginning earlier in the day in 2003 and with shorter time intervals between OSVs. This comparison illustrates the difference in noise-free interval, sound level, distribution, and number of OSVs between years. See figure D-3 for another example of OSV activity at this site during the most recent winter season.

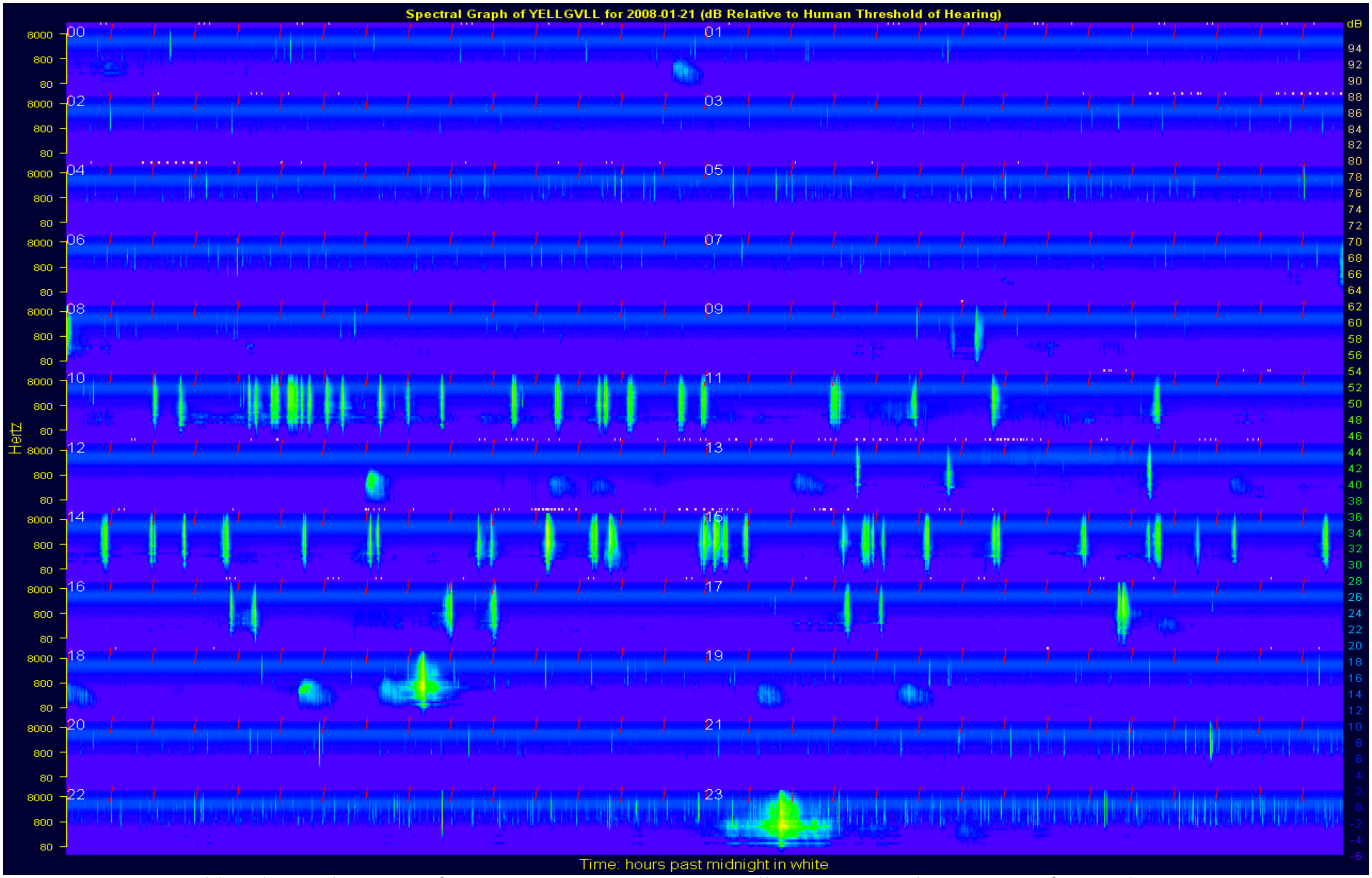

Figure D-1. Sound level visualization of 21 January 2008 at Grant Village Lewis Lake. See text for explanation.

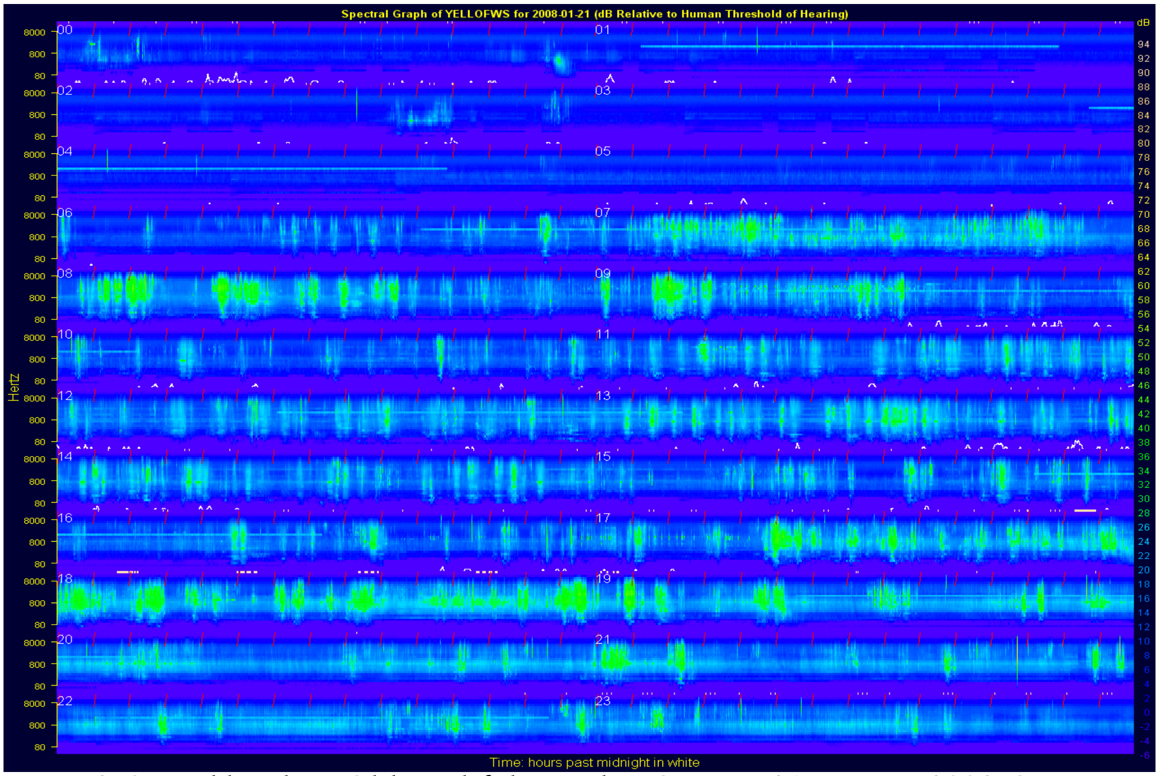

Fig D-2. Sound levels at Old Faithful Weather Station, 21 January 2008. See text for explanation.

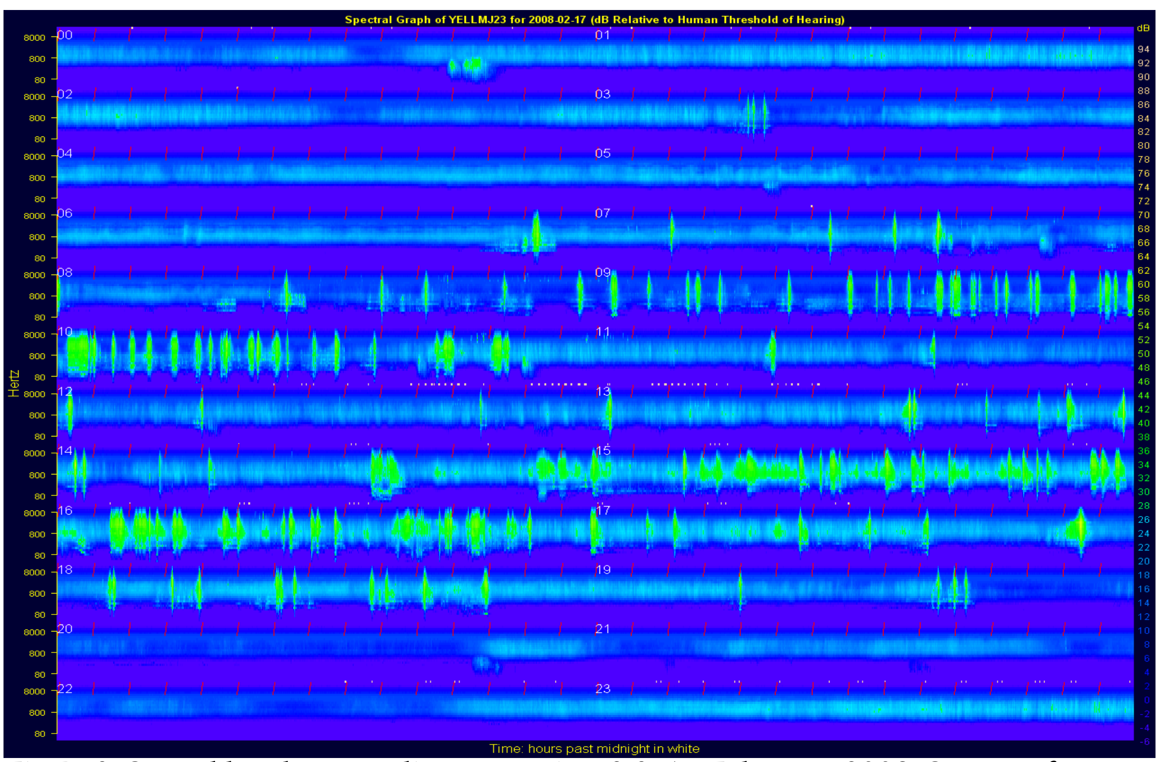

Fig D-3. Sound levels at Madison Junction 2.3, 17 February 2008. See text for explanation.

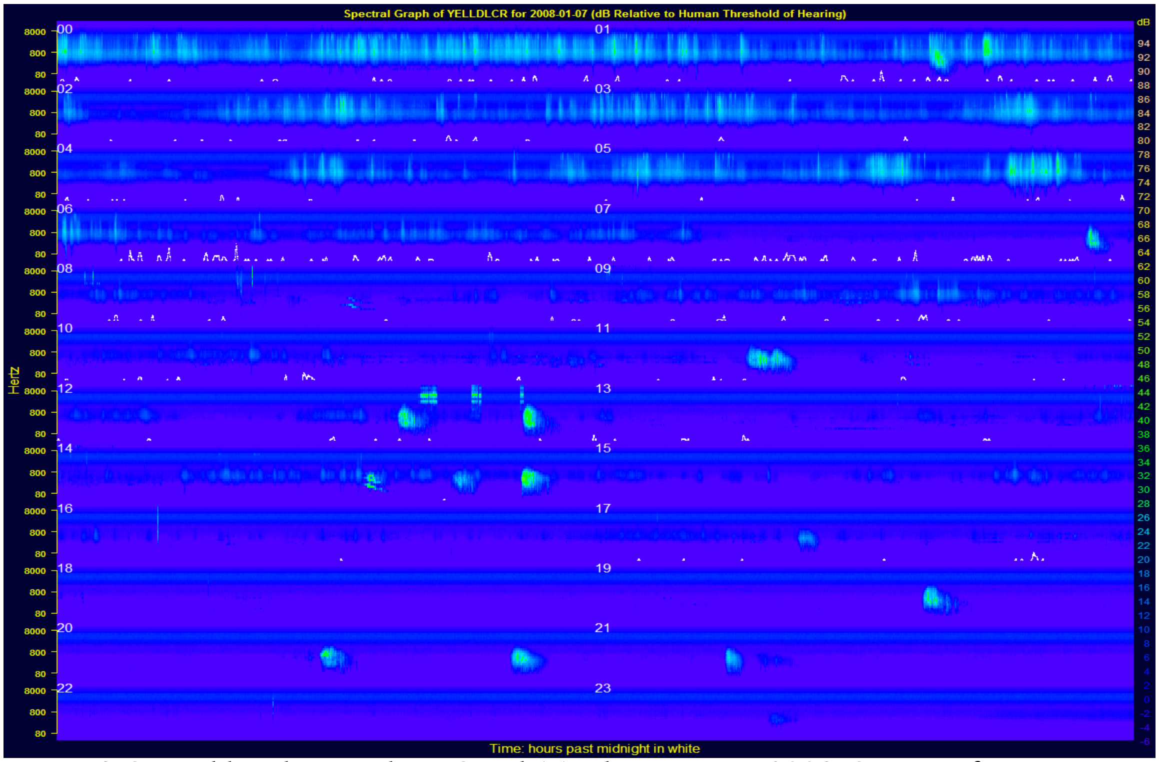

Fig D-4. Sound levels at Delacy Creek Trail, 7 January 2008. See text for explanation.

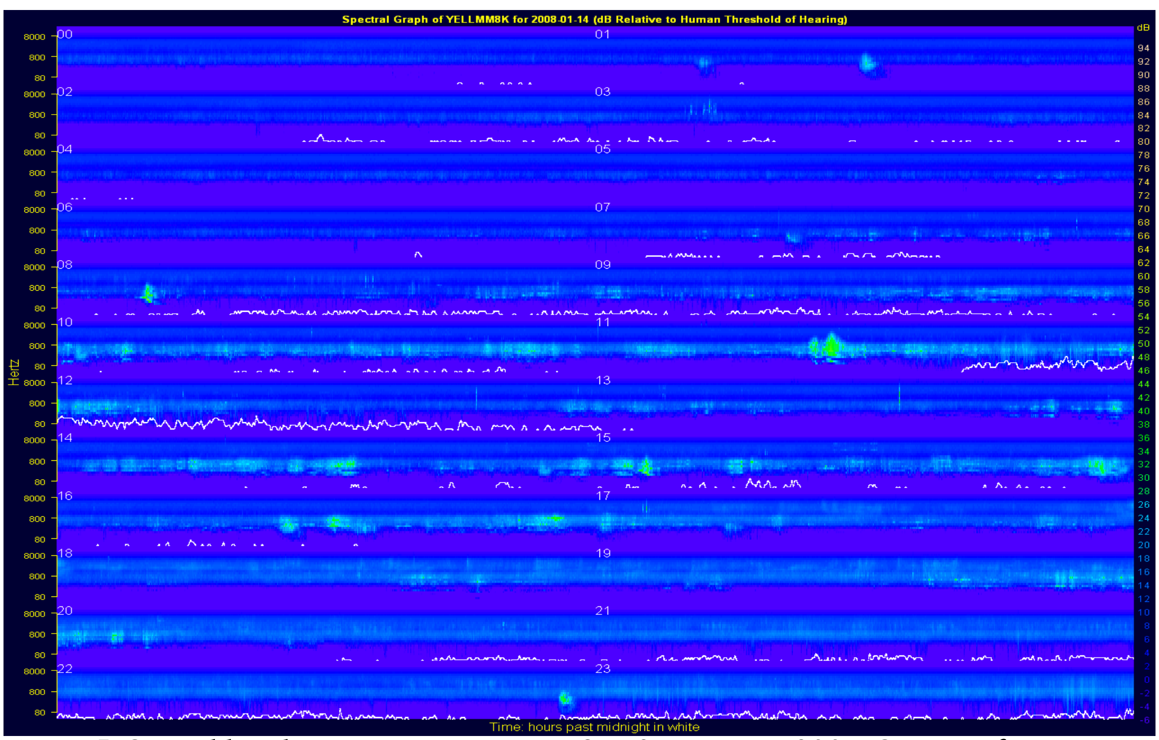

Fig D-5. Sound levels at Mary Mountain 8K, 27 January 2007. See text for explanation.

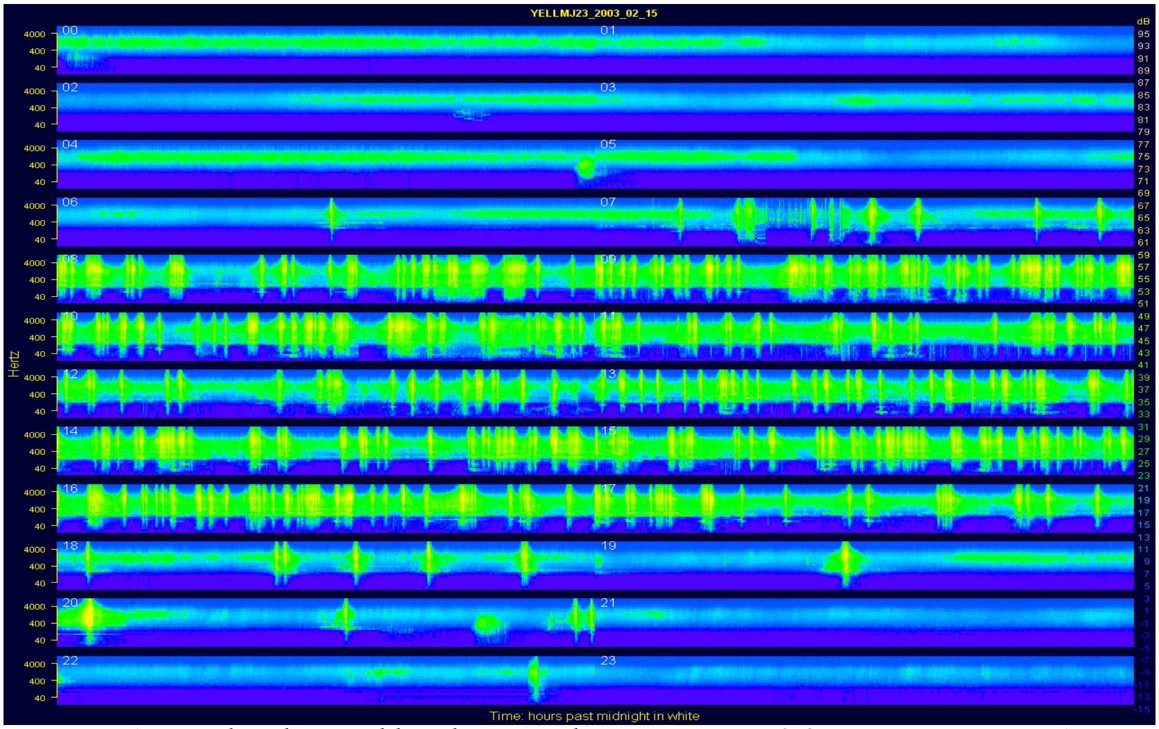

Fig D-7. A-weighted sound levels at Madison Junction 2.3 monitoring site, 15 February 2003. Compare to Fig. D-8 for number and timing of OSVs. See text for explanation.

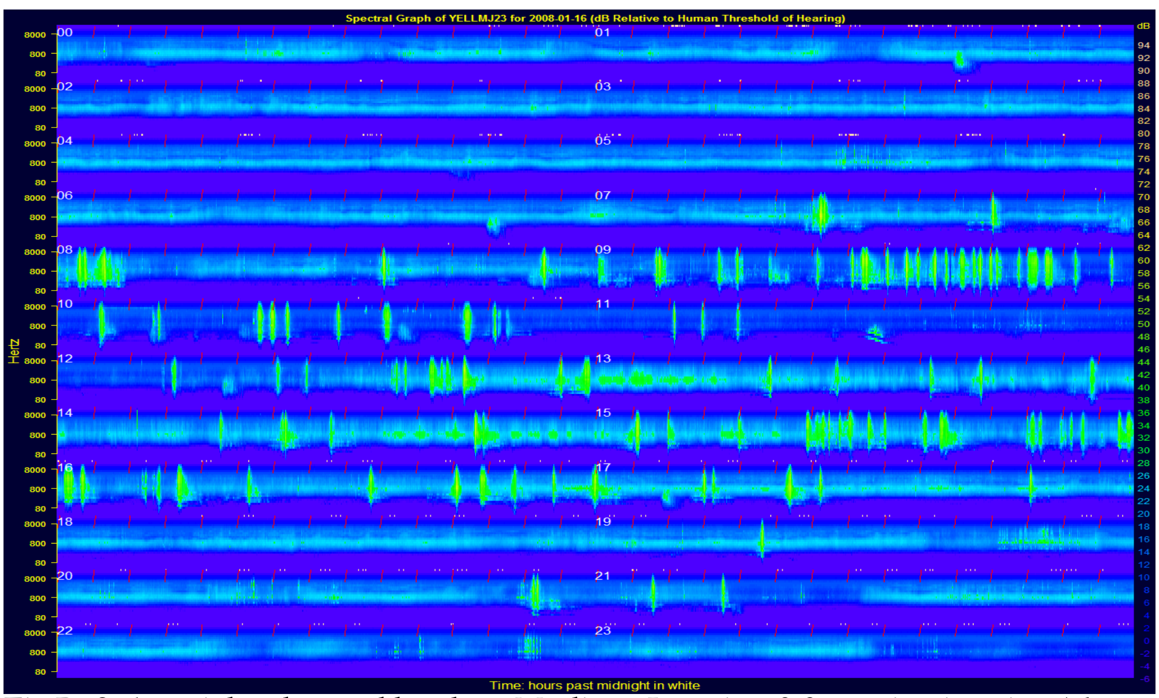

Fig D-8. A-weighted sound levels at Madison Junction 2.3 monitoring site, 16 February 2008. Compare to Fig. D-7 for number and timing of OSVs. See text for explanation.

Appendix E. Observational study of oversnow vehicle usage

The audibility analysis using unattended sound monitoring equipment estimated the percent time all sounds were audible at those locations. Unfortunately, that technique was not able to provide the identity of the user type of oversnow vehicles. To determine the type and proportion of oversnow vehicle usage a separate observational study was conducted during the four winters of 2005-2008. Observers were positioned within view of travel routes at a number of key locations and documented the time audible and type of usage for each oversnow vehicle observed. The data were collected during 128 logging periods at locations within developed areas and along the travel corridors mainly between Lewis Lake and West Yellowstone and Bridge Bay and Cygnet Lake (Table E-1), 17 February-5 March 2005, 20 January-9 March 2006, 26 December 2006-5 March 2007 and 8 January-5 March 2008. The total observer logging time was 168 hr 0 min 04 sec, 7 am to 5 pm, split between morning and afternoon.

Table E-1. Locations used for observational study of oversnow usage patterns during winters 2005-2008 in Yellowstone National Park.

Developed Area	Travel Corridor
Old Faithful Entrance Road	Kepler Cascades Pullout
Old Faithful Parking Lot	Daisy Trailhead
Old Faithful Ranger Station	Mallard Lake Trailhead
Old Faithful Main Road	Midway Geyser Basin
Canyon Junction	Mary Mountain Trailhead
	Madison Junction 2.3
	West Yellowstone 3.1
	Bridge Bay Area
	Talus Slopes
	Tuff Cliff Pullout
	Cygnet Lake Trailhead
	Grant Village Lewis Lake
	Spring Creek

Oversnow usage types included guided visitors, NPS administrative use, contractors, and Xanterra administrative use, (see sample data sheet Table E-2). These data were then transferred to an MS Access^{TM} database for summary and analysis. Tables E-3 to E-6 present these summary analyses. Oversnow vehicles that were not seen, but only heard, were not included in these results because the user group could not be determined.

The number and proportion of snowmobiles was analyzed by group (Table E-3) and by individual machine (Table E-4). The developed area, travel corridor, and combined totals are summarized in both tables. To understand snowmobile usage patterns within Yellowstone NP it is necessary to assess both group and individual patterns. A total of 2,028 groups of oversnow vehicles were documented, including 1,399 groups of snowmobile (E-3). Guided group size ranged from 1-31 (the largest group size numbers were likely from multiple groups that had merged together). Average size for all snowmobile groups was just over four and one half snowmobiles per group; seven snowmobiles per guided group and just over one snowmobile per administrative group. A total of 6,827 individual oversnow vehicles were tallied, including 6,013 snowmobiles (E-4).

Of all individual snowmobiles observed, guided visitors (recreational use) accounted for 94% along travel corridors and 83% in developed areas (Table E-4). Guided visitors comprised 70% of all groups documented along travel corridors (Table E-3). As would be expected, more administrative travel occurred in developed areas than along travel corridors between developed areas (Tables E-3 and E-4). Contractors working on the Old Faithful Inn comprised 9% of all groups of snowmobiles documented in developed areas (Table E-3). Other administrative travel totaled 53% of the total number of groups observed in developed areas (Table E-3).

The same analysis was done with snowcoach use in developed areas and travel corridors (Table E-5). Administrative travel is mostly by snowmobile but the NPS and concessions do travel by snowcoach, especially between locations in developed areas. Guided snowcoaches with park visitors comprised 94% of snowcoaches observed along travel corridors and 86% of snowcoaches within developed areas (Table E-5). Of the 629 snowcoaches observed, 9 out of 10 were guided (Table E-5).

Guided snowmobiles comprised 51% of all audible snowmobiles and 58% of all audible motorized vehicles (Table E-6). Guided snowcoaches comprised 26% of all audible motorized vehicles (Table E-6). All oversnow vehicles were audible for 54% of the study period and comprised 90% of the motorized sounds audible (Table E-6). Snowmobiles were audible for 59 hours 18 minutes and 27 seconds (35%) of the 168 hours 00 minutes and 04 second study period (Table E-6). No motorized sounds were audible for 40% of the time during the study period (Table E-6).

Table E-2. Field data sheet for logging oversnow usage type in Yellowstone National Park, during the winters of 2005-2008.

Date:		Time: Start/End	Page of
Name, Address, Telephone:	Shan Burson Grand Teton National Park 307 739 3584		
Location Description:		Latitude:	
		Longitude:	
		Elevation (ASL, feet):	
Habitat types (up to three, include percentage) and Terrain within .5 km:			
Weather	Temperature (F):	Cloud cover (%):	
	Wind (MPH/from):	Precipitation:	

Time Start:	Source*:	Time Stopped:	Location:	Remarks:
10:41:05	4.2	10:46:08	Eastbound	Yellow Bombardier
10:45:12	4.1	10:48:50	Out headed south	8 in guided group leaving OF
24 hr. time. Include exact Obs.Time Start and End				

*Source:				Instructions
0	None audible	8	People	
1.1	Aircraft, jet	10	Building sounds	Record when non-natural sounds are audible. Give priority to oversnow.
1.2	Aircraft, propeller	11	Construction	Record other non-natural sounds as possible. Note when ignoring them.
1.3	Aircraft, helicopter	19	Non-natural other	Record time in hours, minutes and seconds. Try to use GPS time (that is.
2	Vehicle (type)	20	Non-natural unk.	accurate time). Record stop time as well as start time.
3	Watercraft (type)			Record oversnow type (4.1, 4.2, 4.3, 4.4) and number making up group.
4	Oversnow Vehicle			Record type of user (contractor, Xanterra, NPS researcher, Ranger, admin,
4.1	Snowmobile			snowcoach or guided snowmobile group) in Remarks column.
4.2	Snowcoach			Note type of snowcoach (Mattrax, Red or Yellow Bomb, Yellow Bus, etc.)
4.3	Snowmobile or Snowcoach			Record type of snowmobile if not 4 stroke.
4.4	Snow Groomer			Record anything else that would improve understanding of circumstances.
6	Motors			Record direction of travel in Location column

Table E-3. Number and proportion of snowmobile groups by usage type traveling within Yellowstone National Park, winters 2005-2008.

Location	Guided Snowmobiles	Contractor	NPS Maintenance	Ranger	Research	NPS Other/Unknown	Concession Admin	Unknown Admin	Xanterra Admin	Total
Developed Area	244	55	47	76	9	85	18	4	97	635
	38%	9%	7%	12%	1%	13%	3%	1%	15%	100%
				NPS-All[a]	217					
					34%					
				Admin-All[b]	336					
					53%					
Travel Corridor	534	11	10	49	43	90	15	0	12	764
	70%	1%	1%	6%	6%	12%	2%	0%	2%	100%
				NPS-All	192					
					25%					
				Admin-All	153					
					20%					
All Areas	778	66	57	125	52	175	33	4	109	1399
	56%	5%	4%	9%	4%	13%	2%	0%	8%	100%
				NPS-All	260					
					19%					
				Admin-All	358					
					26%					

[a]NPS-All Includes maintenance, rangers, research and NPS others/unknown

[b]Admin-All Includes all but guided snowmobiles and contractors

Table E-4. Number and proportion of individual snowmobiles by usage type traveling within Yellowstone National Park, winters 2005-2008.

Location	Guided Snowmobiles	Contractor	NPS Maintenance	Ranger	NPS Research	NPS Other/Unknown	Concession Admin	Unknown Admin	Xanterra Admin	Total
Developed Area	1651	73	51	54	11	65	10	5	77	1997
	83%	4%	3%	3%	1%	3%	1%	0%	4%	100%
				NPS-All[a]	181					
					9%					
				Admin-All[b]	273					
					14%					
Travel Corridor	3653	23	13	41	44	90	24	0	12	3900
	94%	1%	0%	1%	1%	2%	1%	0%	0%	100%
				NPS-All[a]	188					
					5%					
				Admin-All[b]	224					
					6%					
All Areas	5304	96	64	95	55	155	34	5	89	5897
	90%	2%	1%	2%	1%	3%	1%	0%	2%	100%
				NPS-All[a]	369					
					6%					
				Admin-All[b]	497					
					8%					

[a]NPS-All Includes maintenance, rangers, research and NPS others/unknown

[b]Admin-All Includes all but guided snowmobiles and contractors

Table E-5. Number and proportion of individual snowcoaches by usage type traveling within Yellowstone National Park, winters 2005-2008.

Location	Guided Snowcoach	Contractor	NPS Maintenance	NPS Ranger	NPS Other/Unknown	Concession Admin	Unknown Admin	Xanterra Admin	Total
Developed Area	249	2	1	1	5	5	3	23	289
	86%	1%	0%	0%	2%	2%	1%	8%	100%
				NPS-All[a]	7				
					2%				
				Admin-All[b]	38				
					13%				
Travel Corridor	318	0	0	1	5	5	0	11	340
	94%	0%	0%	0%	1%	1%	0%	3%	100%
				NPS-All	6				
					2%				
				Admin-All	22				
					6%				
All Areas	567	2	1	2	10	10	3	34	629
	90%	0%	0%	0%	2%	2%	0%	5%	100%
				NPS-All	13				
					2%				
				Admin-All	60				
					10%				

[a]NPS-All Includes maintenance, rangers, research and NPS others/unknown

[b]Admin-All Includes all but guided snowmobiles and contractors

Table E-6. Elapsed time (hours:minutes:seconds) and percentages for motorized vehicles during an observational study, winters 2005-2008, Yellowstone National Park. Totals may not appear correct due to rounding errors.

User Group	Elapsed Time	Percentage	Combined Total
All Motorized Sounds			
Jets	4:31:01	4%	
Props	1:51:58	2%	
Helicopters	0:32:43	1%	7%
Snowmobile	59:18:27	58%	
Snowcoach	26:30:02	26%	
Snowmobile or Snowcoach	1:35:29	2%	
Unknown Oversnow Vehicle	3:47:17	4%	90%
Groomer	2:10:15	2%	2%
Unknown/Other Motorized	1:17:15	1%	3%
	101:34:27		
Snowmobiles Only			
Guided Snowmobile	30:14:07	51%	51%
Contractor	1:09:21	2%	2%
NPS-Maintenance	1:26:03	2%	
NPS-Ranger	3:39:19	6%	
NPS-Research	1:17:06	2%	
NPS-Other/Unknown	4:46:36	8%	19%
Admin-Concession	2:38:12	4%	
Admin-Xanterra	2:10:17	4%	
Admin-Unknown	0:02:20	0%	8%
Unknown User	11:55:06	20%	20%
	59:18:27		
Total Observation Time	**168:00:04**		
Motorized Sounds	101:34:27	60%	
Oversnow Vehicles	91:11:15	54%	
Snowmobiles	59:18:27	35%	
No Motorized Sounds	66:25:37	40%	

Appendix F. Monitoring results from the winters of 2003-2007

The following figures include monitoring results from previous winters. These figures are useful for comparison to the analysis presented for the 2007-2008 winter season in the body of this report.

Two differences between the analyses of the winters 2003-2004 and the following three winters should be noted. The hourly sound levels by month are calculated using median values for the L_{eq}, L_{50}, and L_{90} values for 2004-2005, 2005-2006, and 2006-2007. The same metrics were calculated as log means for winter 2003-2004. All sound levels collected when the wind speed was greater than 11 mph were deleted from the analysis in 2004-2005, 2005-2006, and 2006-2007. During 2003-2004 some data were retained with wind speeds higher than 11 mph. These differences among years would tend to increase the L_x values for the winter 2003-2004 during those periods with high wind and at sites with few loud events. The log means are more influenced by higher values than is the median and the retention of high wind speeds would also have increased the L_x values. However, at the YNP monitoring sites there would be generally less then 5% difference between the metrics calculated using the two methodologies (Mike Donaldson, pers. comm.).

Old Faithful Weather Station

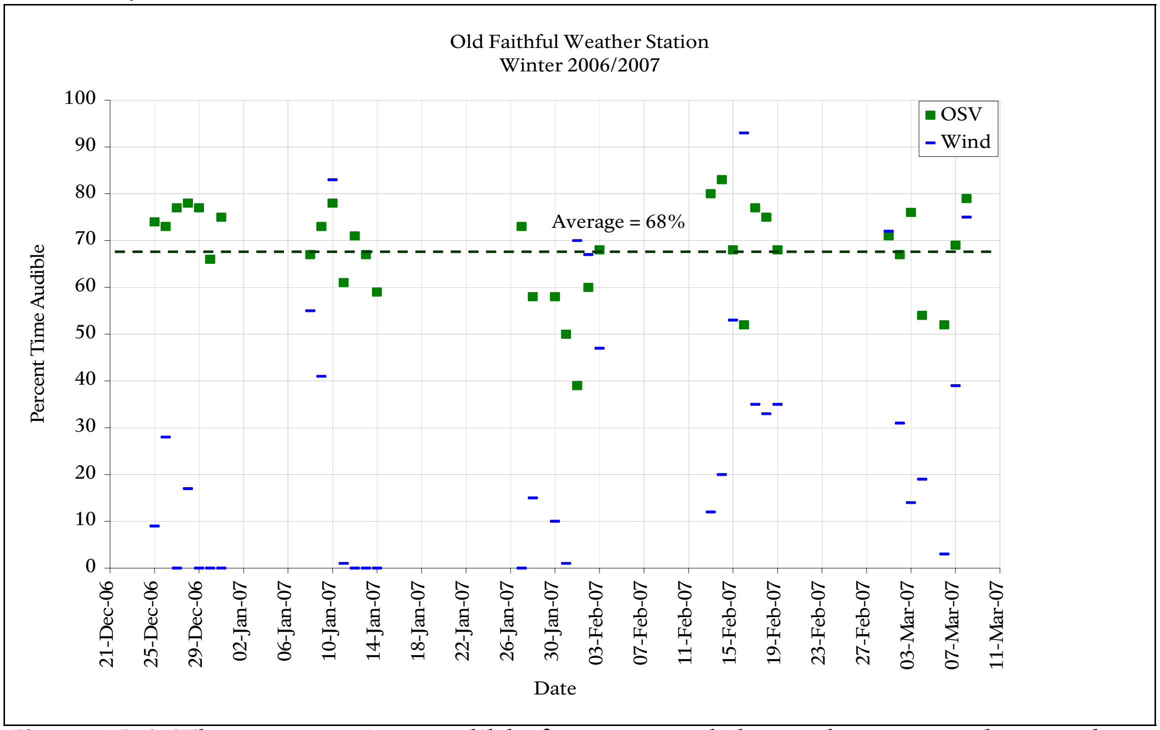

Figure F-1. The percent time audible for snowmobiles and snowcoaches, and wind by date at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 20 December 2006 to 11 March 2007.

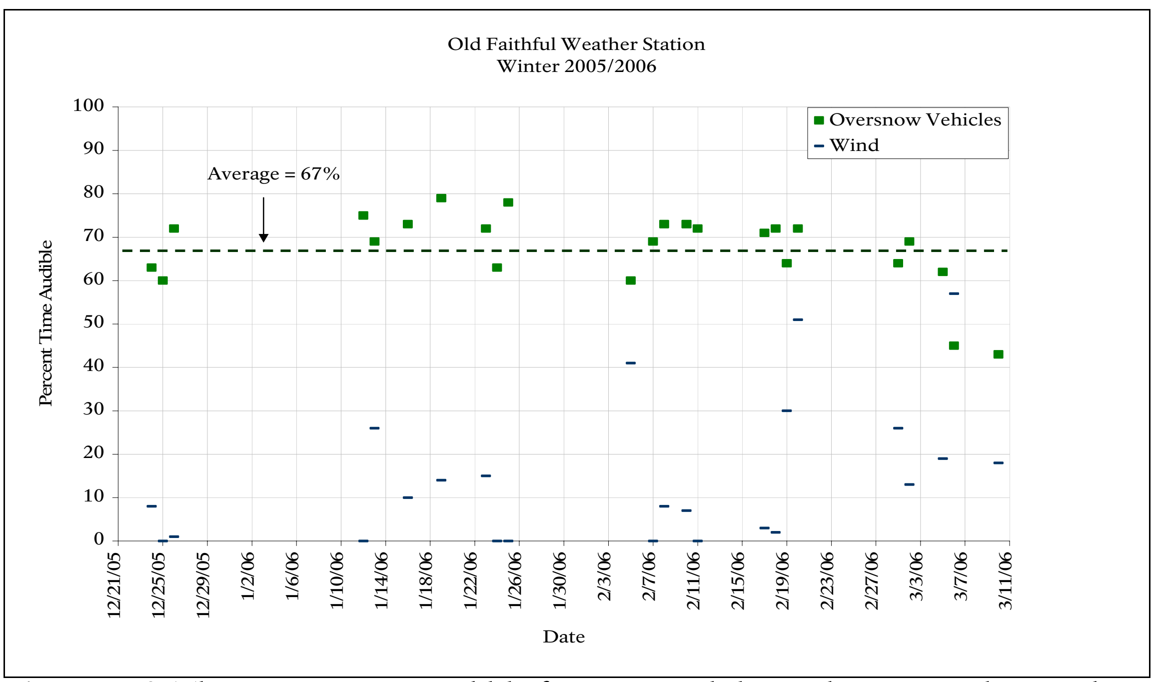

Figure F-2. The percent time audible for snowmobiles and snowcoaches, and wind by date at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 21 December 2005 to 12 March 2006.

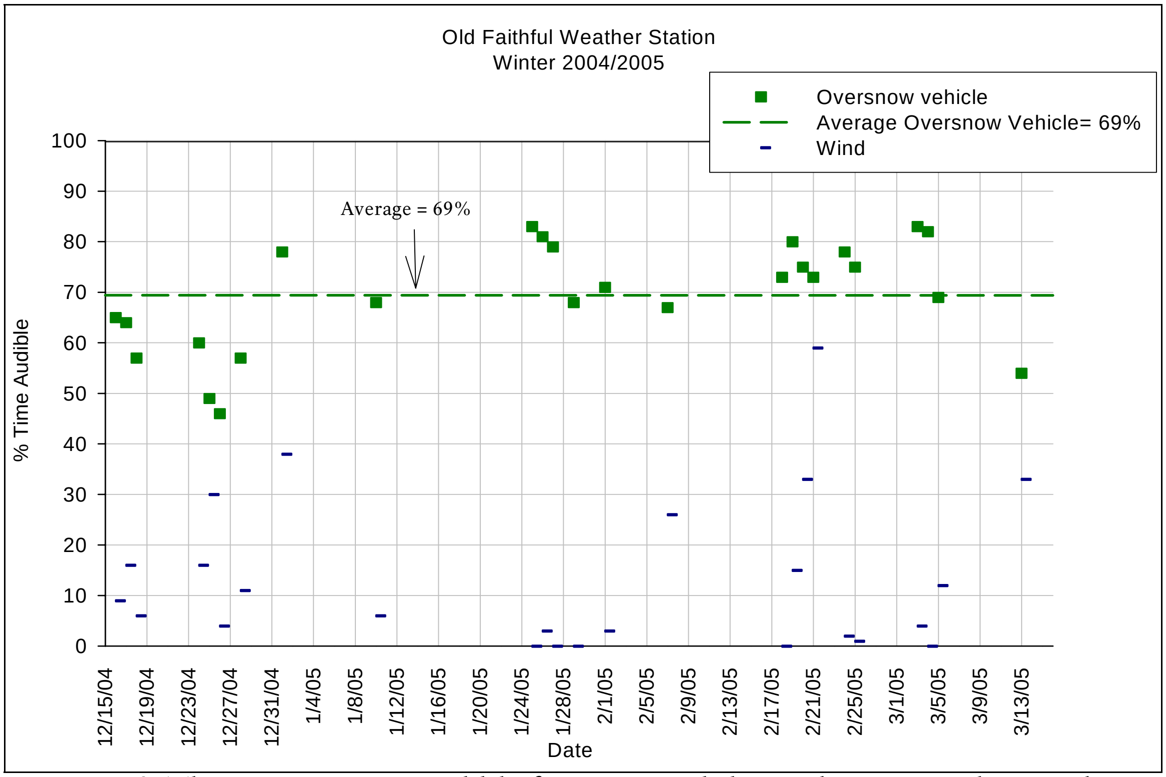

Figure F-3. The percent time audible for snowmobiles and snowcoaches, and wind by date at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 15 December 2004 to 13 March 2005.

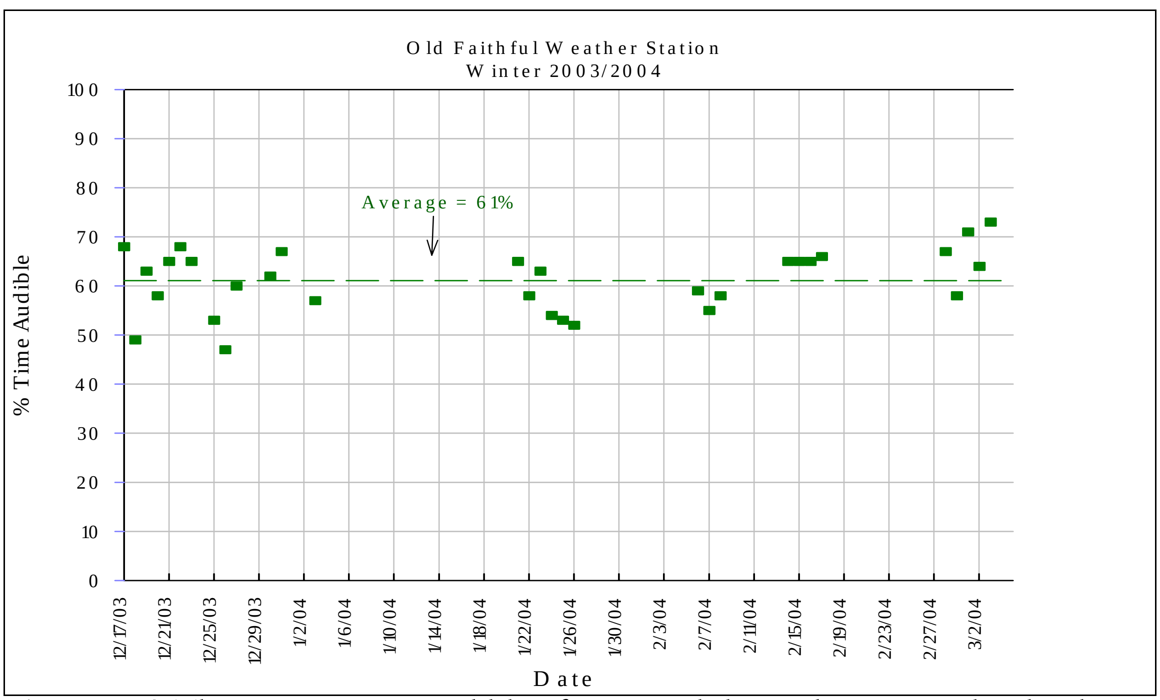

Figure F-4. The percent time audible of snowmobiles and snowcoaches by date at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 17 December 2003 to 3 March 2004.

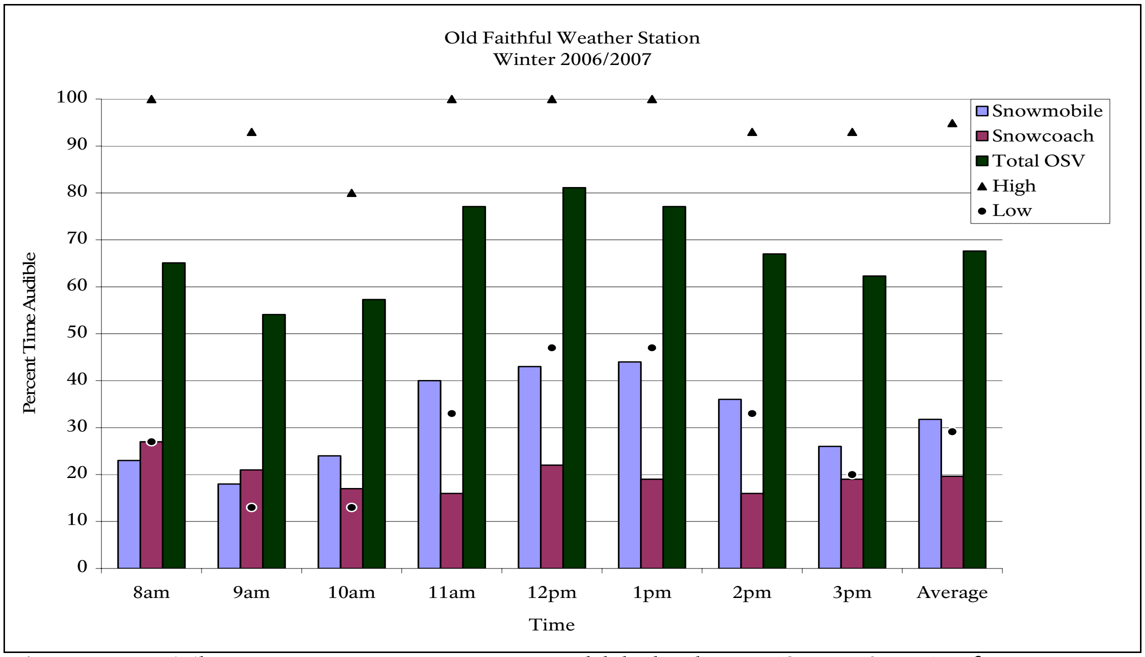

Figure F-5. The average percent time audible by hour (8 am-4 pm) of snowmobiles (left light blue bar), snowcoaches (middle maroon bar), and combined category (right dark green bar), and high and low OSV values at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 20 December 2006 to 11 March 2007.

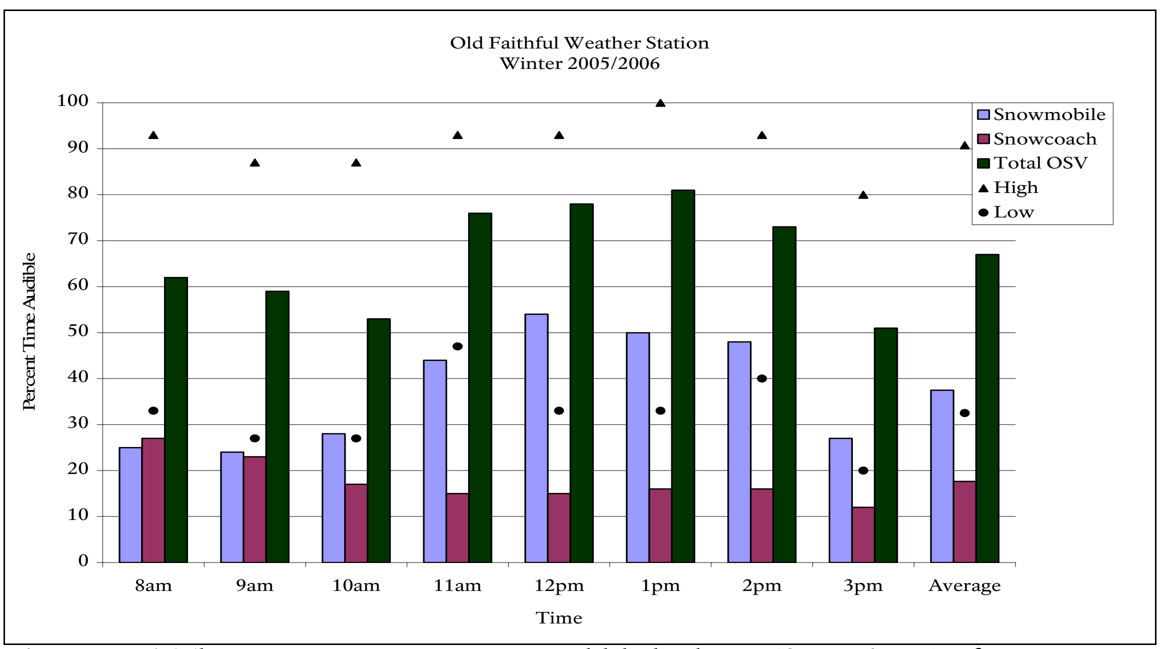

Figure F-6. The average percent time audible by hour (8 am-4 pm) of snowmobiles (left light blue bar), snowcoaches (middle maroon bar), and combined category (right dark green bar), and high and low OSV values at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 21 December 2005 to 12 March 2006.

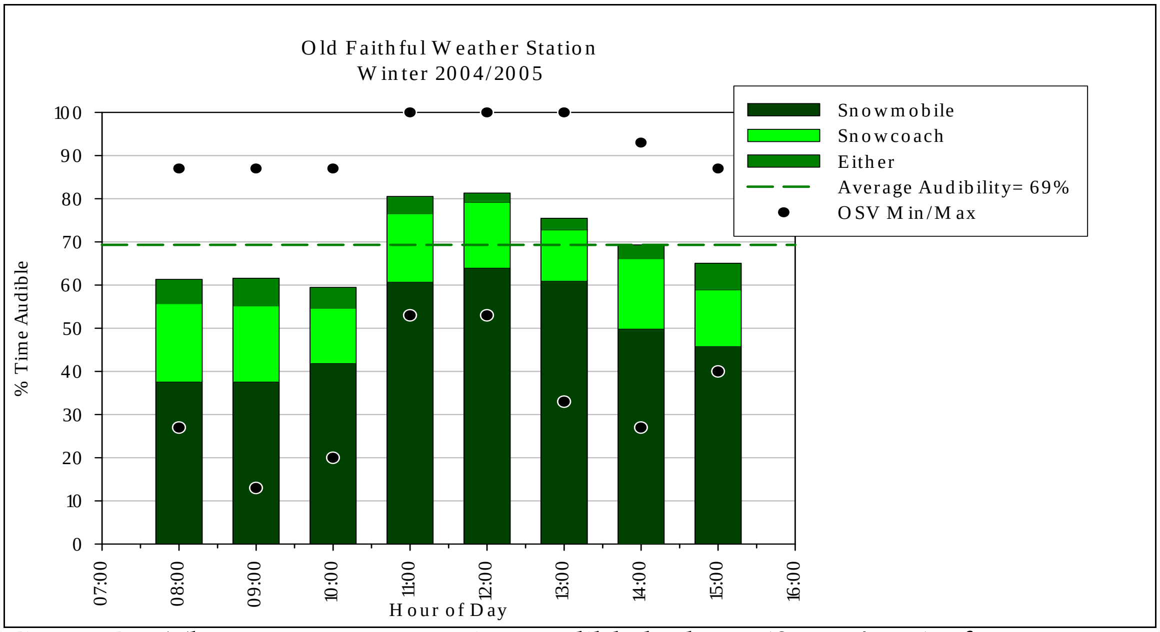

Figure F-7. The average percent time audible by hour (8 am-4 pm) of snowmobiles (bottom bar category), snowcoaches (middle bar category), combined category (top), and high and low range at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 15 December 2004 to 13 March 2005.

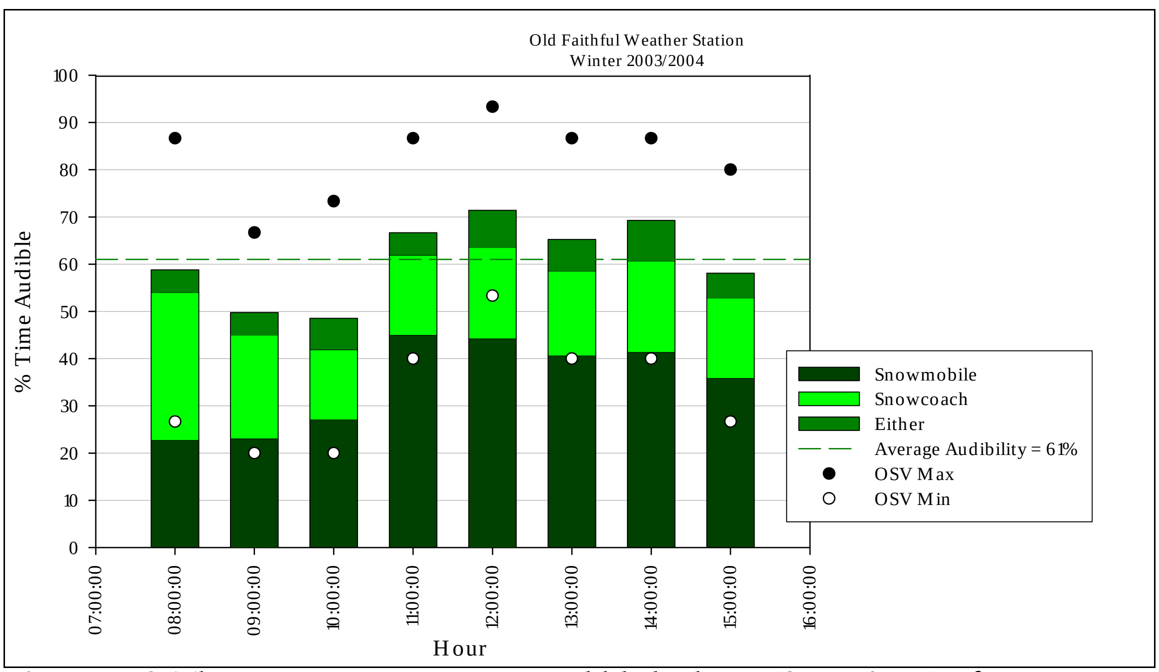

Figure F-8. The average percent time audible by hour (8 am-4 pm) of snowmobiles (bottom bar category), snowcoaches (middle bar category), combined category (top), and high and low range at Old Faithful Weather Station, Yellowstone National Park from 8 a.m. to 4 p.m., 17 December 2003 to 14 March 2004.

Madison Junction 2.3

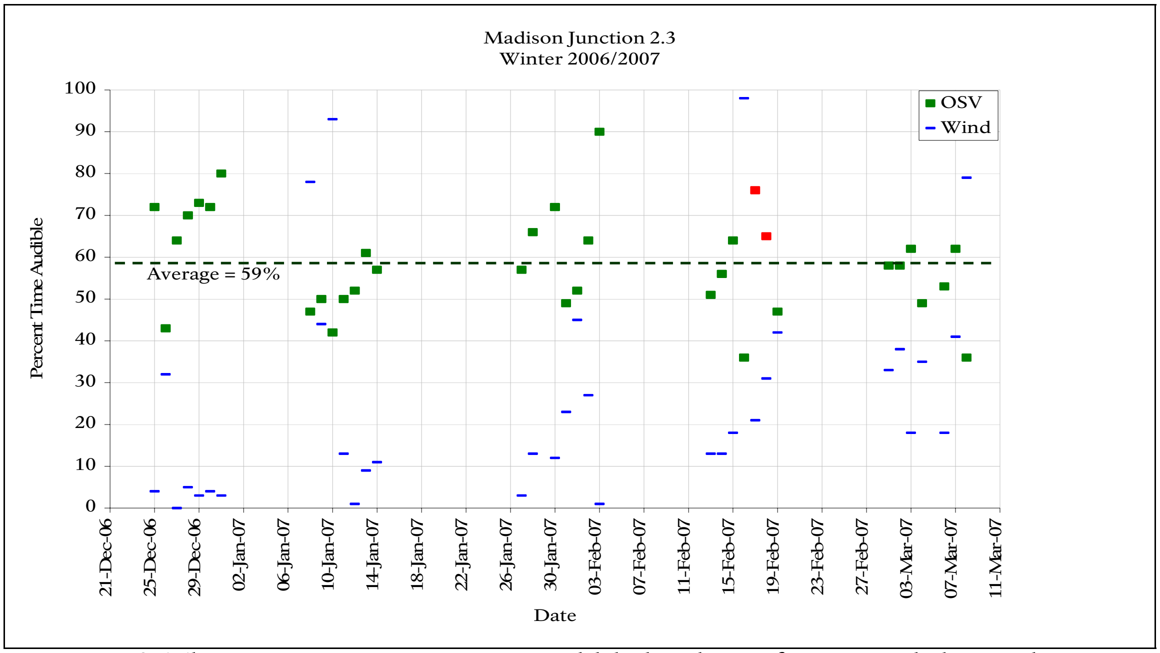

Figure F-9. The average percent time audible by date of snowmobiles and snowcoaches, and wind at 2.3 miles (3.7 km) west of Madison Junction along the West Entrance Road Yellowstone National Park, 20 December 2006-11 March 2007. Red squares indicate OSV numbers over Presidents Day Weekend for 2007.

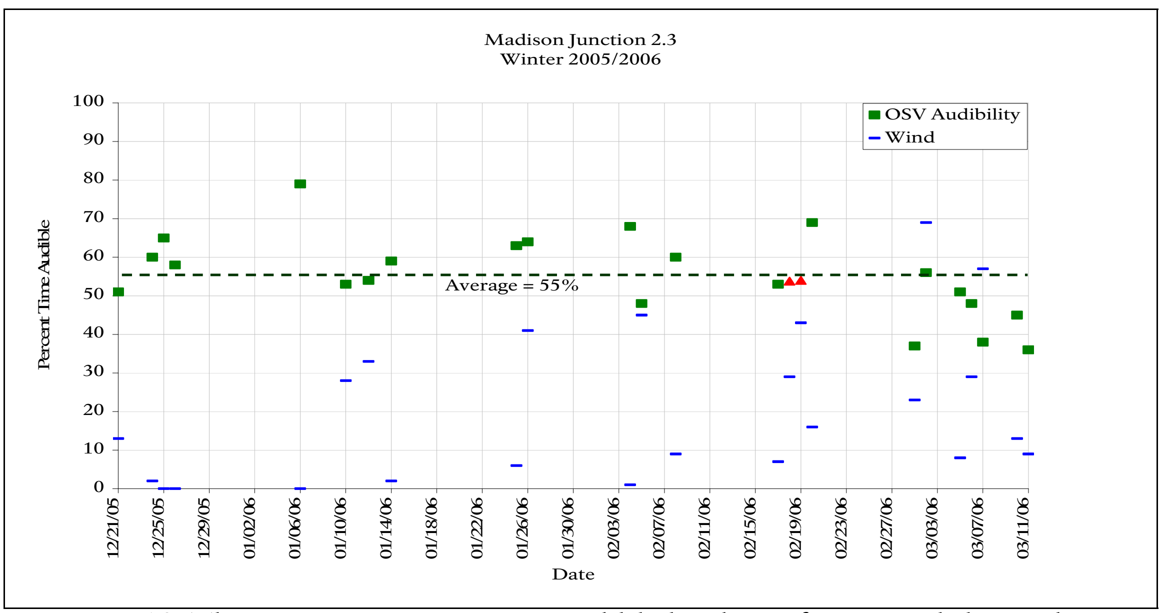

Figure F-10. The average percent time audible by date of snowmobiles and snowcoaches at 2.3 miles (3.7 km) west of Madison Junction along the West Entrance Road Yellowstone National Park, 21 December 2005-12 March 2006. Red triangles indicate Presidents Day Weekend for 2006 (54%) for comparison to prior years.

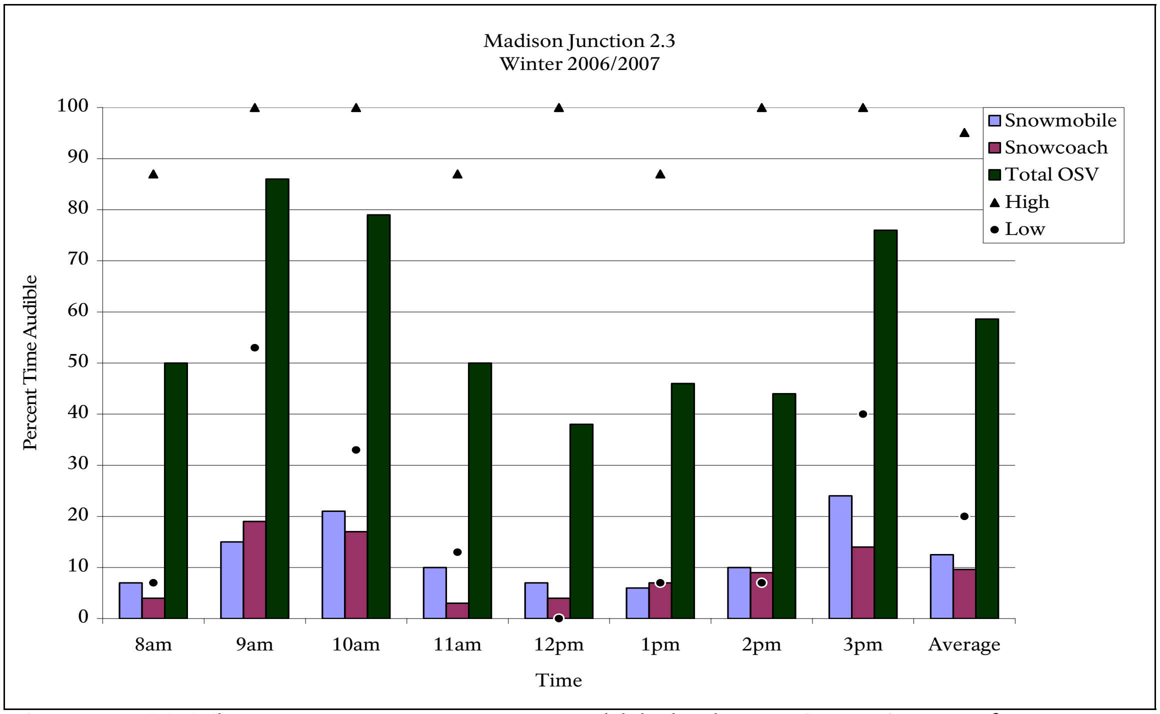

Figure F-11. The average percent time audible by hour (8 am-4 pm) of snowmobiles and snowcoaches, and high and low OSV values at 2.3 miles (3.7 km) west of Madison Junction along the West Entrance Road Yellowstone National Park, 20 December 2006- 11 March 2007.

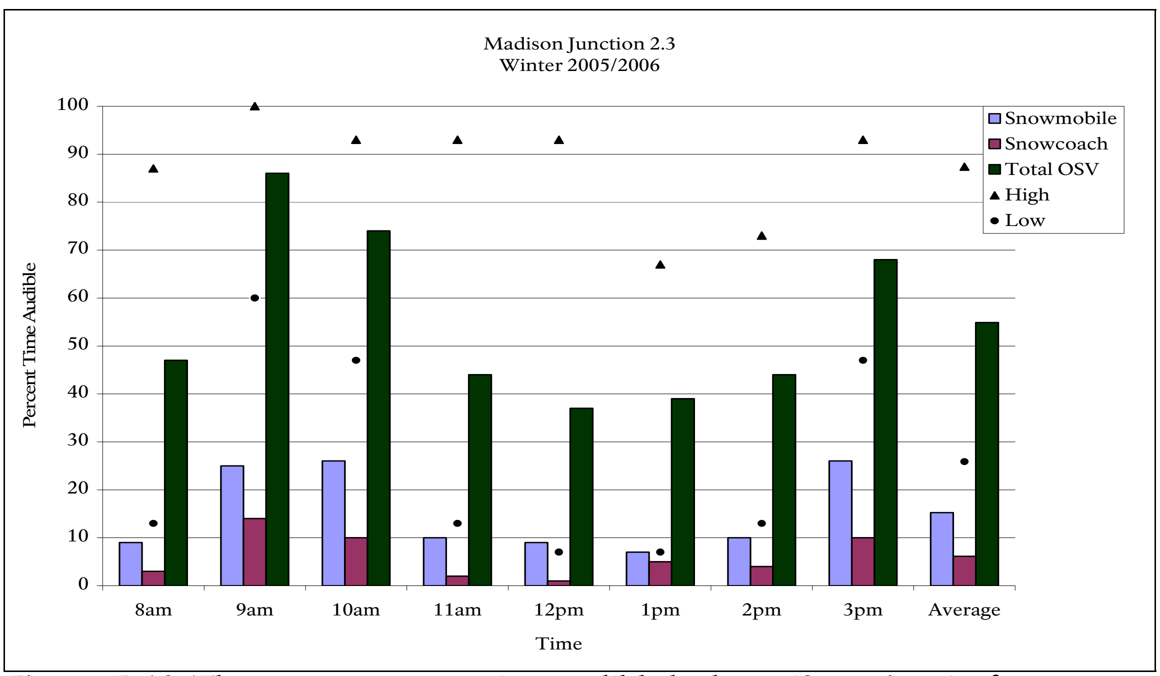

Figure F-12. The average percent time audible by hour (8 am-4 pm) of snowmobiles and snowcoaches at 2.3 miles (3.7 km) west of Madison Junction along the West Entrance Road Yellowstone National Park, 21 December 2005- March 2006.

Old Faithful Weather Station

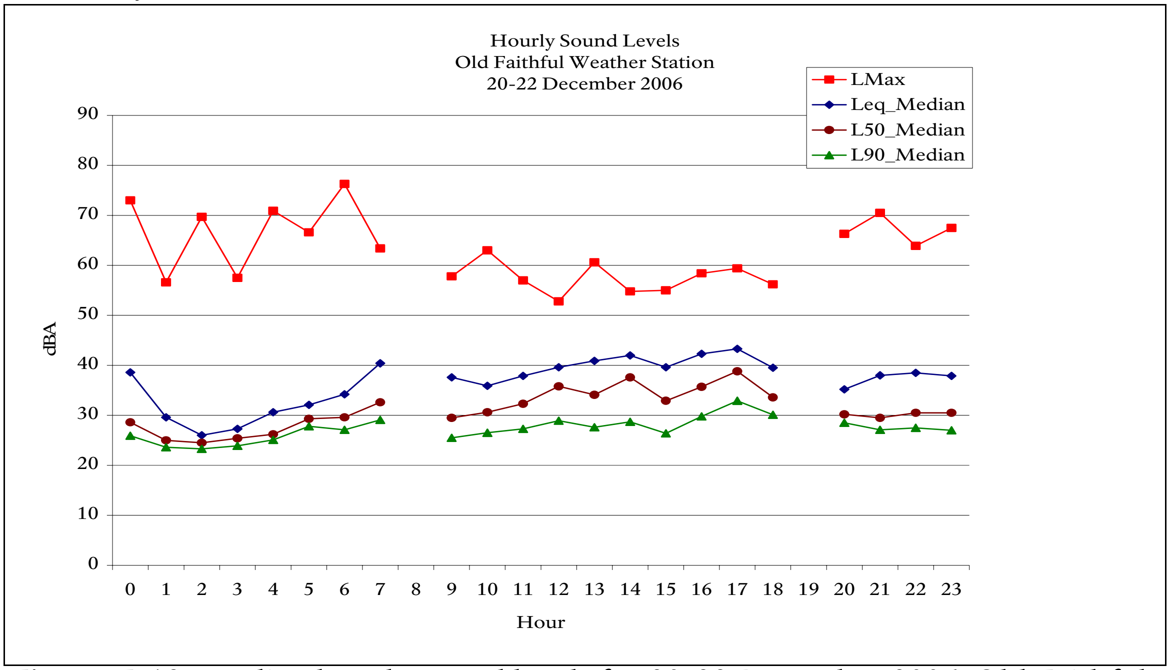

Figure F-13. Median hourly sound levels for 20-22 December 2006, Old Faithful Weather Station, Yellowstone National Park. These sound levels include all natural and non-natural sounds. L_{max} is the highest sound level measured during the measurement period. Missing hours are due to site visits and those with too few seconds. (n=55 hours)

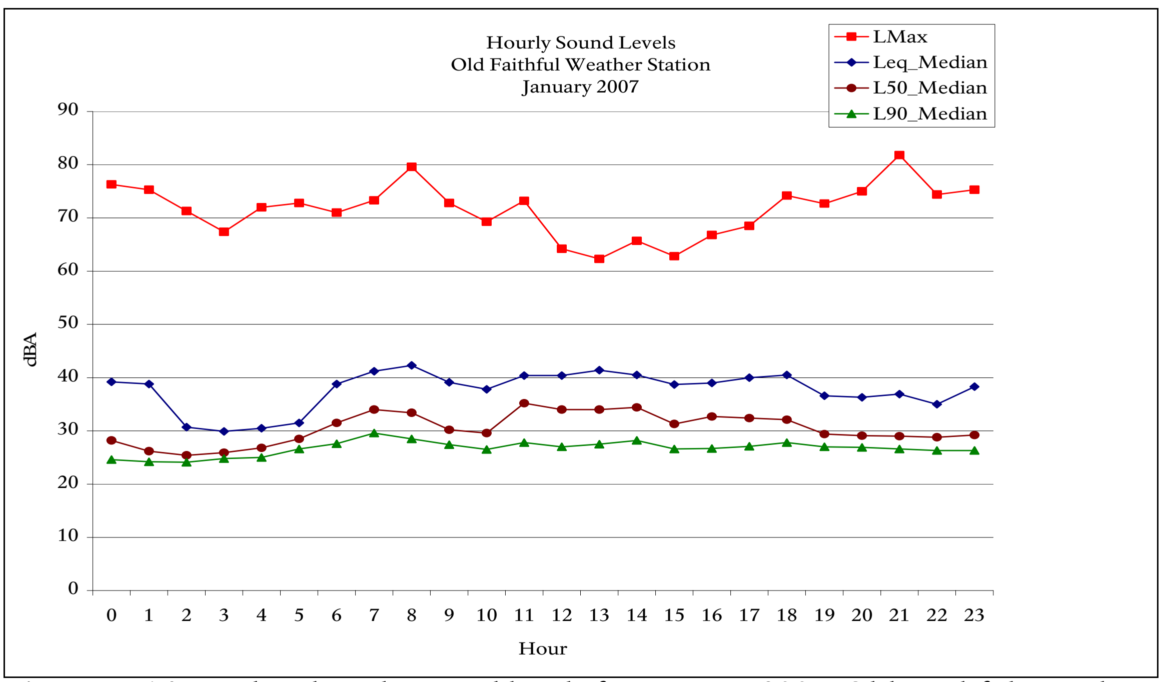

Figure F-14. Median hourly sound levels for January 2007, Old Faithful Weather Station, Yellowstone National Park. See Fig. 9 caption for more details. (n=637 hours)

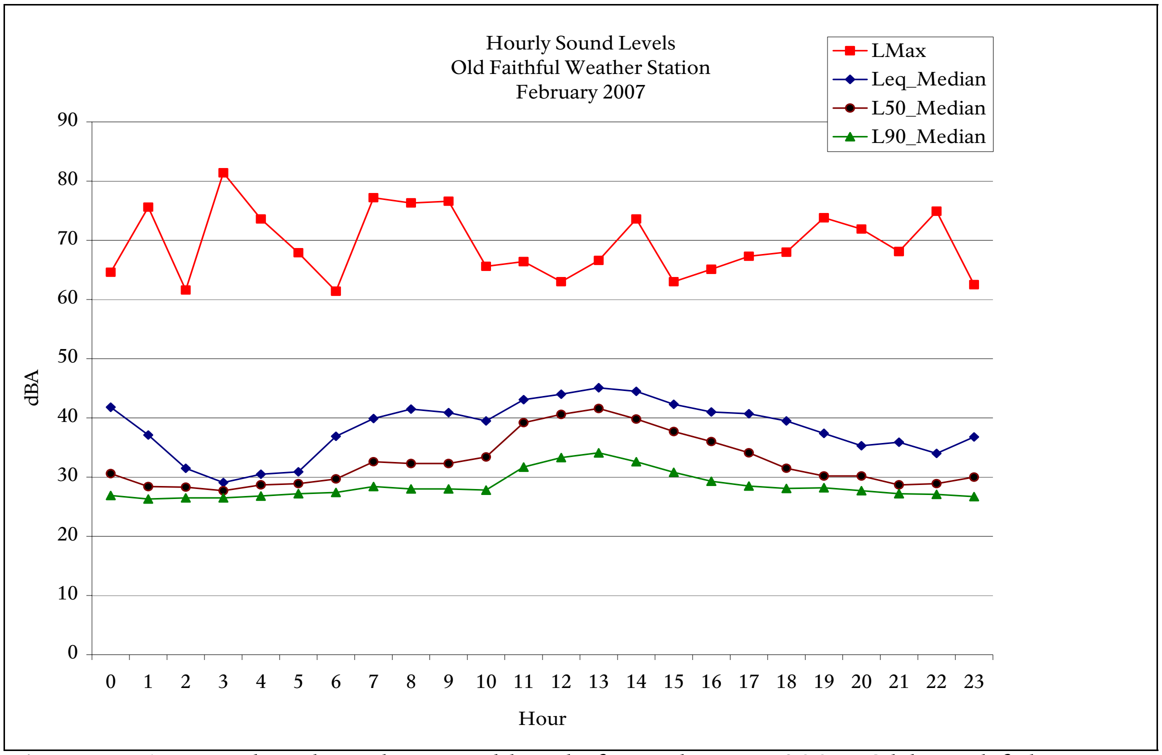

Figure F-15. Median hourly sound levels for February 2007, Old Faithful Weather Station, Yellowstone National Park. See Fig. 9 caption for more details. (n=666 hours)

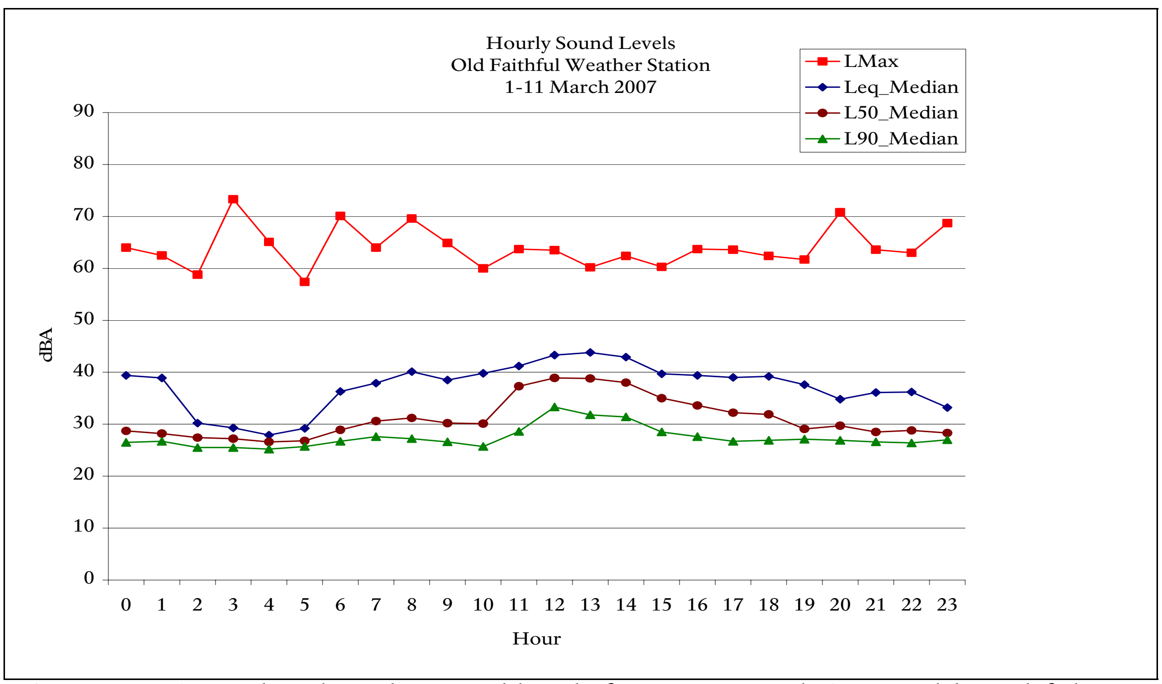

Figure F-16. Median hourly sound levels for 1-11 March 2007, Old Faithful Weather Station, Yellowstone National Park. See Fig. 9 caption for more details. (n=262 hours)

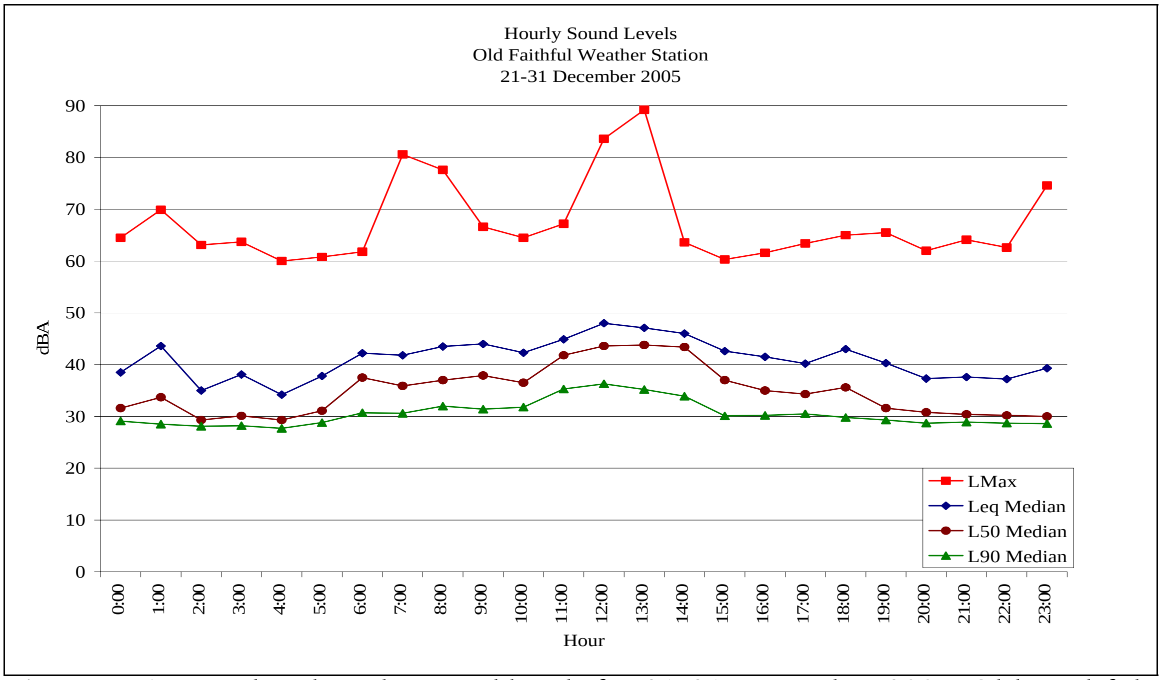

Figure F-17. Median hourly sound levels for 21-31 December 2005, Old Faithful Weather Station, Yellowstone National Park. These sound levels include all natural and non-natural sounds. L_{max} is the highest sound level measured during the measurement period. (n=258 hours)

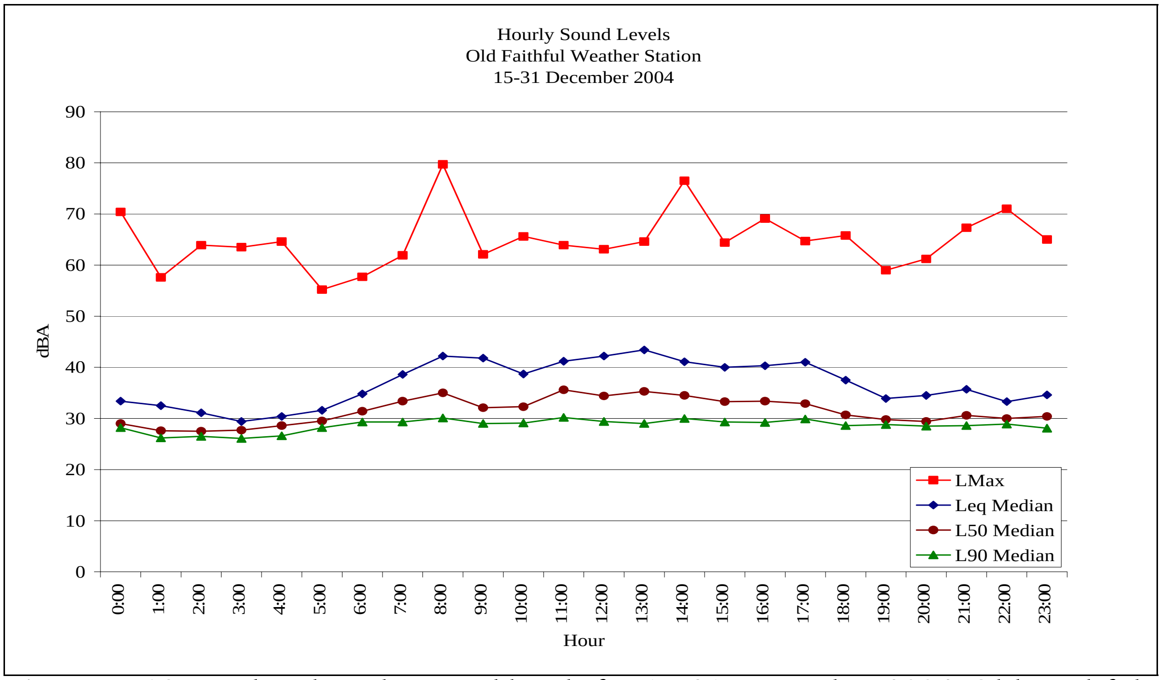

Figure F-18. Median hourly sound levels for 15-31 December 2004, Old Faithful Weather Station, Yellowstone National Park. These sound levels include all natural and non-natural sounds. (n=370 hours)

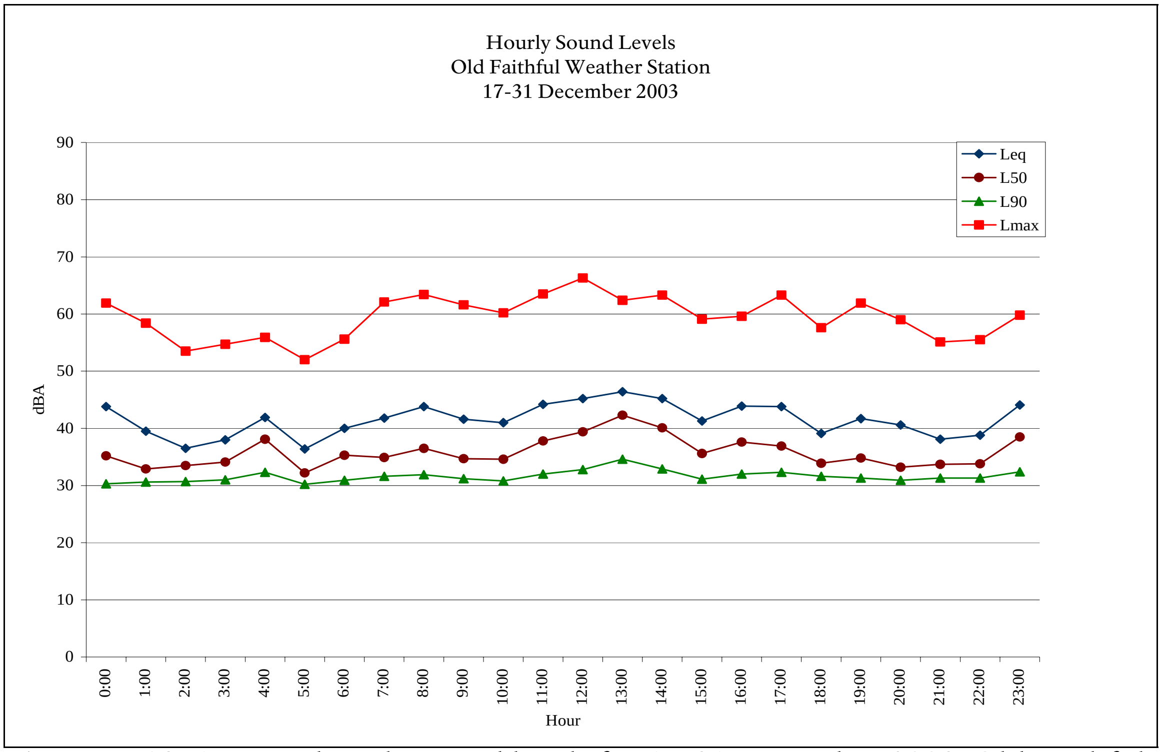

Figure F-19. Average hourly sound levels for 17-31 December 2003, Old Faithful Weather Station, Yellowstone National Park. These sound levels include all natural and non-natural sounds. (n=358 hours)

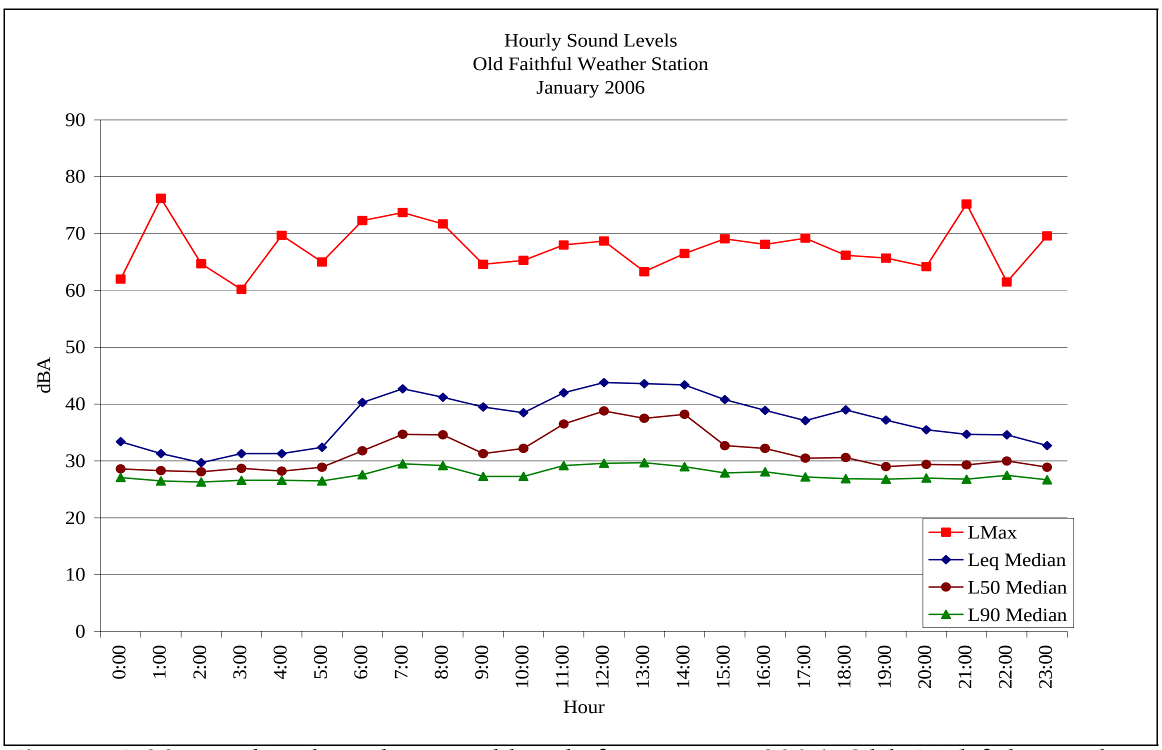

Figure F-20. Median hourly sound levels for January 2006, Old Faithful Weather Station, Yellowstone National Park. (n=728 hours)

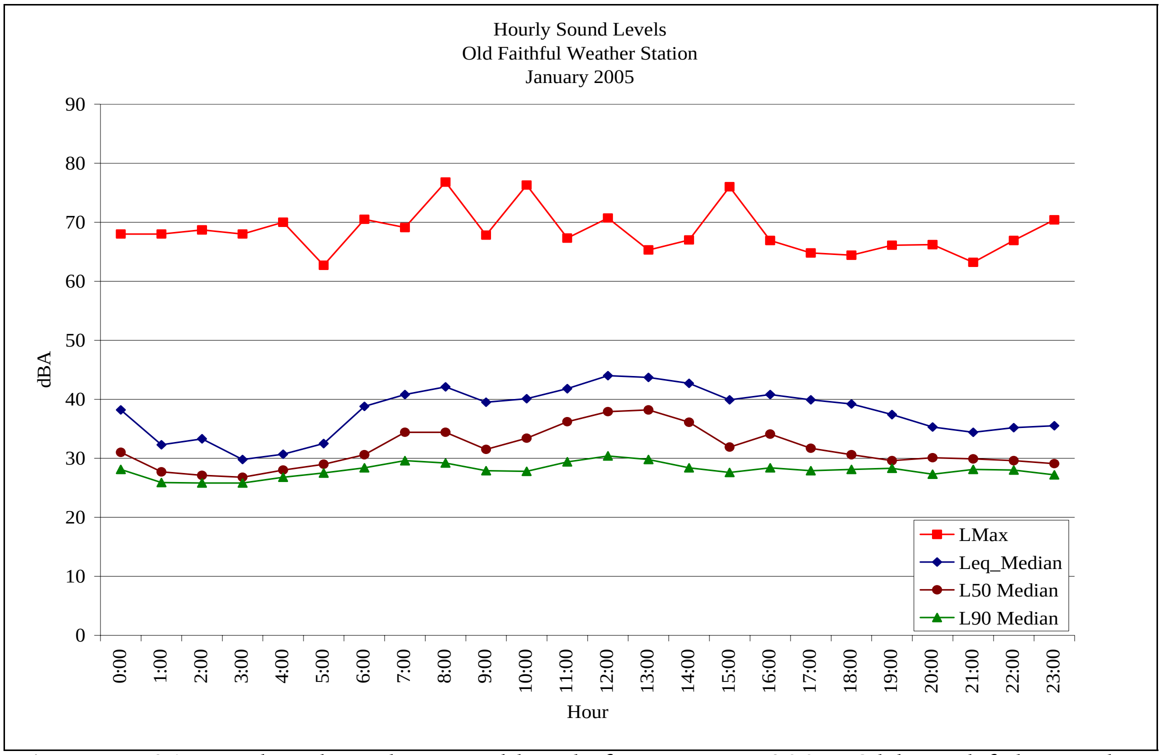

Figure F-21. Median hourly sound levels for January 2005, Old Faithful Weather Station, Yellowstone National Park. (n=736 hours)

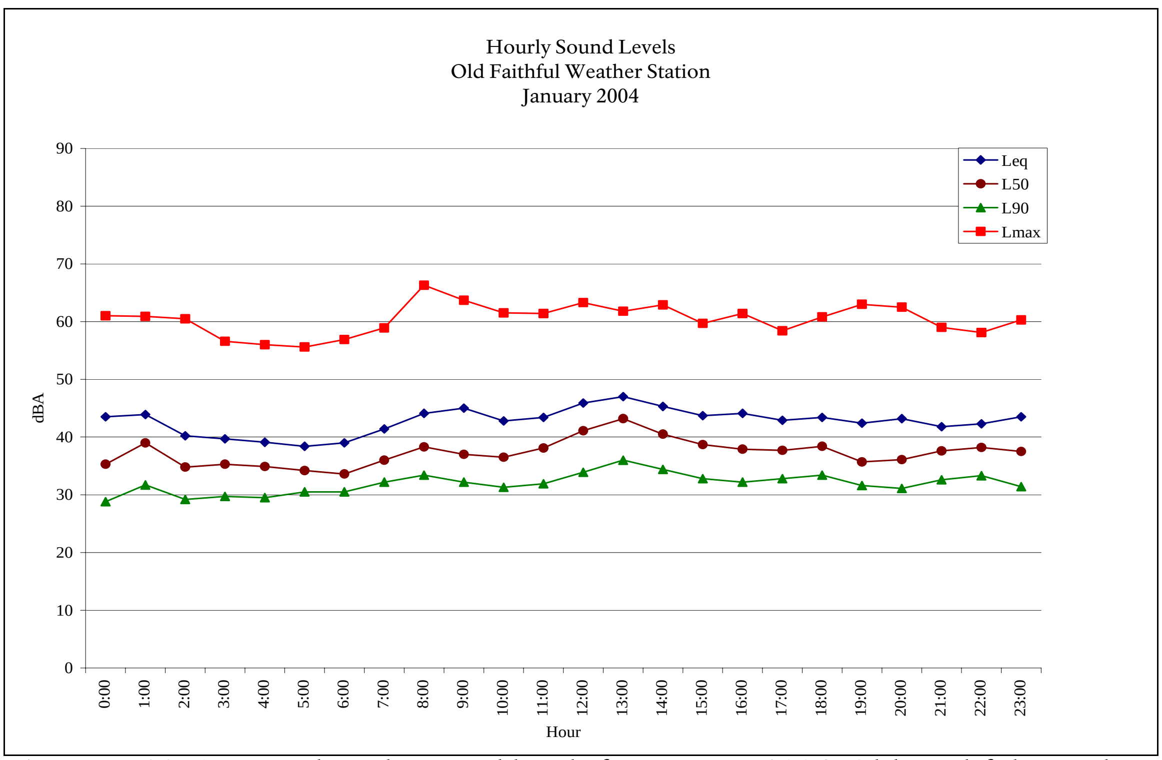

Figure F-22. Average hourly sound levels for January 2004, Old Faithful Weather Station, Yellowstone National Park. (n=735 hours)

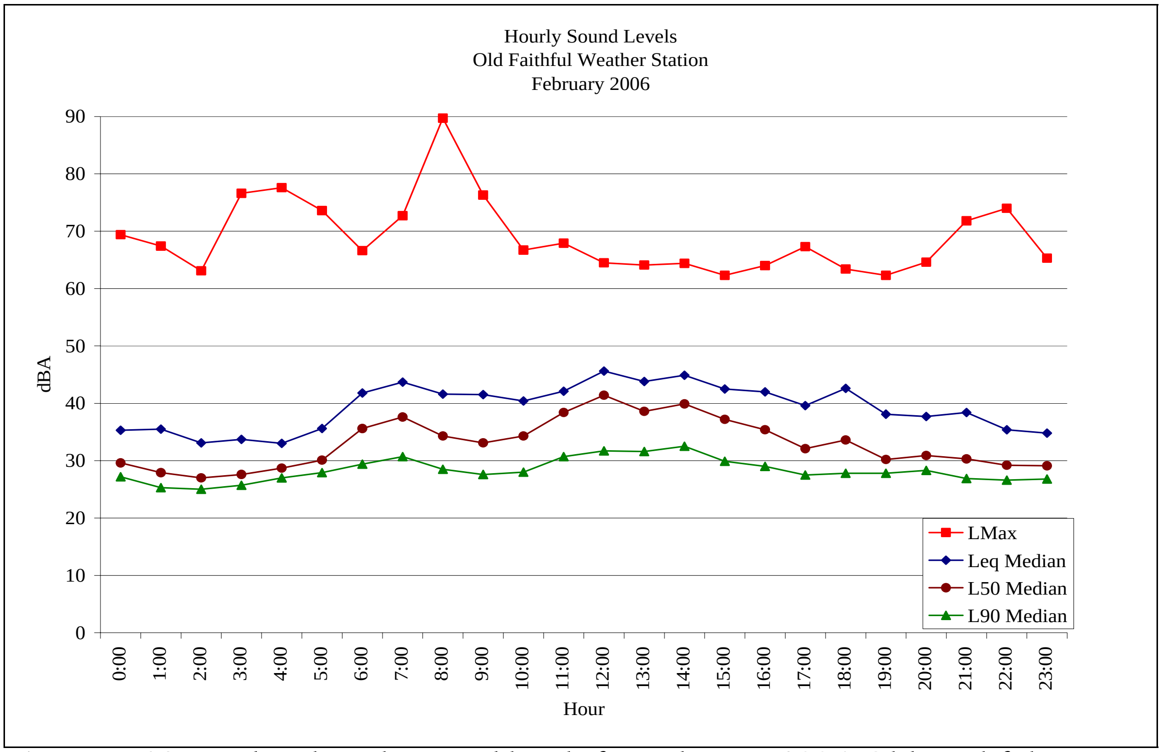

Figure F-23. Median hourly sound levels for February 2006, Old Faithful Weather Station, Yellowstone National Park. (n=637 hours)

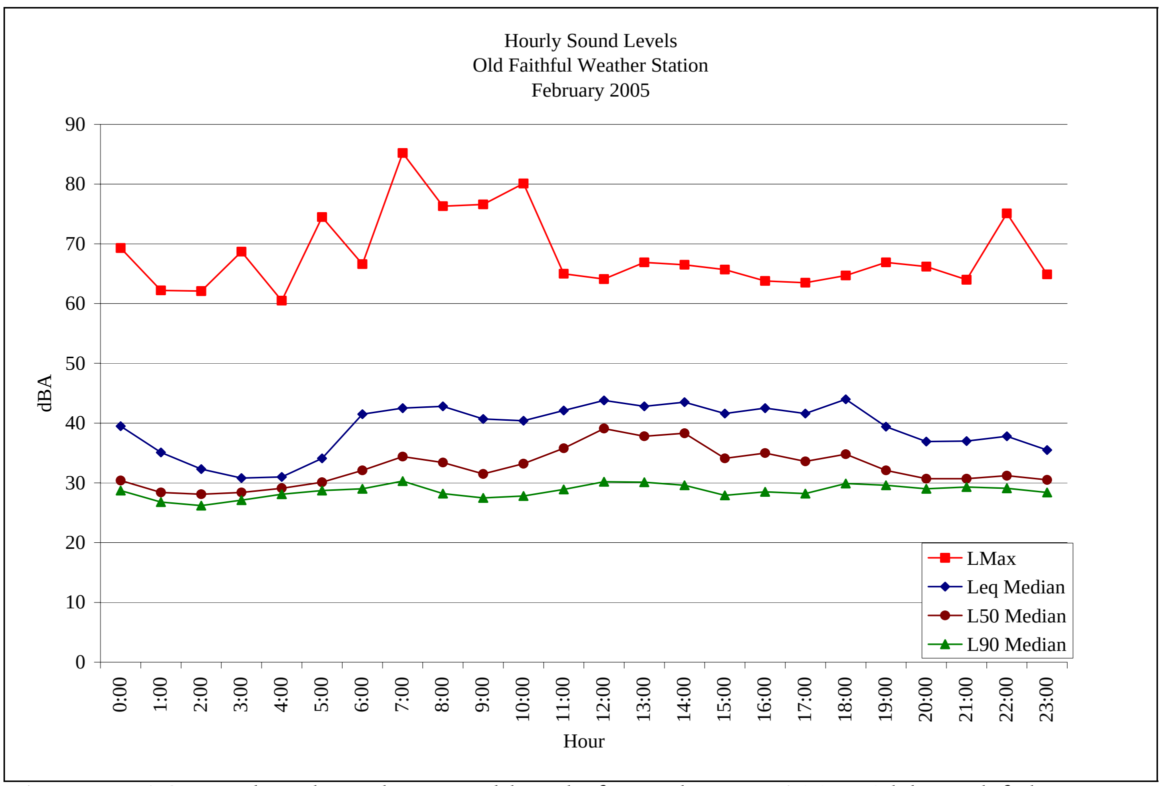

Figure F-24. Median hourly sound levels for February 2005, Old Faithful Weather Station, Yellowstone National Park. (n=609 hours)

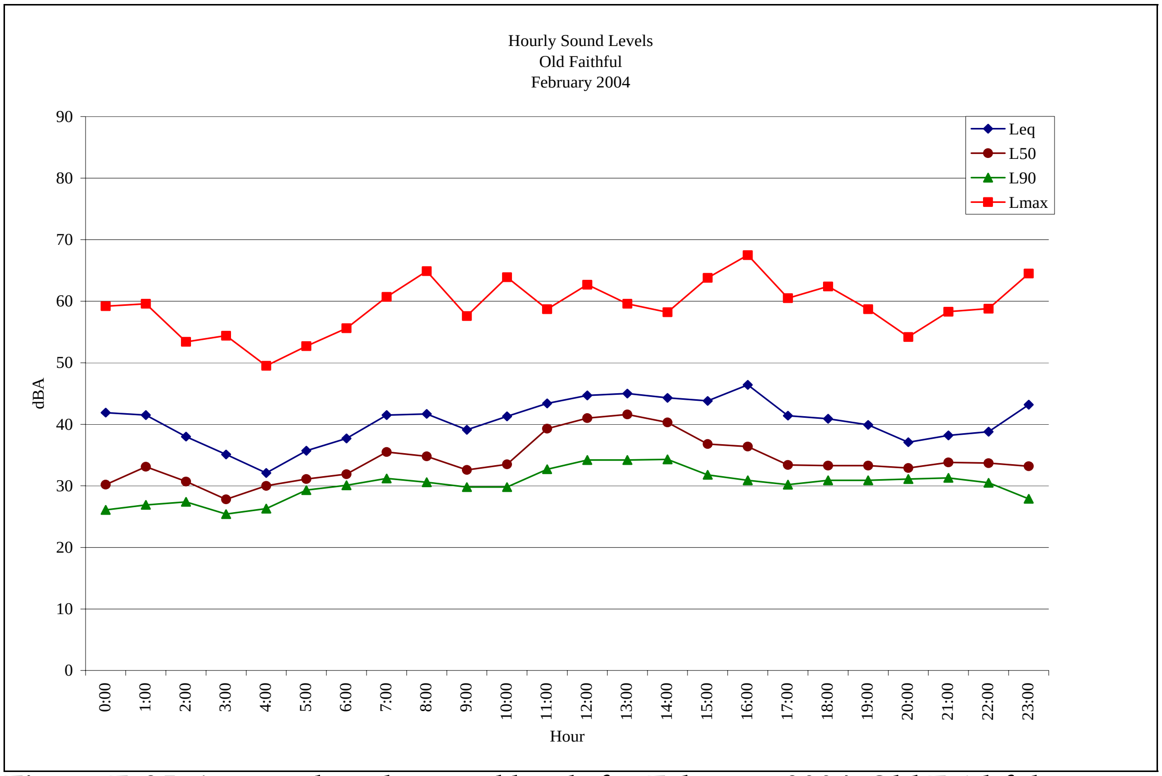

Figure F-25. Average hourly sound levels for February 2004, Old Faithful Weather Station, Yellowstone National Park. (n=435 hours)

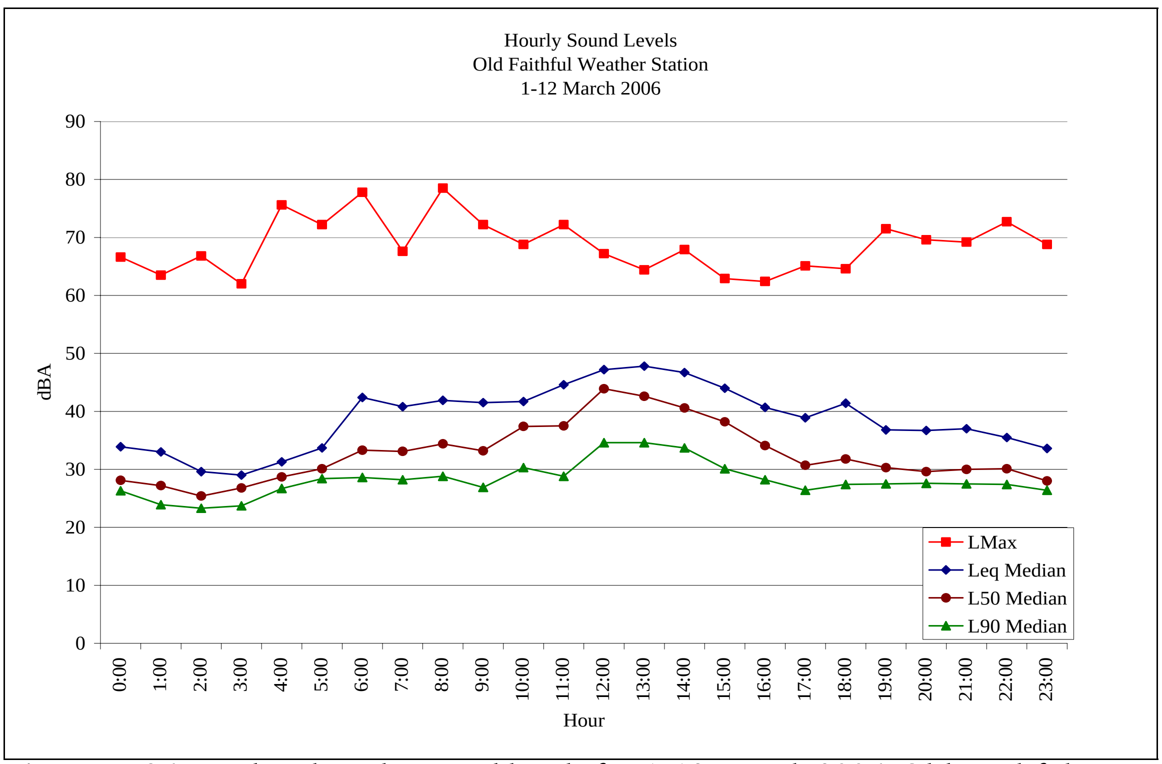

Figure F-26. Median hourly sound levels for 1-12 March 2006, Old Faithful Weather Station, Yellowstone National Park. (n=281 hours)

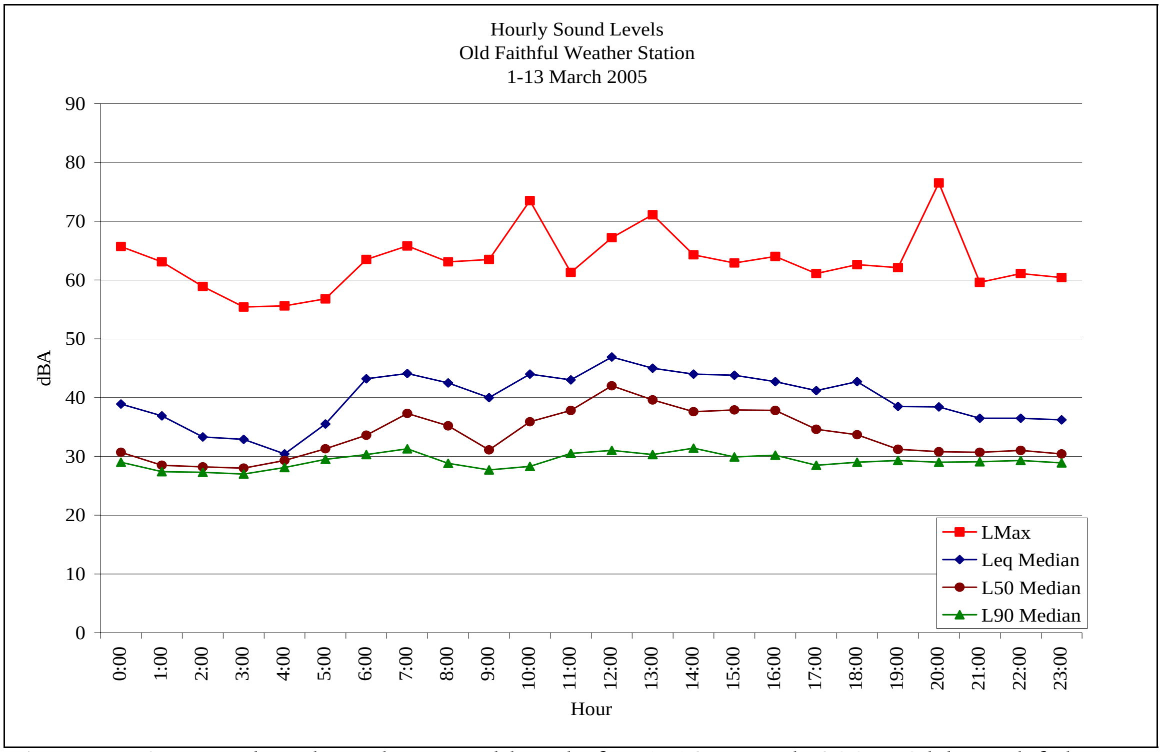

Figure F-27. Median hourly sound levels for 1-13 March 2005, Old Faithful Weather Station, Yellowstone National Park. (n=281 hours)

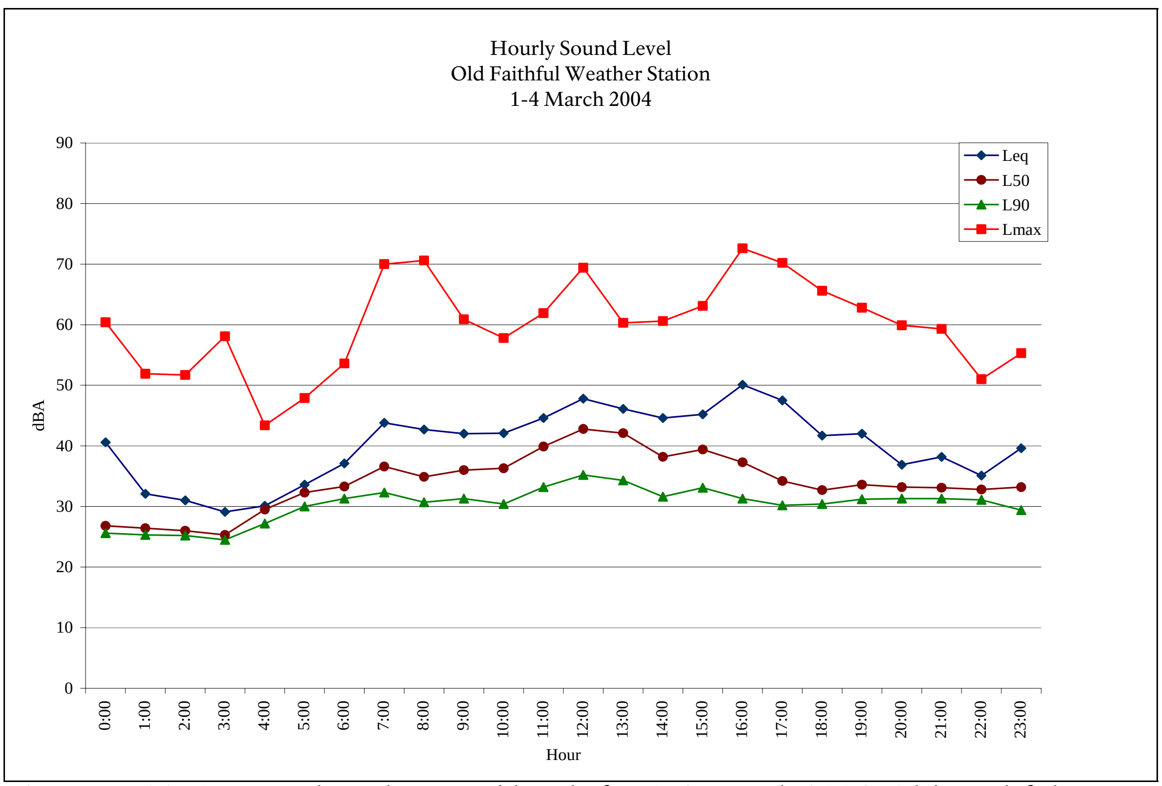

Figure F-28. Average hourly sound levels for 1-4 March 2004, Old Faithful Weather Station, Yellowstone National Park. (n=82 hours)

Madison Junction 2.3

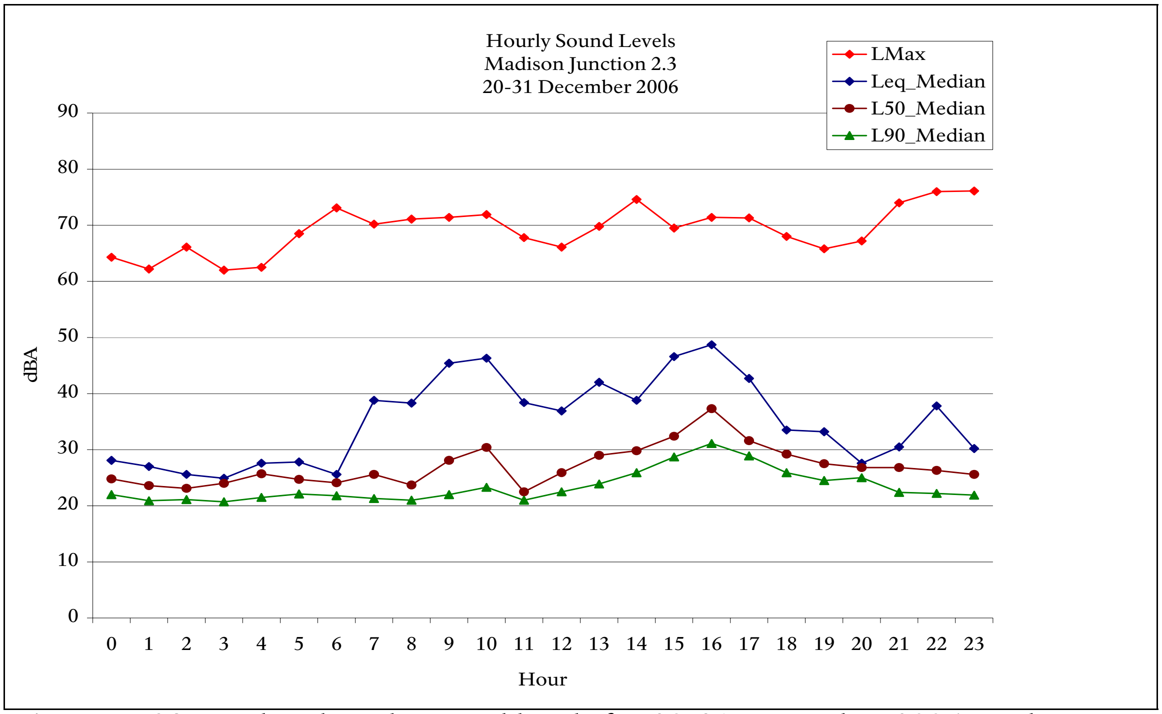

Figure F-29. Median hourly sound levels for 20-31 December 2006 Madison Junction 2.3, Yellowstone National Park. See Fig. 9 caption for more details. (n=263 hours)

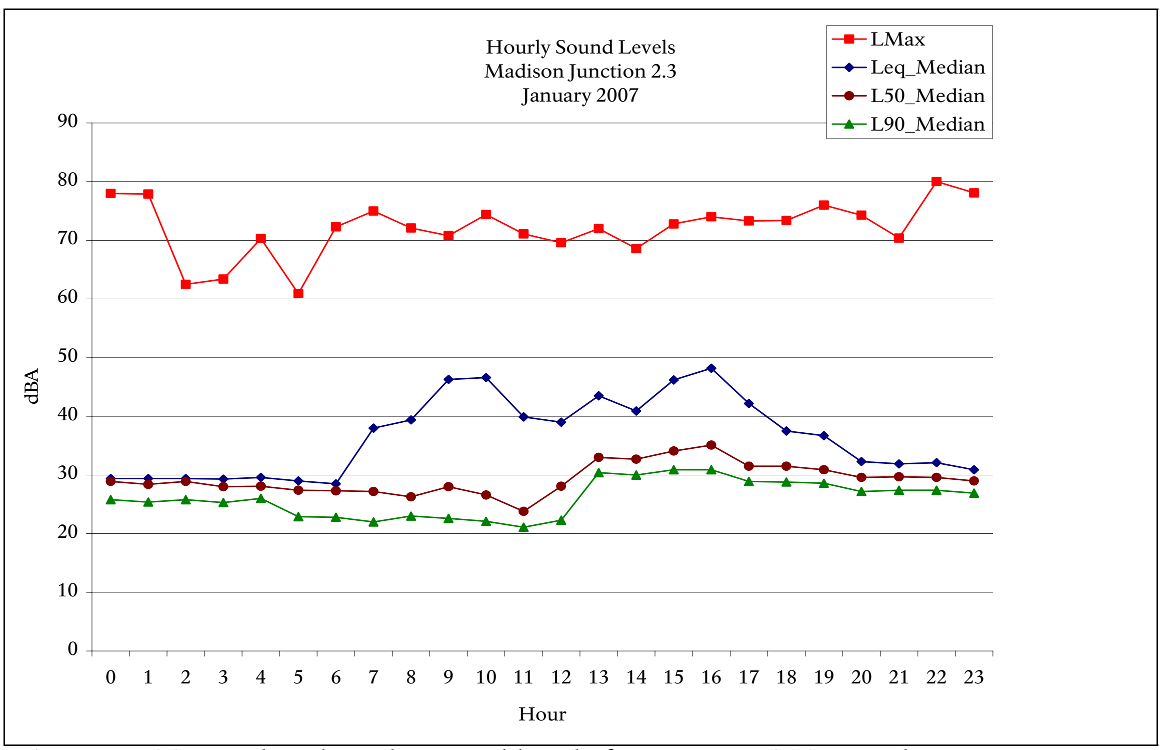

Figure F-30. Median hourly sound levels for January 2007 Madison Junction 2.3, Yellowstone National Park. See Fig. 9 caption for more details. (n=714 hours)

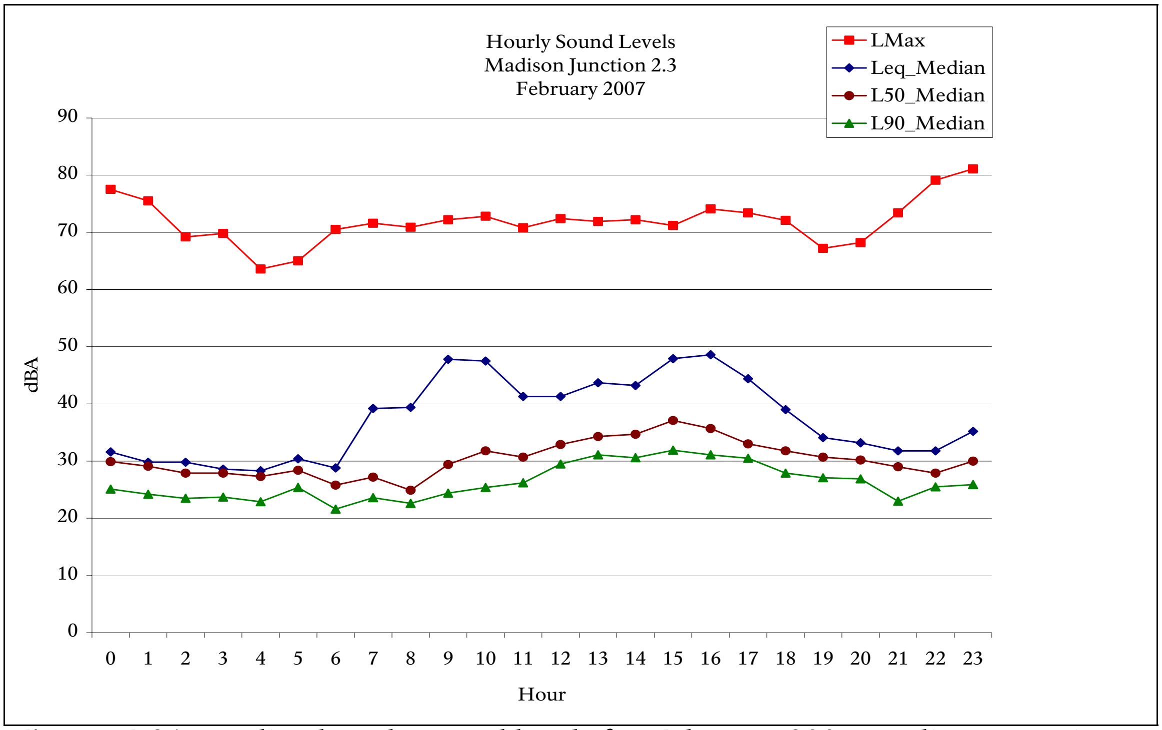

Figure F-31. Median hourly sound levels for February 2007 Madison Junction 2.3, Yellowstone National Park. See Fig. 9 caption for more details. (n=653 hours)

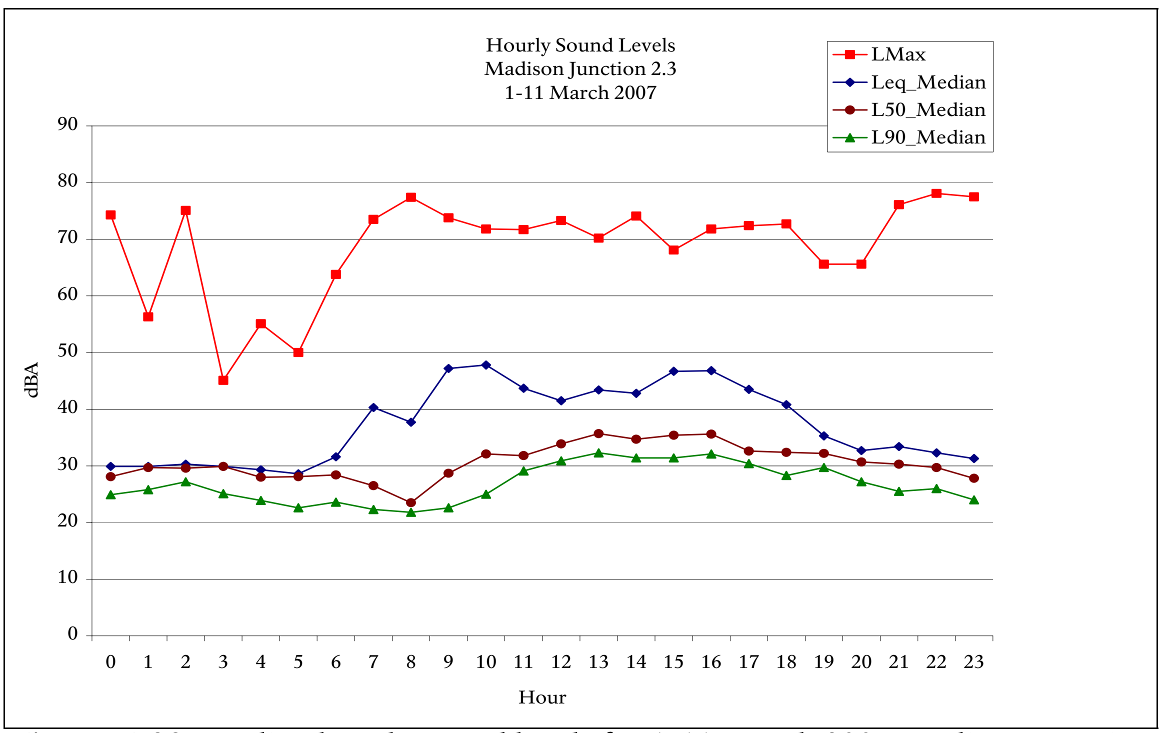

Figure F-32. Median hourly sound levels for 1-11 March 2007 Madison Junction 2.3, Yellowstone National Park. See Fig. 9 caption for more details. (n=245 hours)

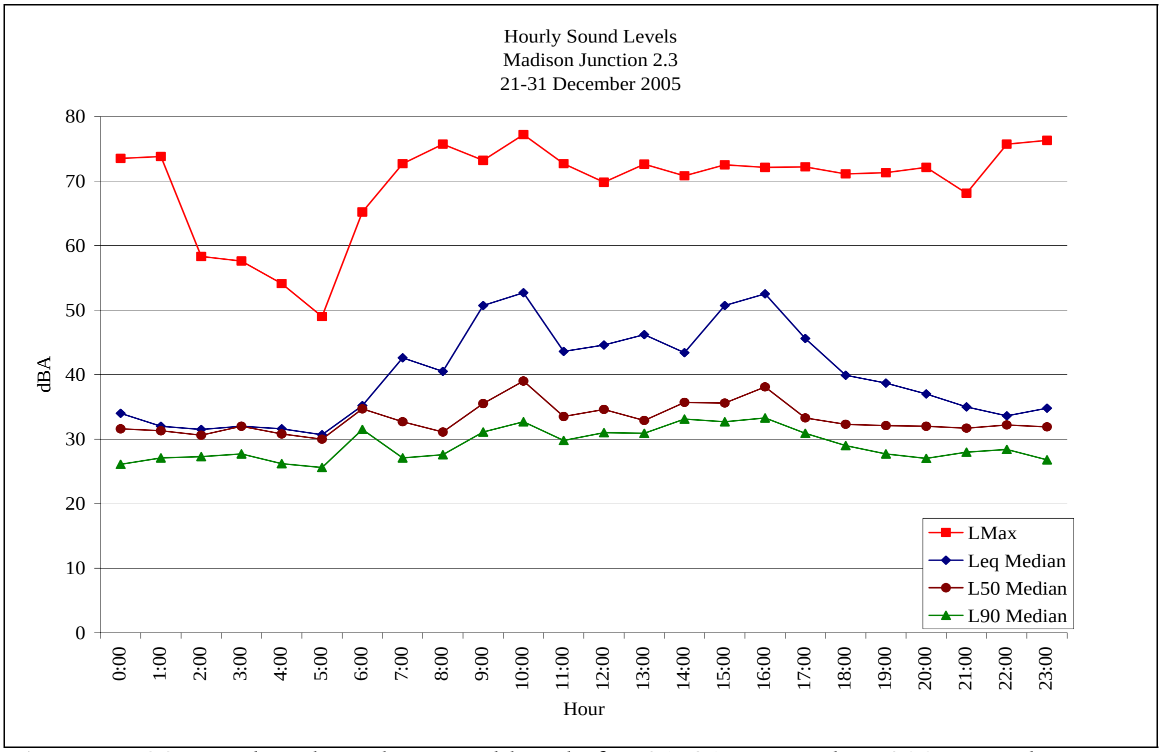

Figure F-33. Median hourly sound levels for 21-31 December 2005, Madison Junction 2.3, Yellowstone National Park. (n=259 hours)

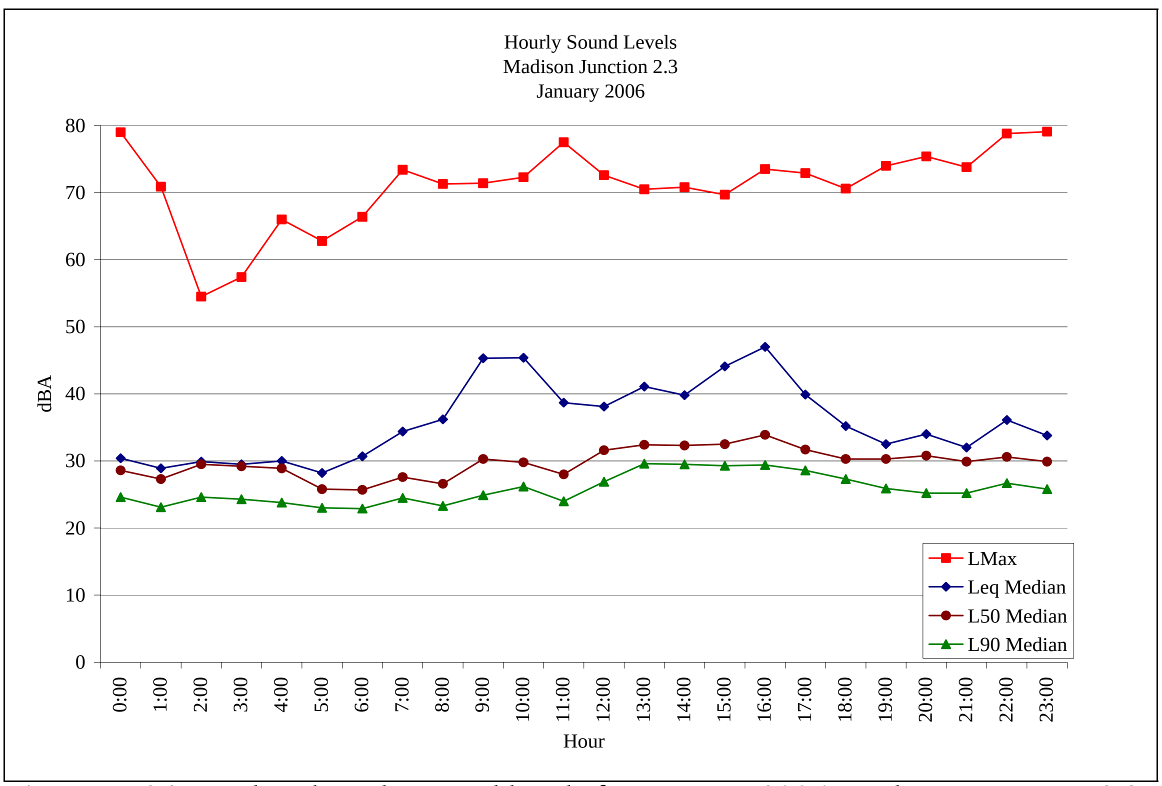

Figure F-34. Median hourly sound levels for January 2006 Madison Junction 2.3, Yellowstone National Park. (n=729 hours)

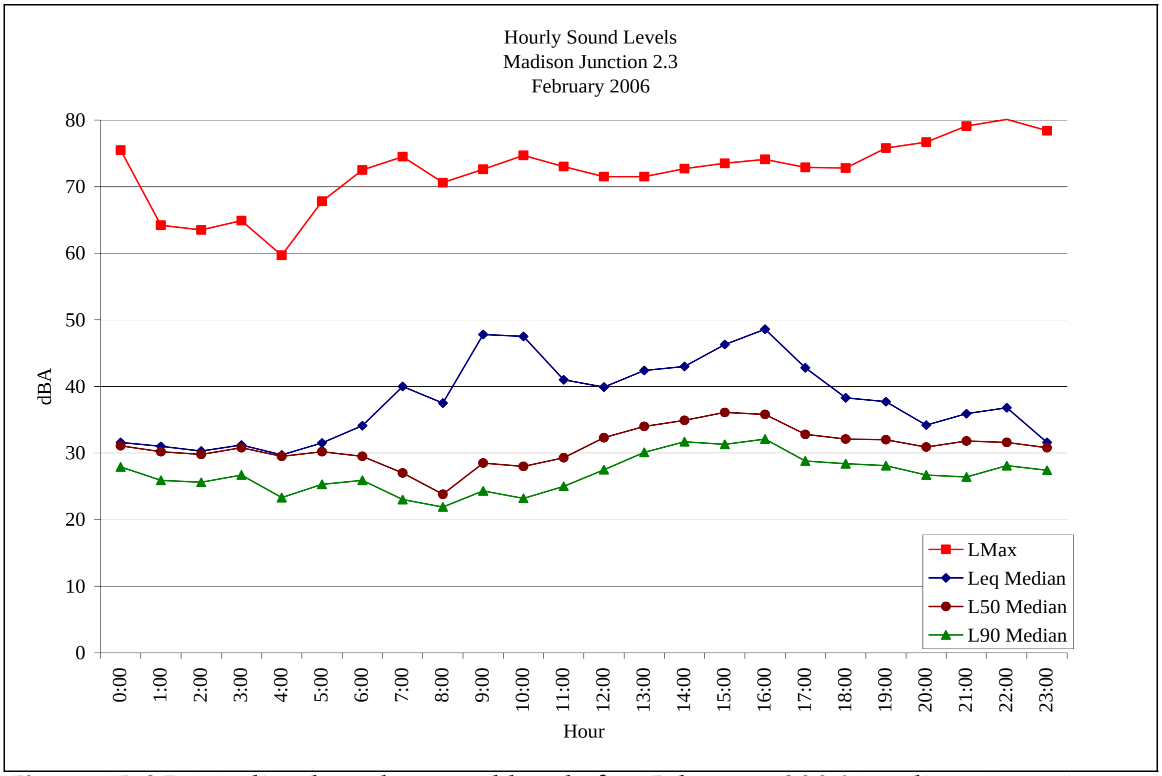

Figure F-35. Median hourly sound levels for February 2006 Madison Junction 2.3, Yellowstone National Park. (n=666 hours)

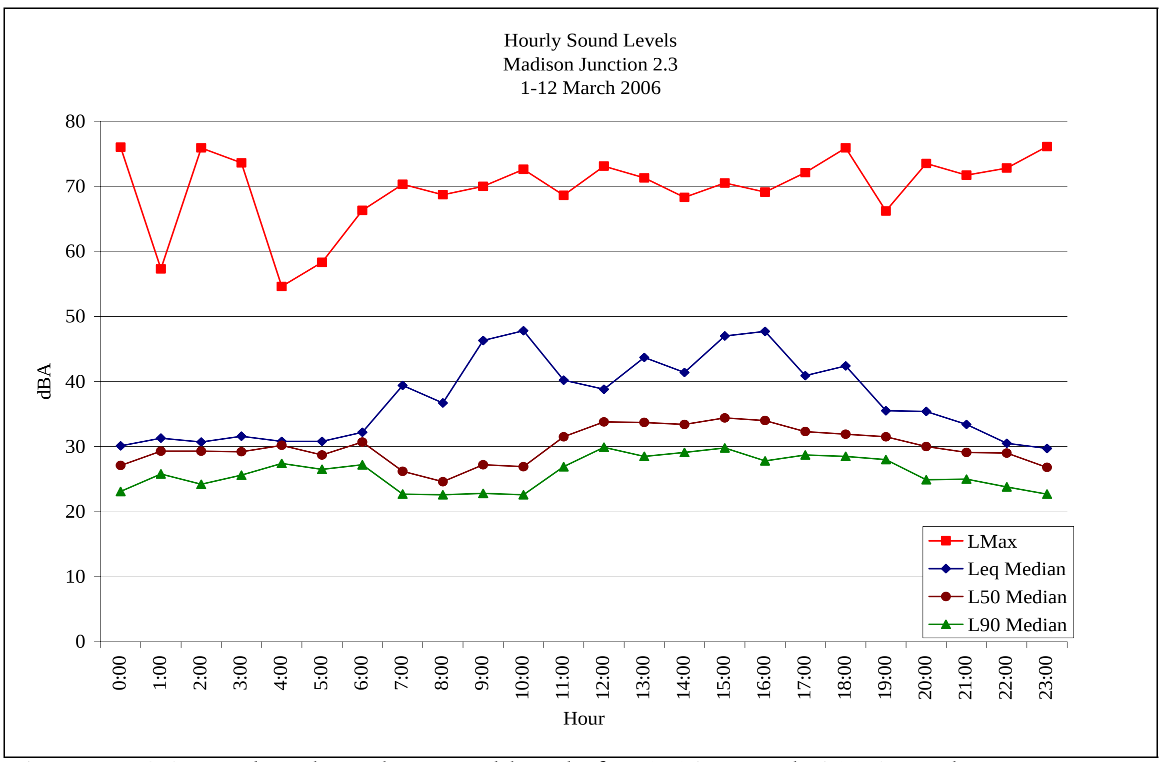

Figure F-36. Median hourly sound levels for 1-12 March 2006 Madison Junction 2.3, Yellowstone National Park. (n=286 hours)

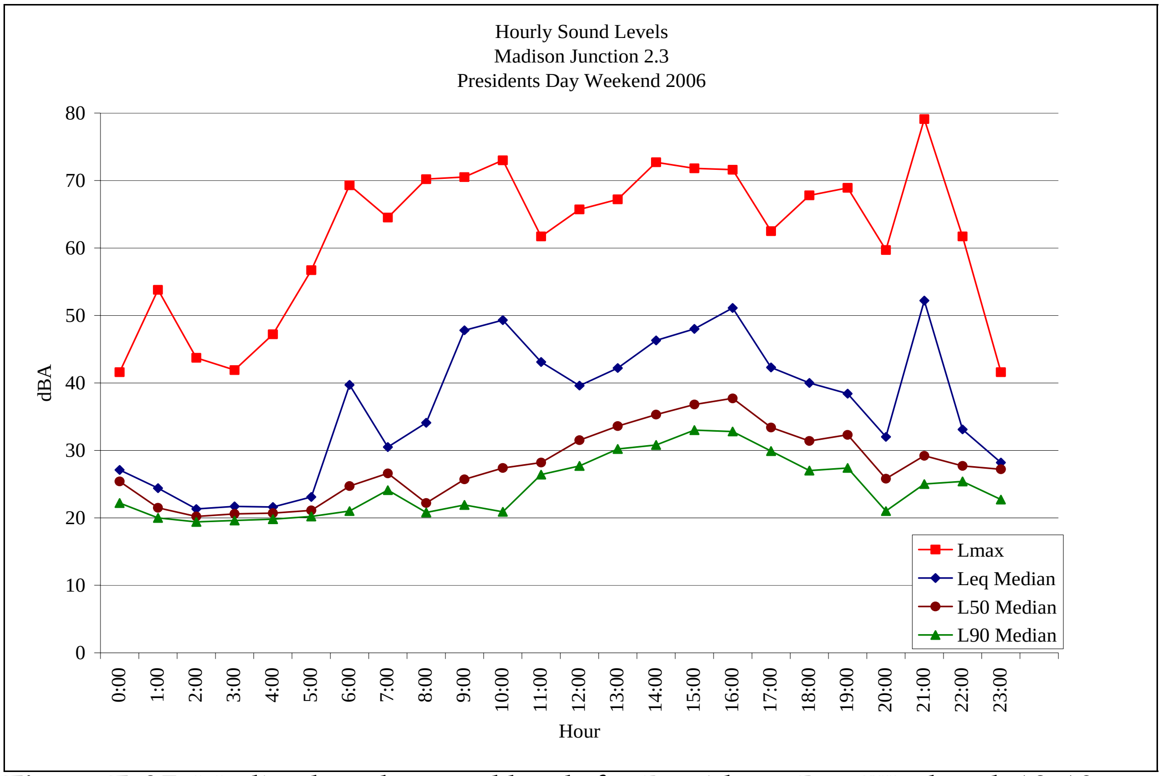

Figure F-37. Median hourly sound levels for Presidents Day Weekend, 18-19 February 2006, Madison Junction 2.3, Yellowstone National Park. (n=48 hours)

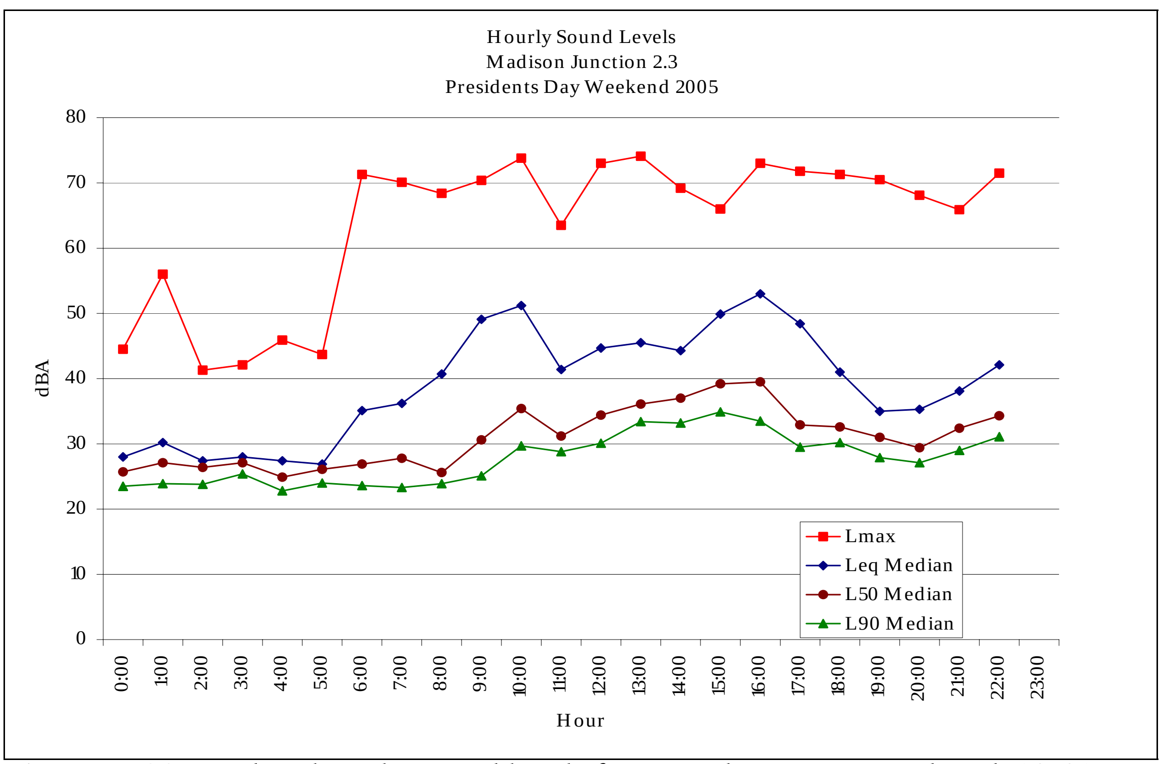

Figure F-38. Median hourly sound levels for Presidents Day Weekend, 19-20 February 2005, Madison Junction 2.3, Yellowstone National Park. (n=46 hours)

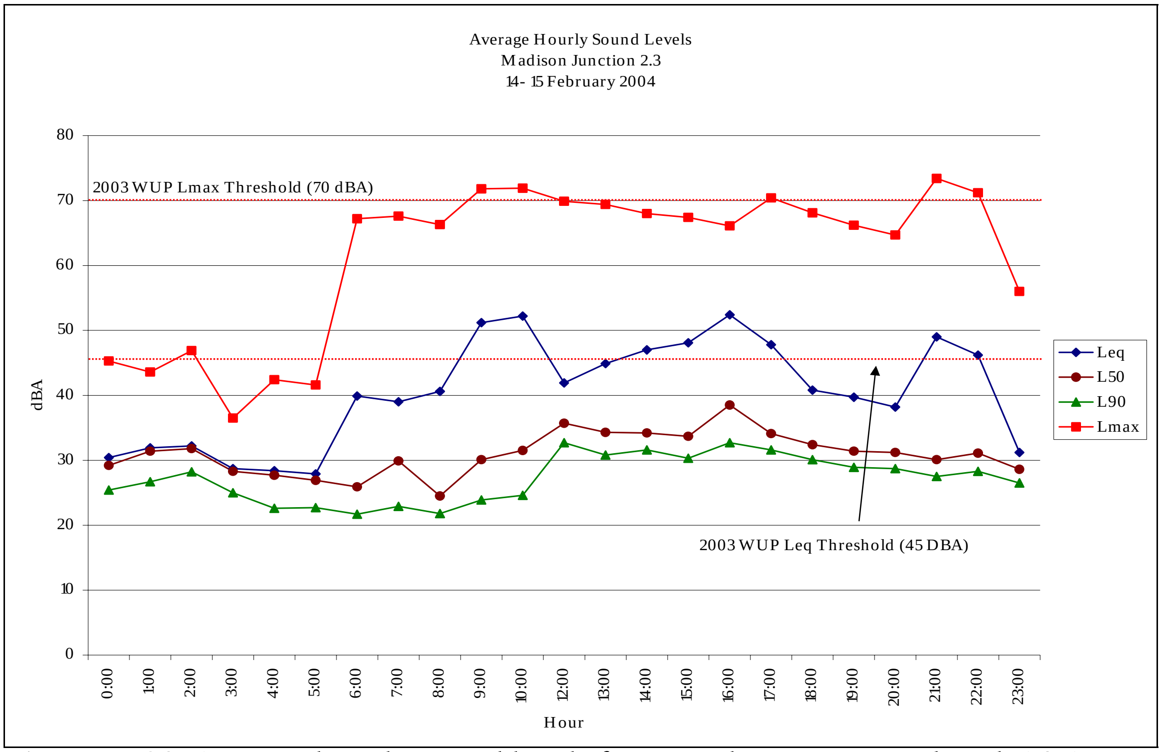

Figure F-39. Average hourly sound levels for Presidents Day Weekend, 14-15 February 2004, Madison Junction 2.3, Yellowstone National Park. (n=47 hours)

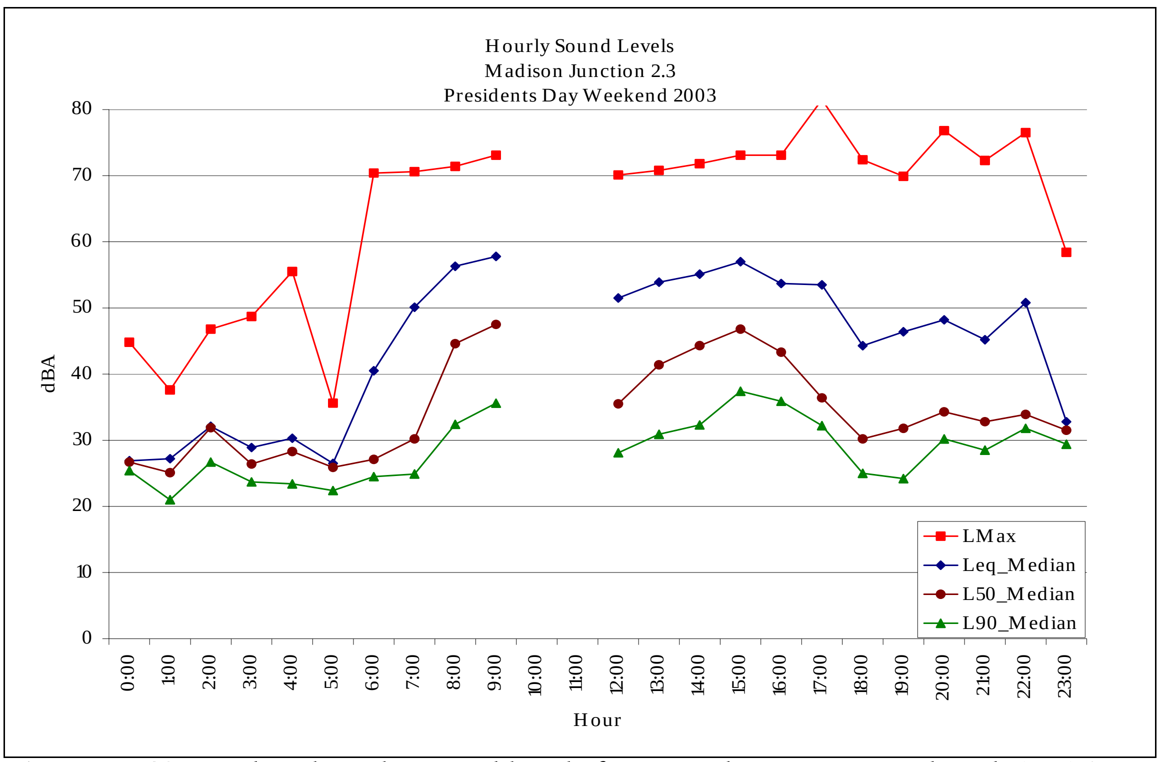

Figure F-40. Median hourly sound levels for Presidents Day Weekend, 15-16 February 2003, Madison Junction 2.3, Yellowstone National Park. Missing hours are due to site visits. (n=44 hours)

Appendix G. Oversnow vehicle percent time audible complications

As was discussed in the Results and Discussion section, the percent time OSVs were audible at any one point depended on several variables. For the last four winter use plans, audibility was measured by the percent of time between 8 am and 4 pm that OSVs were audible at a given point. The primary travel corridor monitoring site was Madison Junction on the busiest travel corridor in winter. For the winter season 2007-2008, OSVs were audible 53% of the 8-hour day. When the period of analysis is expanded to 7 am to 9 pm, the hours when the park is open to the public, OSV audibility was 45%. Audibility was 81% during the busiest hour of the day, 9 am to 10 am, and was 31% during the noon hour. This illustrates that the periods of analysis can greatly influence the value of percent time audible. Table G-1 illustrates the range of audibility figures depending on one's selection of monitoring site(s) and periods of analysis.

Table G-3: Audibility is partly a function of monitoring site and period of analysis.

Site(s)	**Period of Analysis**	**Audibility**
Madison Junction	noon to 1 pm	31%
Madison Junction	7 am to 9 pm	45%
Madison Junction	8 am to 4 pm	53%
Madison Junction	9 am to 10 am	81%
Grant Village/Lewis Lake	8 am to 4 pm	37%
All travel corridor monitoring sites in Yellowstone	8 am to 4 pm	42%

In addition to the influence of time period and monitoring site, naturally occurring sounds also affect the value of percent time audible. Two simple correlation analyses give a rough approximation of the relative contribution of wind and the number of OSVs that entered the park by day on the percent time OSVs were audible at Madison Junction 2.3 (Fig. G-1 and Fig. G-2). As would be expected the percent time OSVs were audible was lower on windy days and was higher during days of higher OSV numbers. However, by looking at the scatter of the values off the regression line (and the R-squared value), wind at this site explains OSV audibility better than the number of OSVs that entered the park. One would expect much better correlation with the number of OSVs that actually passed the monitoring site.

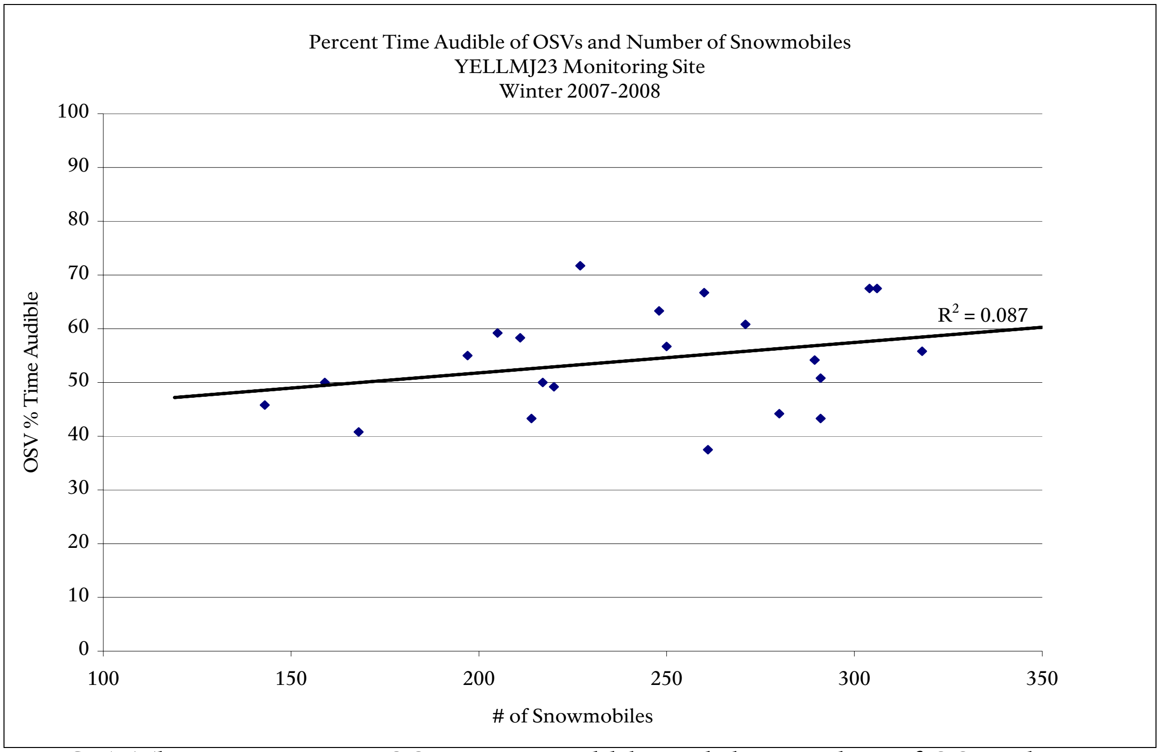

Fig. G-1. The percent time OSVs were audible and the number of OSVs that entered YNP, Madison Junction 2.3, December 2007-March 2008.

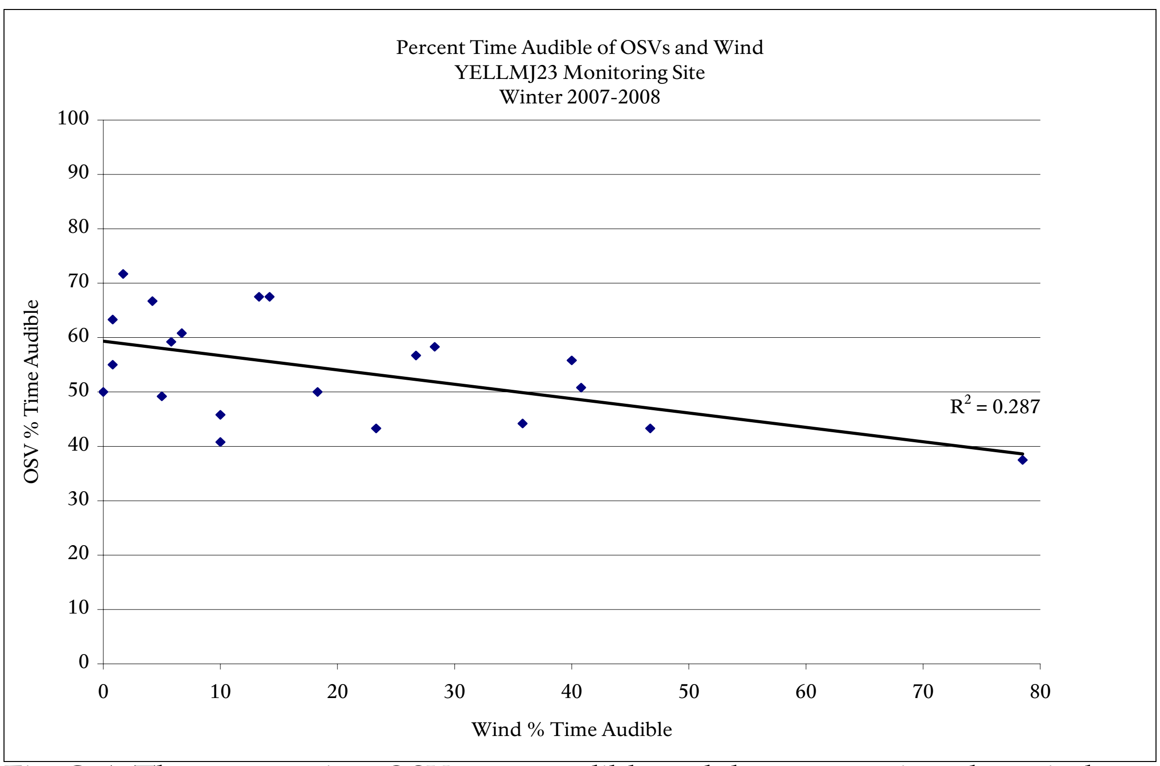

Fig. G-1. The percent time OSVs were audible and the percent time that wind was audible at Madison Junction 2.3, December 2007-March 2008.