Winter Acoustic Monitoring in Yellowstone National Park December 2012-March 2013

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Shan Burson/NPS Photo

Shan Burson
Yellowstone Center for Resources
Yellowstone National Park, WY 82190

and

Science and Resource Management
Grand Teton National Park
Moose, Wyoming 83012
(307) 739-3584

Executive Summary:

The natural soundscape of Yellowstone National Park is highly variable, ecologically important, valued by visitors, and protected by policy. Common natural sounds in winter include bird calls, mammal vocalizations, flowing water, wind, and thermal activity. These sounds vary by hour, day, month, and location. The natural soundscape is predominant in the park's backcountry and even in developed areas during the night. The natural soundscape predominates along travel corridors a majority of the time during the day in the winter use season. Environmental conditions, including air temperature and wind, have a substantial effect on how far both natural and non-natural sounds can be heard.

Noise associated with oversnow vehicles (snowmobiles and snowcoaches) is an important management concern at the park. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Sounds from both visitor and administrative oversnow vehicles were included in this study. We measured the sound levels and the duration and timing when oversnow vehicles could be heard (percent time audible and noise-free intervals) along travel corridors, in destination areas, and at backcountry sites.

Acoustical data were collected at three winter-long sites and two shorter-term sites in Yellowstone National Park during the winter use season, 15 December 2012-15 March 2013. This report includes, with few exceptions, only those sites sampled during the 2012-2013 winter. Results of data collected in the previous nine winters have been reported separately.

The audibility of oversnow vehicles during the 8 am to 4 pm time period was calculated in two ways. An overall winter use season average was calculated using all the sampled days at each site, and a daily audibility percentage was calculated by summing the time oversnow vehicles were audible during each eight hour day (8 am to 4 pm) and dividing by the eight hour period.

The noise-free interval was calculated as the period of time during 8 am to 4 pm that no motorized vehicles (oversnow and wheeled vehicles and aircraft) were audible. An additional noise-free interval was calculated using only oversnow vehicle noise. Noise-free intervals were not calculated for developed areas where human-caused sound was nearly constant.

The official winter use season was 91 days. Except where otherwise indicated, the summary statistics shown in this report are for the full 91-day winter use season.
The oversnow vehicles' overall winter use audibility in the most heavily-used developed area, Old Faithful, averaged 63% (*SD* = 9%).

Oversnow vehicles were audible for an overall average of 51% (*SD* = 12%) of the day near Madison Junction along the busiest road corridor in the winter, between Old

Faithful and the West Entrance. The noise-free interval between 8 am and 4 pm averaged three minutes and 59 seconds but varied by time of day. The average oversnow vehicle noise-free interval was seven minutes and 11 seconds.

Oversnow vehicles were audible for a winter use overall average of 5% (*SD* = 3%) at Sylvan Lake 3 along the East Entrance road corridor. The noise-free interval averaged 14 minutes and 8 seconds, but varied by time of day. The average oversnow vehicle noise-free interval was 25 minutes and 38 seconds.

Oversnow vehicles were audible for a winter use season average of 8% (*SD* = 10%) at Paycheck Pass Backcountry 3 miles (4.8 km) from the South Entrance Road. The noise-free interval average 33 minutes and 41 seconds but varied by time of day. The average oversnow vehicle noise-free interval was 43 minutes and 11 seconds.

Oversnow vehicles were audible for a winter use season average of 11% (*SD* = 14%) at Heart Lake Backcountry 5.4 miles (8.8 km) from the South Entrance Road. The noise-free interval averaged 16 minutes and 48 seconds, but varied by time of day. The oversnow vehicle noise-free interval was 27 minutes and 14 seconds.

The maximum sound levels of oversnow vehicles often exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor at the Madison Junction 2.3 monitoring sites and did occasionally at the Old Faithful Weather Station site. The majority of these higher sound levels were caused by old technology snowcoaches.

Consistent with acoustic data collected during the previous nine winter seasons, the sound levels and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels in the winters after 2002-2003 were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The percent time that snowmobiles are audible continues to be more closely associated with the number and distribution of groups rather than the total number of individual snowmobiles.

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Introduction:

Natural soundscapes are a valued resource at national parks including Yellowstone National Park (YNP). The 2006 National Park Service (NPS) Management Policies state that natural soundscapes (the unimpaired sounds of nature) are to be preserved or restored as is practicable. Natural soundscapes are intrinsic elements of the environment and are necessary for natural ecological functioning and therefore associated with park purposes. Natural soundscapes are highly valued by park visitors during their winter trips into Yellowstone. The existing winter soundscape at Yellowstone consists of both natural and non-natural sounds. Common natural sounds include bird calls, mammal vocalizations, flowing water, wind, and thermal activity. Non-natural sounds include motorized sounds of snowmobiles, snowcoaches, snow-grooming, wheeled vehicles, aircraft, and the sounds associated with facility utilities and other human activity in destination and support areas.

Previous Winter Use Plans of YNP and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway (NPS 2000, 2003, 2004, 2007, 2009, and 2013) concluded that historical oversnow vehicle (OSV) use created unacceptable adverse impacts on natural soundscapes and other resources. To minimize the impact of sounds from OSVs on the natural soundscape and other resources, the NPS established limits on the number and group sizes of transportation events and a guiding requirement. The primary purpose of this project's acoustical monitoring was to measure the impact of snowmobile and snowcoach sound on the park's natural soundscape. Data collected by automated sound monitors included sounds from both guided visitor and unguided administrative OSVs (but see Appendix B). See Burson (2004-2012) for additional information on park soundscapes and details of this study's methods, and the Winter Use Plans (NPS 2000, 2003, 2004, 2007, and 2009, 2013) for additional details of OSV management.

Study Area:

The major roads within YNP that are open to vehicles during the summer are groomed for OSV travel during the winter use season (December to March) with the exception of the road between Canyon and Tower and the plowed road between Mammoth and Cooke City along YNP's northern boundary.

During the winter use season, between 15 December 2012 and 15 March 2013, 16,850 guided snowmobiles and 2,557 guided snowcoaches, totaling 19,407 oversnow vehicles, entered YNP (NPS unpublished data). The majority (18,645, 96.1%) of snowmobiles entered through the West and the South entrances. Most of these winter visitors traveled to Old Faithful. Guests staying overnight at Old Faithful can partake in daytrips that originate from Old Faithful. These daytrips in previous winters averaged about seven to nine snowmobiles and snowcoaches per day but their numbers are unavailable from this past winter. These daytrips were not included in the number of OSVs given above and, unless otherwise indicated, elsewhere in this report.

Instrumentation:

Automated acoustic monitors (initially developed by Skip Ambrose, Sandhill Company, Castle Valley, UT and Mike Donaldson, Far North Aquatics, Fairbanks, AK) collected continuous one-second sound levels and digital recordings. See Burson (2012) for detailed instrumentation.

Acoustic Measurement Locations:

The 2012-2013 sound monitoring locations (Fig. 1; Table 1) were chosen to include high and low OSV use and represented three soundscape management zones (Developed, Travel Corridor, and Backcountry). Using aerial photos, habitat cover percentages listed below were calculated in a 500 meter radius of the sound monitor.

The Sylvan Lake 3 site was located on the road segment between the East Entrance and Fishing Bridge. The Paycheck Pass Backcountry site was 3 miles (4.8 km) from the South Entrance Road between Grant Village and Lewis Lake. The Heart Lake Cabin Backcountry site was 5.4 miles (8.8 km) from the South Entrance Road between Grant Village and Lewis Lake. These were the first long-term monitoring sites along those two road segments.

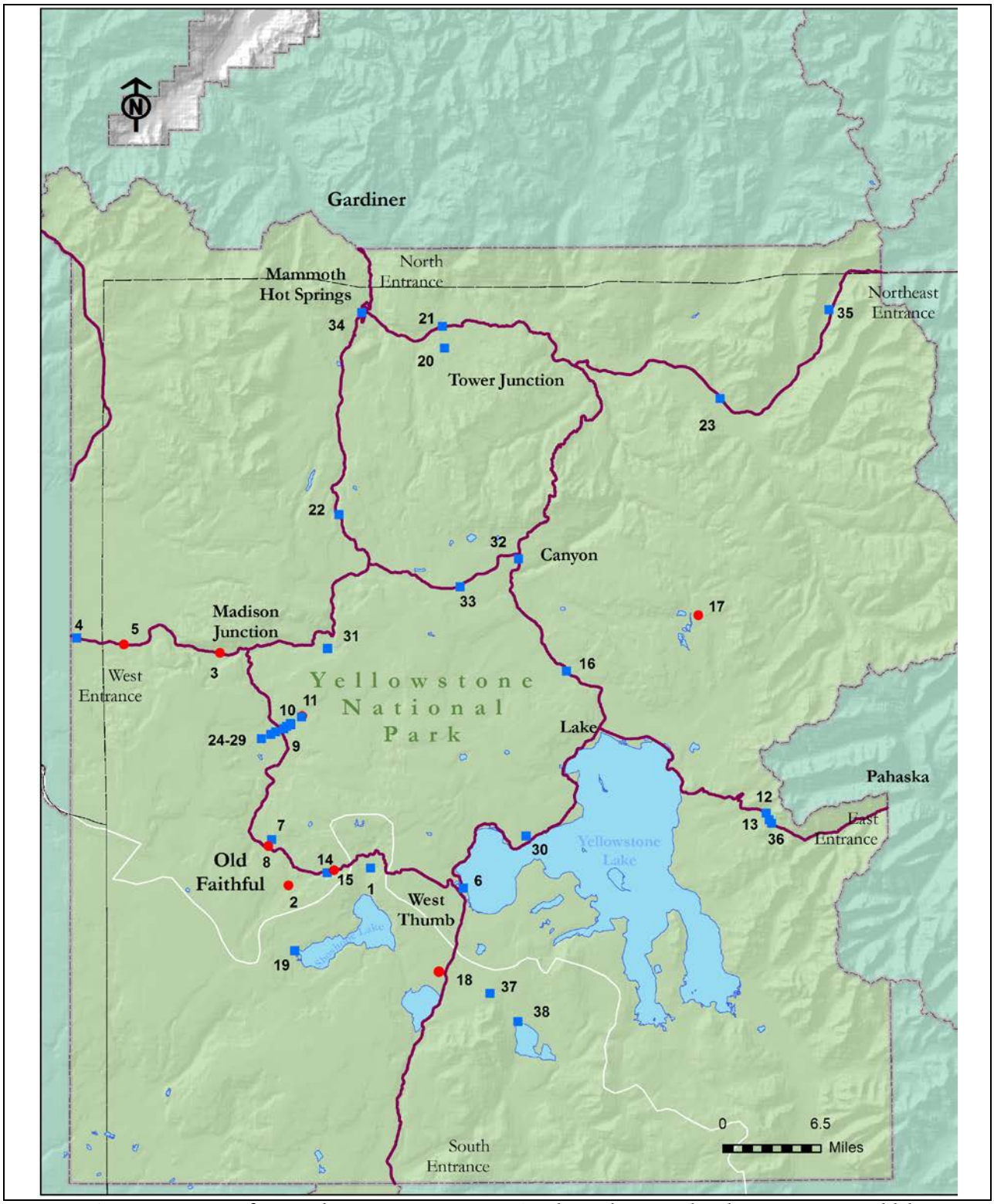

Figure 1. Locations of sound monitoring sites (red circles- multiple seasons, and blue squares- winter only) within YNP, December 2003-March 2013. See associated table for year and labels (Table 1). Only FY13 sampling locations are included in detail in this report (but see Burson [2004-2012] for previous winters' sampling results).

Table 1. Site name and years of sound monitoring locations within YNP, December 2003-March 2013. See associated map (Fig. 1) and labels.

Label	Site Name	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
1	Delacy Creek	Y					Y					
2	Lone Star Geyser		Y	Y								
3	Madison Junction 2.3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	West Yellowstone	Y										
5	W. Yellowstone 3.1			Y	Y							
6	West Thumb			Y	Y							
7	Old Faithful Upper Basin			Y	Y							
8	Old Faithful Weather Station	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
9	Mary Mountain Trail		Y									
10	Mary Mountain 4K		Y									
11	Mary Mountain 8K			Y	Y		Y					
12	Avalanche Creek				Y							
13	Sylvan Lake				Y							
14	Spring Creek				Y							
15	Spring Creek 2					Y						
16	Mud Volcano					Y						
17	Fern Lake					Y						
18	Grant Village Lewis Lake						Y					
19	Shoshone Geyser Basin						Y					
20	Blacktail Backcountry							Y				
21	Blacktail Roadside							Y				
22	North Twin Lake							Y				
23	Lamar Valley Willow								Y			
24	Mary Mountain Transect East 1								Y			
25	Mary Mountain Transect East 2								Y			
26	Mary Mountain Transect East 3								Y			
27	Mary Mountain Transect West 1								Y			
28	Mary Mountain Transect West 2								Y			
29	Mary Mountain Transect West 3								Y			
30	Pumice Point Roadside									Y		
31	Caldera Rim Picnic Area									Y		
32	Canyon Village Developed Area										Y	
33	Cygnet Lake Roadside										Y	
34	Mammoth Canary Springs										Y	
35	Middle Barronette Meadow										Y	
36	Sylvan Lake 3 Roadside											Y
37	Paycheck Pass Backcountry											Y
38	Heart Lake Backcountry											Y

Old Faithful Weather Station

Latitude:	44.45688
Longitude:	110.83178
Elevation:	7400 feet (2255 m)
Habitat:	50% open (parking lot, road, buildings), 30% open (wetlands, thermal area), 20% forested (sparse lodgepole pine)
Management Zone:	Developed

Photo 1. Old Faithful Weather Station sound monitor location within fenced enclosure in center of photograph.

The Old Faithful Weather Station monitor was located within the fenced area of the weather station (in the center background of the photo above) adjacent to the Ranger Station. The site and nearby motorized routes were in a mostly flat long wide valley. The microphones were located 40 feet (12 m) from a walking/ski trail, 200 feet (61 m) from the Ranger Station, 230 feet (70 m) from the entrance road used by oversnow traffic, 300 feet (91 m) from the large parking lot between the Ranger Station and the Visitors Center, 600 feet (183 m) from the Old Faithful Inn, and 700 feet (213 m) from the Snow Lodge. The monitor was powered by AC electricity. See Tables 2 and 3 for dates of operation.

Madison Junction 2.3

Latitude:	44.64253
Longitude:	110.89645
Elevation:	6800 feet (2073 m)
Habitat:	80% forested (small post-burn lodgepole pines), 20% open (road, river)
Management Zone:	Travel Corridor

Photo 2. Madison Junction 2.3 sound monitor location.

The Madison Junction 2.3 monitor (in the center of the photo above in trees) was located 2.3 miles (3.7 km) west of Madison Junction, 100 feet (30 m) from the West Entrance-Madison Junction Road within a large area of small (4 to 12 feet [1-4 m]) lodgepole pines, and 275 feet (84 m) from the Madison River. The site and nearby motorized route were in a long mostly flat valley, one mile (1.6 km) wide, bounded on both sides by steep bluffs. The Madison Junction 2.3 monitor was powered by 12 volt batteries charged by solar panels. See Tables 2 and 3 for dates of operation.

Sylvan Pass 3 Roadside

Latitude:	44.47571
Longitude:	110.15714
Elevation:	8500 feet (2500 m)
Habitat:	1% open (road), 12% open (water), 12% open (meadow), 75% conifer forest
Management Zone:	Travel Corridor

Photo 3. Sylvan Pass 3 Roadside sound monitor location.

The Sylvan Pass Roadside monitor (in the center of the photo above) was located 100 feet (30 m) from the road between Sylvan Lake and Sylvan Pass along the East Entrance Road. The microphone was among large conifer trees. The site was 187 feet (57 m) southeast of Sylvan Lake and 1.7 miles (2.7 km) from Sylvan Pass. See Tables 2 and 3 for dates of operation.

Paycheck Pass Backcountry

Latitude:	44.31467
Longitude:	110.53602
Elevation:	8100 feet (2470 m)
Habitat:	40% open (meadow), 60% conifer forest
Management Zone:	Backcountry Area

Photo 5. Paycheck Pass Backcountry sound monitor location.

The Paycheck Pass Backcountry monitor (in the foreground center left of the photo above) was located 3 miles (4.8 km) from the South Entrance Road between Grant Village and Lewis Lake. The microphone was within a small stand of mature conifers in a mosiac of meadow and conifer. The site was 50 feet (16 m) north of the Heart Lake Trail, and 545 yards (500 m) north of active geothermal activity. See Tables 2 and 3 for dates of operation.

Heart Lake Backcountry

Latitude:	44.28741
Longitude:	110.49879
Elevation:	7500 feet (2280 m)
Habitat:	75% open (meadow), 20% open (water), 5% conifers
Management Zone:	Backcountry Area

Photo 4. Heart Lake Backcountry sound monitor location.

The Heart Lake Backcountry monitor (in the center left of the photo above) was located 5.4 miles (8.8 km) from the South Entrance Road between Grant Village and Lewis Lake. The microphone was within a small stand of mature conifers in an open mosaic of meadow and conifer. The site was 500 feet (152 m) northwest of the Heart Lake Patrol Cabin and 280 feet (85 m) east of the Heart Lake Trail. See Tables 2 and 3 for dates of operation.

Methods and Analyses:

Winter-long acoustical measurements were collected at Old Faithful Weather Station, Madison Junction 2.3, and Sylvan Pass 3 Roadside. Additional acoustic data were collected for one month at Heart Lake Backcountry and Paycheck Pass Backcountry, (see previous section for site details). Data collection began on 15 December 2012 and continued throughout the winter use season (15 December 2012-15 March 2013). All sound level data collected during the winter use season were analyzed and are presented here. Selected digital recordings were chosen for analysis based on stratified sampling by site. Every third day was analyzed at Old Faithful Weather Station, Madison Junction 2.3, and Sylvan Pass Roadside. Every other day was analyzed at Heart Lake Backcountry and Paycheck Pass Backcountry. If a site visit fell on a day to be analyzed the day before or after was randomly selected for substitution.

The recent Winter Use Plan (WUP) impact thresholds applied only to motorized OSV sounds from 8 am to 4 pm so for the audibility analyses only those periods are presented in this report. Because the majority of OSV use was during 8 am to 4 pm, using the full 14-hour period of the day when OSV use was permitted would lower the resulting average daily percent time audible values (see Appendix C). For comparative value the sound levels are presented for the 24 hour day although the WUP thresholds applied only to 8 am to 4 pm.

The very low natural ambient sound levels documented near Sylvan Pass and Craig Pass (Ambrose et al. 2006, Burson 2007) were similar in habitat to monitoring locations measured for this study. Audibility of OSVs is determined, in part, by the natural ambient sound levels. Lower natural ambient sound levels can result in higher vehicle percent time audible. At some monitoring locations the lowest minimum sound levels can be below the range (noise floor) of the instrumentation for many hours of the day. The actual minimum sound levels are therefore unknown. Because of this uncertainty, and other factors, the association between the number of OSVs, the natural ambient sound levels, and the distances OSVs are audible is not straightforward.

Acoustic data were collected at YNP during the past eleven winter seasons, although the first winter consisted of only short-term data collection. This dataset provides information on trends, similarities among years and variability in time and location (Table 5). Soundscapes are highly variable over time, both in minutes and seasons. All attempts to summarize long-term datasets therefore fail to fully explain this inherent variability. Methods and techniques to completely address the soundscapes variability are currently unavailable. Attempts to draw tight correlations between certain actions, such as the daily number of OSVs allowed to enter YNP and the percent time audible at a particular location require more detailed data collection and analyses than is available in this study. Nevertheless, the acoustic dataset that has been collected during the winter-use season and upon which this report is based is one of the most extensive national park winter acoustic datasets in existence and a substantial amount of useful

information can be gathered from the data as collected and presented. See Burson (2012) for detailed methods.

Audibility

Ten seconds of every four minutes of the continuous digital recordings were analyzed. These daily 360 10-second samples were combined, calibrated, and analyzed. The entire 24-hour period was used, but to compare to previous years, the time period 8 am to 4 pm (120 samples totaling 20 minutes per day) is reported here.

The percent time audible for each sound source was calculated using the 10-second samples every four minutes as a surrogate for all periods of the day. For example, if a particular sound source was audible for half of the samples (180 of 360 samples) its percent time audible was calculated as 50%. Although any sampling scheme may miss an occasional sound, comparison with attended logging, other sampling schemes and continuous recordings demonstrated that a 10 seconds/4 minute scheme, over multiple days, closely approximate actual percent time audible of frequent sound sources (e.g., oversnow vehicles).

It was increasingly difficult to identify sound sources as distances increased from the recording location to the sound source. Therefore sound source codes are hierarchal (e.g., snowmobile; oversnow vehicle; motorized sound; non-natural sound; unknown). The most specific identification possible was used. Snowmobiles were sometimes difficult to distinguish from snowcoaches. When the source was known to be either a snowcoach or a snowmobile but could not be positively identified to the exact source, that unknown OSV source was added into a third, total OSVs, category that included all OSVs (road maintenance snow groomers were not included as OSVs). Figures 3 and 6 provide examples of the relative proportions of snowmobiles, snowcoaches, and the total OSVs. When sound sources could only be identified as motorized vehicles they were not included in the OSV category, although it is likely that many were oversnow vehicles.

The noise-free interval was calculated by analyzing one full hour for each of the eight hours between 8 am and 4 pm at Madison Junction 2.3, Sylvan Pass 3 Roadside, Heart Lake Backcountry and Paycheck Pass Backcountry. At Madison Junction 2.3 these eight hours were combined with 24 hours collected the last three winters for a total of 32 hours. The days chosen to represent each hour were randomly selected. Continuous recordings were analyzed for each of these 56 hours. Noise-free intervals were not calculated for Old Faithful because human-made noise was nearly always audible. The average and maximum (the longest) noise-free interval was calculated for both each hour and for the entire sampling period for each site both for all human-made noise (NFI) and only oversnow vehicle noise (OSVNFI).

Sound levels

This report relies on a number of common acoustical metrics for the sound level data and descriptive statistics, mostly medians, for the audibility data. Because estimates of

variability beyond the minimum and maximum values are also desirable, information about the sound levels exceeded 10, 50, and 90 percent of the time is provided.

See Appendix A for a discussion and examples of a technique to visualize daily sound levels. This technique provides another avenue to understand the natural soundscape and the sound impact of oversnow vehicles. See Appendix B for the results of a multi-year observational study that estimates the proportion of usage categories for OSVs (e.g., percent of total snowmobiles driven by park visitors). See Appendix C for additional considerations of OSV percent time audible summaries.

Results and Discussion:

Selected digital recordings (Tables 2 and 3) were chosen for analysis based on stratified sampling by site. All sound level data from each site was analyzed (Table 4).

Table 2. Dates used for audibility analyses at five locations in YNP, December 2012-March 2013. Daily average number of guided snowmobiles was 185/day[1] for the 91-day winter use season, excluding OSVs originating from Old Faithful. Total number of days analyzed, 120.

Paycheck Pass Backcountry	Heart Lake Backcountry	Sylvan Pass 3 Roadside	Old Faithful Weather Station	Madison Junction 2.3
15 days	16 days	27 days	31 days	31 days
17 Jan 13	17 Jan 13	22 Dec 12	15 Dec 12	15 Dec 12
18 Jan 13	18 Jan 13	24 Dec 12	18 Dec 12	18 Dec 12
20 Jan 13	20 Jan 13	27 Dec 12	22 Dec 12	22 Dec 12
22 Jan 13	22 Jan 13	30 Dec 12	24 Dec 12	24 Dec 12
24 Jan 13	24 Jan 13	5 Jan 13	27 Dec 12	27 Dec 12
26 Jan 13	26 Jan 13	8 Jan 13	30 Dec 12	30 Dec 12
28 Jan 13	28 Jan 13	11 Jan 13	2 Jan 13	2 Jan 13
30 Jan 13	30 Jan 13	14 Jan 13	5 Jan 13	5 Jan 13
1 Feb 13	1 Feb 13	16 Jan 13	8 Jan 13	8 Jan 13
3 Feb 13	3 Feb 13	20 Jan 13	11 Jan 13	11 Jan 13
5 Feb 13	5 Feb 13	23 Jan 13	14 Jan 13	14 Jan 13
7 Feb 13	7 Feb 13	26 Jan 13	16 Jan 13	16 Jan 13
9 Feb 13	9 Feb 13	29 Jan 13	20 Jan 13	20 Jan 13
11 Feb 13	11 Feb 13	1 Feb 13	23 Jan 13	23 Jan 13
13 Feb 13	13 Feb 13	4 Feb 13	26 Jan 13	26 Jan 13
	15 Feb 13	7 Feb 13	29 Jan 13	29 Jan 13
		10 Feb 13	1 Feb 13	1 Feb 13
		13 Feb 13	4 Feb 13	4 Feb 13
		16 Feb 13	8 Feb 13	7 Feb 13
		19 Feb 13	10 Feb 13	10 Feb 13
		22 Feb 13	13 Feb 13	13 Feb 13
		24 Feb 13	16 Feb 13	16 Feb 13
		28 Feb 13	19 Feb 13	19 Feb 13
			22 Feb 13	22 Feb 13
			25 Feb 13	25 Feb 13
			28 Feb 13	28 Feb 13
			3 Mar 13	3 Mar 13
			6 Mar 13	6 Mar 13
			9 Mar 13	9 Mar 13
			12 Mar 13	12 Mar 13
			15 Mar 13	15 Mar 13

[1]Average number of snowmobiles was calculated using all snowmobiles entering Yellowstone. Not all snowmobiles would pass by each site and numbers varied by day. Administrative OSV use was not counted in these totals. Average daily number of snowcoaches for the winter use season was 28/day.

Table 3. Hours and dates used for analysis of noise-free intervals at Madison Junction, Sylvan Pass 3 Roadside, Heart Lake Backcountry and Paycheck Pass Backcountry. Total number of days and hours analyzed, 56.

	Madison Junction 2.3	**Sylvan Pass 3 Roadside**	**Heart Lake Backcountry**	**Paycheck Pass Backcountry**
Hour	**Date**	**Date**	**Date**	**Date**
8 am	**12/24/09, 2/22/11, 12/25/11, 3/6/13**	**12/24/12**	**2/11/13**	**1/17/13**
9 am	**1/4/10, 1/7/11, 1/19/12, 1/29/13**	**2/24/13**	**2/5/13**	**1/30/13**
10 am	**1/10/10, 2/4/11, 2/27/12, 1/20/13**	**1/20/13**	**1/20/13**	**2/13/13**
11 am	**1/15/10, 12/19/10, 1/28/12, 2/8/13**	**1/26/13**	**1/24/13**	**1/20/13**
12 pm	**1/30/10, 2/7/11, 12/27/11, 2/13/13**	**1/29/13**	**1/30/13**	**2/5/13**
1 pm	**2/5/10, 3/2/11, 2/2/12, 2/4/13**	**2/28/13**	**1/17/13**	**2/9/13**
2 pm	**2/10/10, 1/21/11, 2/24/12, 2/16/13**	**2/24/13**	**1/24/13**	**1/18/13**
3 pm	**2/20/10, 12/25/10, 1/18/12, 2/4/13**	**1/8/13**	**2/3/13**	**2/1/13**

Table 4. Dates used for sound level analyses at five locations in YNP, December 2012-March 2013. Total hours 7,423.

Old Faithful (2,101 hours) 15 December 2012-15 March 2013	Madison Junction 2.3 (2,177 hours) 15 December 2012-15 March 2013
Sylvan Pass 3 Roadside (1,656 hours) 22 December 2012-1 March 2012	Heart Lake Backcountry Area (752 hours) 16 January 2013-16 February 2013
Paycheck Pass Backcountry (737 hours) 15 January-15 February 2013	

Audibility:

Each audible sound (snowmobile, wheeled vehicle, animal, aircraft, wind, thermal activity, etc.) was identified each day during 8 am-4 pm. The proportion of each sound source sample out of the possible 120 was used to calculate the percent time audible for each sound source; however, only the snowmobile, snowcoach and wind percent time audible is presented. OSVs were often audible outside the 8 am-4 pm time period, but these data are generally not presented. Often multiple snowmobiles or snowmobiles and snowcoaches were audible simultaneously, but at other times one masked the sound of the other. Audibility of OSVs were calculated using existing ambient conditions, that is,

other non-natural sound sources could have been present and may have masked OSV sounds. This potential masking was only regularly present at developed areas. The only non-natural sounds other than OSVs at travel corridors and backcountry sites were occasional aircraft. The average number of snowcoaches entering YNP during the winter season was 28/day (range 9-50). The average number of guided snowmobiles entering YNP during the winter season was 185/day (range 45-276).

Regarding oversnow vehicles, an important question is the relationship between the number of snowmobiles and snowcoaches entering YNP and the percent of time that they are audible at a particular measurement location. At first glance this appears an easily answered question. It seems intuitively obvious that more snowmobiles and snowcoaches would make more sound and that they would be heard a greater proportion of the day. This is true in general and is obvious in the acoustic data collected during the past winters. Several factors, though, complicate the relationship. First, not all snowmobiles are part of guided groups; there are many NPS and concession snowmobiles and snowcoaches used within the park, especially in destination areas such as Old Faithful (see Appendix B for information about the relative contribution of guided versus administrative OSV use). Second, not all OSVs that enter the park travel along the same route. Therefore the number of OSVs entering the park is not directly related to the number passing any particular section of the road and hence their impact on the natural soundscape of that area. Third, as the numbers of visitors entering the park increases, additional snowmobiles are often added to existing groups enlarging group size, but not creating additional groups. The percent time that snowmobiles are audible is more closely associated with the number and distribution of groups rather than the number of individual snowmobiles. Fourth, audibility also depends on environmental conditions, such as temperature, wind conditions, inversions, the natural ambient sound level and other factors (as discussed in the next paragraph) that vary spatially and temporally. These factors added together reduce the potentially close relationship between the number of visitor snowmobiles and snowcoaches and OSV percent time audible.

A related audibility issue involves an acoustical metric called the noise-free interval (NFI). NFIs measure the uninterrupted periods of time when only silence or natural sounds are audible. For the purposes of this report, NFIs were the times when no oversnow or wheeled vehicles or aircraft (on average audible 5% or less of the day) were audible. Oversnow vehicle noise-free intervals (OSVNFI) were the times when no oversnow vehicle noise was audible. Using logic and common sense, the number and distribution of vehicles largely determine the OSVNFI. Given the same number of vehicles, OSVNFIs measured near travel corridors would be longer with larger rather than smaller groups (however as group size increases they would likely be heard at increasing distances). A particular percent time audible can have varying NFIs. For example, if OSVs were audible for 50% of an hour, depending on the distribution of these vehicles they could all be audible in the first 30 minutes and not audible the remaining 30 minutes. Or OSVs could be audible every other 10 minute period during the hour. The OSVNFI of the first scenario would be 30 minutes but only 10 minutes for

the second. The management requirement for groups of guided snowmobiles have increased the OSVNFIs at YNP compared to non-grouped snowmobiles (personal observation, and Appendix D; Fig. A-6 and A-7).

Audibility depends on the sound level of and distance from the sound source as well as the presence of other natural sounds and non-sound source variables such as atmospheric conditions, wind speed and direction, topography, snow cover, and vegetative cover. These various factors influenced day to day audibility at any given location including the sound monitoring sites. In general, distant OSVs were masked by wind if it was present. The presence or absence of wind made the most appreciable difference in the percent time that OSVs were audible at sites where OSVs could be heard at low sound levels during calm wind conditions. All audibility results reported here are from the analyses of actual field recordings from the monitoring sites. Therefore, all sounds, both natural and non-natural influenced the reported audibility of OSVs. No two days were identical, but patterns were regularly observed and differences among monitoring locations are apparent.

Old Faithful Weather Station

Acoustic data were collected at this site for the tenth full winter (Table 1). Even though this site was Yellowstone's busiest developed area accessed by OSVs, many natural sounds were present, including wind, snow, wolves, coyotes, bison, red squirrels, ravens, ducks, and geese. Non-natural sounds of building utilities, construction activities, and people's voices were frequently audible along with oversnow vehicles. For the winter use season the average daily percent time audible for snowmobiles and snowcoaches was 63% (*SD* = 9%) within the developed area at Old Faithful, (Fig. 2). This compares to 66% (*SD* = 11%) the previous winter and 55-69% during the eight winter use seasons before that (Table 5).

Oversnow vehicles traveling on the main road and within the Old Faithful developed area were audible at this site. Wind, depending on direction and speed, can increase or decrease the distance OSV sounds are audible. However, though typically OSVs are heard at greater distances during calm wind conditions, there appears to be no strong association between days with low to moderate wind and OSV percent time audible at Old Faithful (Fig. 2). This is because the higher ambient sound levels at Old Faithful mask the distant faint OSV sounds that would otherwise be audible during calm conditions.

Percent time audible can be calculated by hour to show the pattern of OSV use between 8 am and 4 pm (Fig. 3). On average, OSVs were audible for more time as visitors arrived closer to mid-day. On average, of the OSVs that were identified, snowmobiles were audible for 35% of the day versus 18% for snowcoaches (Fig. 3). OSVs were audible on average 75% of the time during the busiest (11 am) hour. In addition to average audibility, Figure 3 shows the range of OSV audibility for each hour of the day for the entire sampling period (labeled high and low OSV).

The analyses for the WUP measurement period are restricted to 8 am-4 pm but OSV sounds were often audible outside that time period (e.g., Fig. 4). Many of these OSVs were driven by employees.

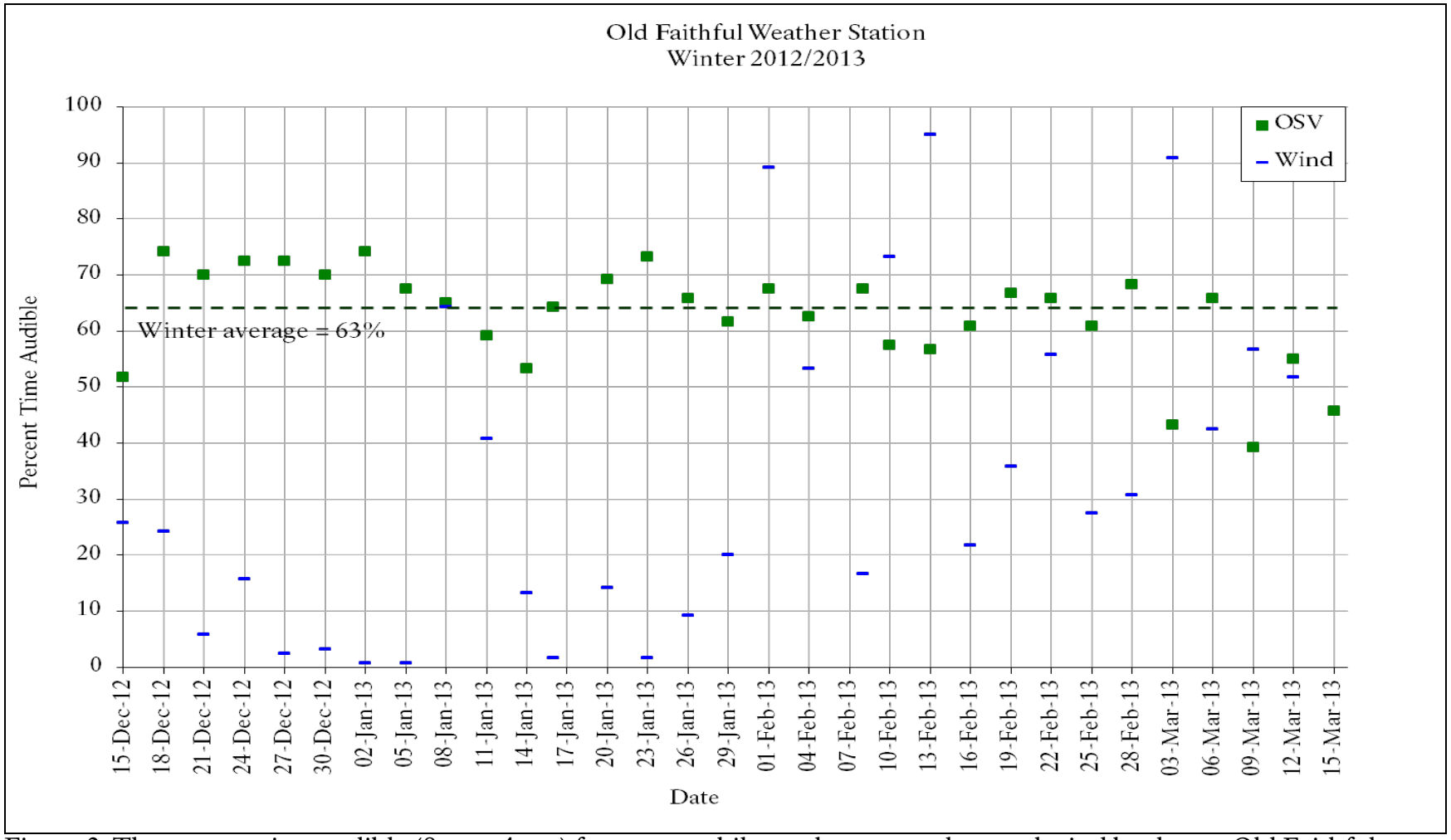

Figure 2. The percent time audible (8 am - 4 pm) for snowmobiles and snowcoaches, and wind by date at Old Faithful Weather Station, YNP, 15 December 2012-15 March 2013.

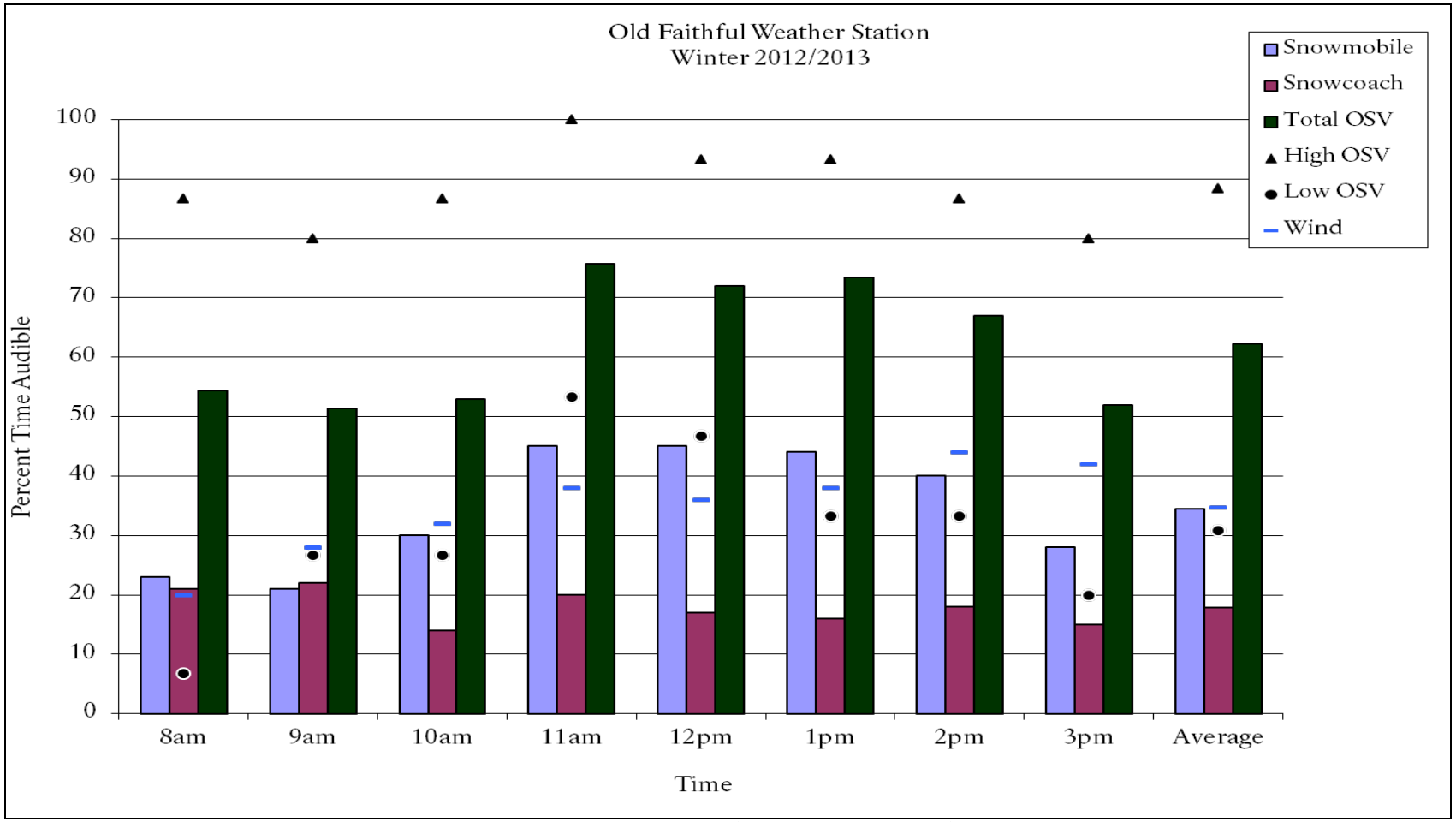

Figure 3. The season average percent time audible by hour of snowmobiles (left light blue bar), snowcoaches (middle maroon bar), and a total OSV category including unidentified OSVs (right dark green bar), and the season's maximum and minimum OSV percent time audible values by hour at Old Faithful Weather Station, YNP from 8 am - 4 pm, 15 December 2012-15 March 2013.

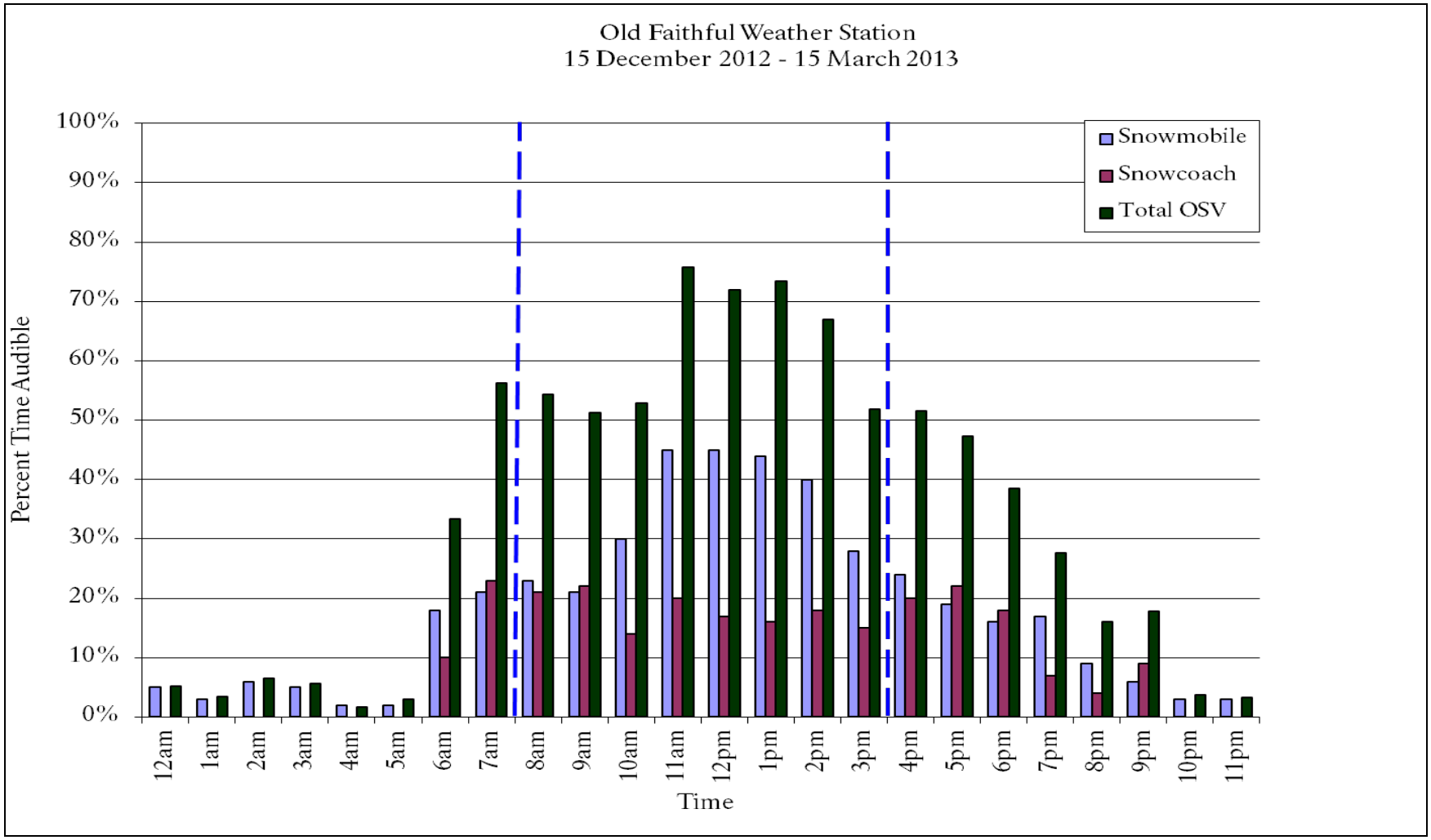

Figure 4. The percent time audible by hour of snowmobiles (left light blue bar), snowcoaches (middle maroon bar), and a total OSV category including unidentified OSVs (right dark green bar) at Old Faithful Weather Station, YNP, 15 December 2012 – 15 March 2013. The winter use analysis time period is between the vertical dashed lines.

Madison Junction 2.3

Madison Junction 2.3 monitoring site was located 100 feet (30 m) off the West Entrance Road 2.3 miles (3.7 km) west of Madison Junction along Yellowstone's busiest OSV travel corridor. Acoustic data have been collected for all or parts of ten winter use seasons (Table 1) at this location. Riffles of the Madison River were audible during quiet periods. Wind was often audible as were swans, ducks, and geese on the river. Coyotes and wolves were more rarely heard, but ravens and other birds were audible daily. Aircraft (a total of 3 helicopters, 11 propeller aircraft, and 73 jets) were audible for a daily (8 am and 4 pm) average of 2.4% during the winter use season.

Snowmobiles and snowcoaches were audible for an average of 51% (*SD* = 12%) of the time during the entire winter use season (Fig. 5). The range during the previous seven full seasons was 47%-59% (Table 5). Wind speed was associated with the audibility of OSVs at this site. OSVs were less audible on days with more wind due to the masking effect of wind on the distant and faint OSV sounds.

The hourly pattern follows a bimodal distribution (Fig. 6) documenting the pulse of OSVs passing the site in the morning on the way into the park and in the afternoon on the way back to West Yellowstone. In addition to average audibility, Figure 6 shows the range of OSV audibility for each hour of the day for the entire sampling period (labeled high and low OSV). Figure 6 also shows that many of the OSVs could not be distinguished as a snowmobile or a snowcoach. This is because it was not possible to specifically identify many distant faint OSVs because of the similar acoustic signature of snowmobiles and snowcoaches.

For the past four winters combined, the average noise-free interval at Madison Junction 2.3 was three minutes and 59 seconds (Figure 7a) during 8 am to 4 pm. Noon had the longest average noise-free interval (over 17 minutes) and longest maximum NFI (over 28 minutes), and 10 am had the shortest average NFI (23 seconds) and shortest maximum NFI (under 2 minutes) during the winter use day. To measure the contribution of aircraft to the NFI, Fig. 7a shows the noise-free interval including aircraft for the past four winters compared to Fig. 7b that shows the noise-free interval for only oversnow vehicles (OSVNFI) for the winter of 2012-2013. Additional samples would give a better representation of typical noise-free conditions, however, this noise-free interval analysis again reflects the pulse of OSVs traveling by the site during the morning and afternoon hours (Figure 7a).

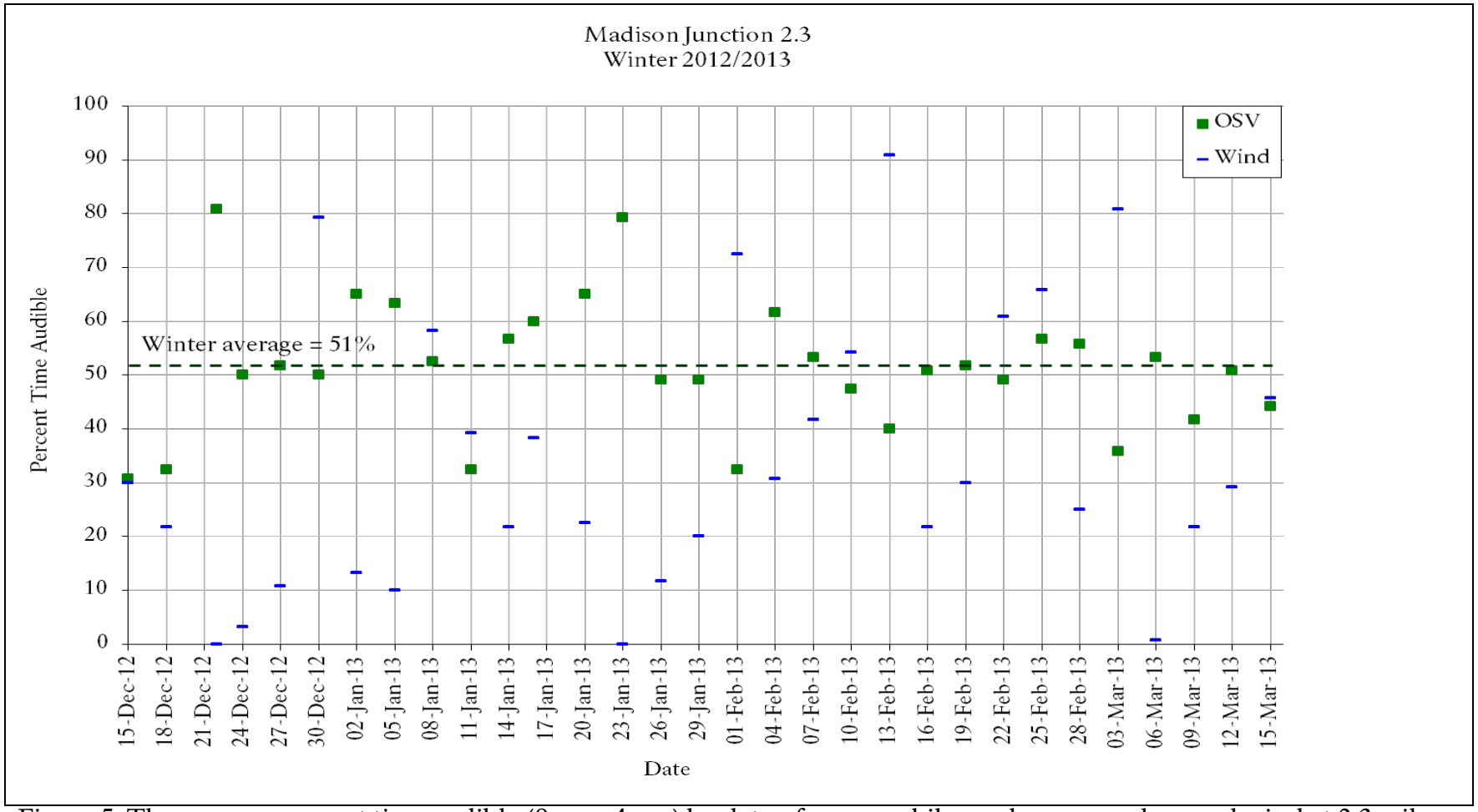

Figure 5. The average percent time audible (8 am - 4 pm) by date of snowmobiles and snowcoaches, and wind at 2.3 miles 3.7 km) west of Madison Junction along the West Entrance Road YNP, 15 December 2012-15 March 2013.

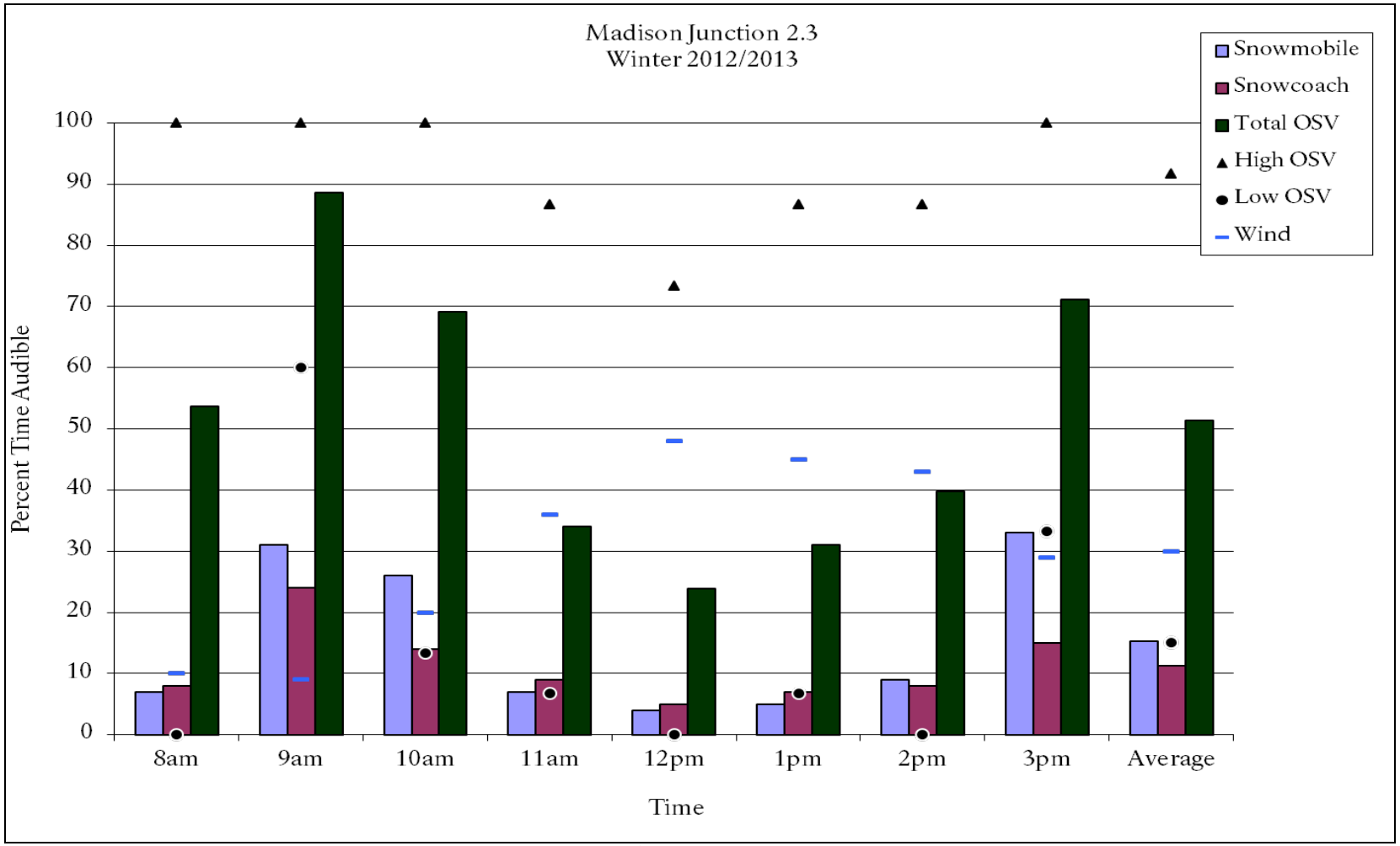

Figure 6. The average percent time audible by hour of snowmobiles and snowcoaches, and total OSVs including unidentified OSVs, and the season's maximum and minimum OSV percent time audible values by hour at 2.3 miles (3.7 km) west of Madison Junction along the West Entrance Road, YNP, 15 December 2012-15 March 2013.

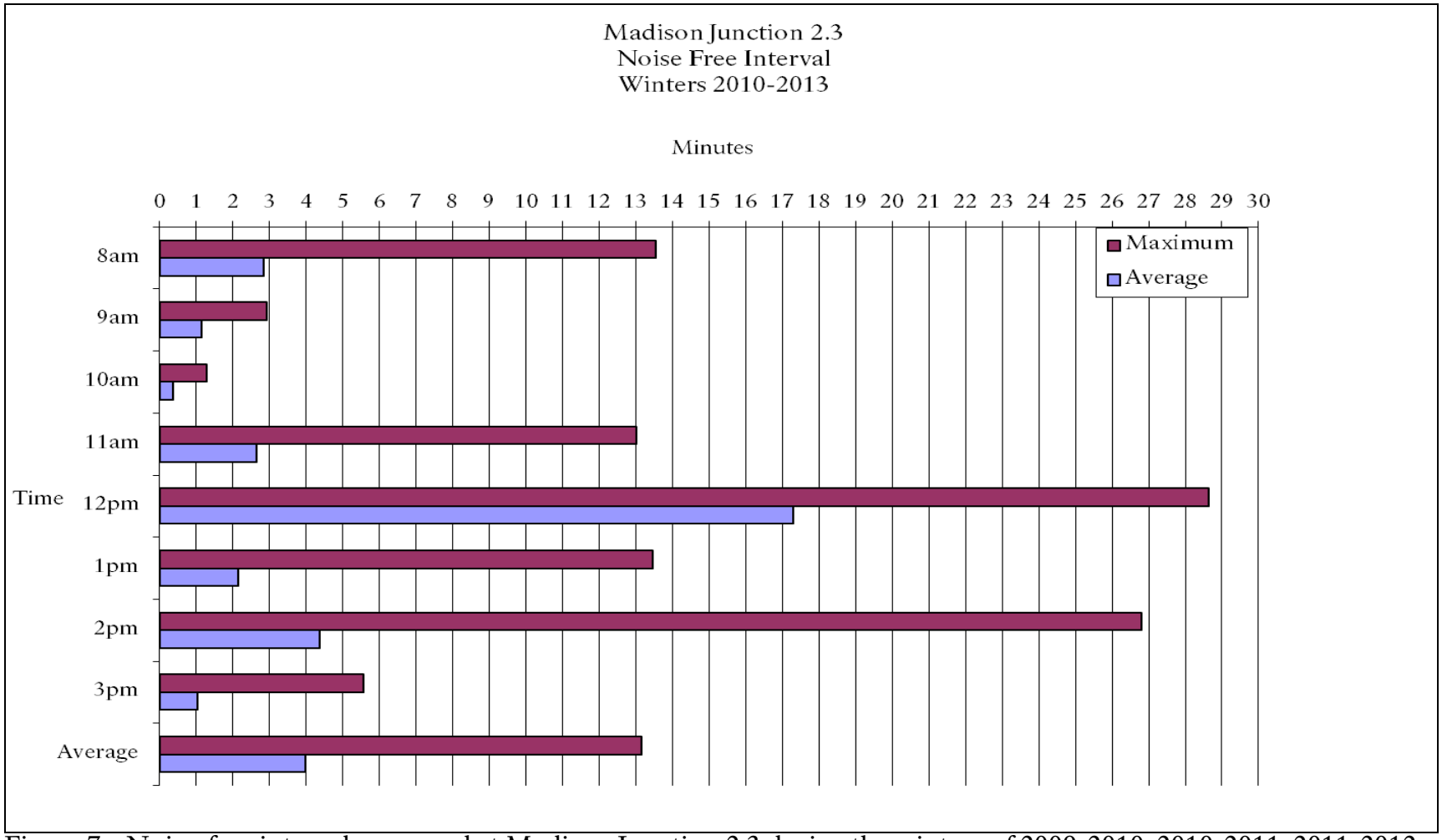

Figure 7a. Noise-free interval measured at Madison Junction 2.3 during the winters of 2009-2010, 2010-2011, 2011-2012, and 2012-2013, YNP. See Table 3 for dates used, and text for more details.

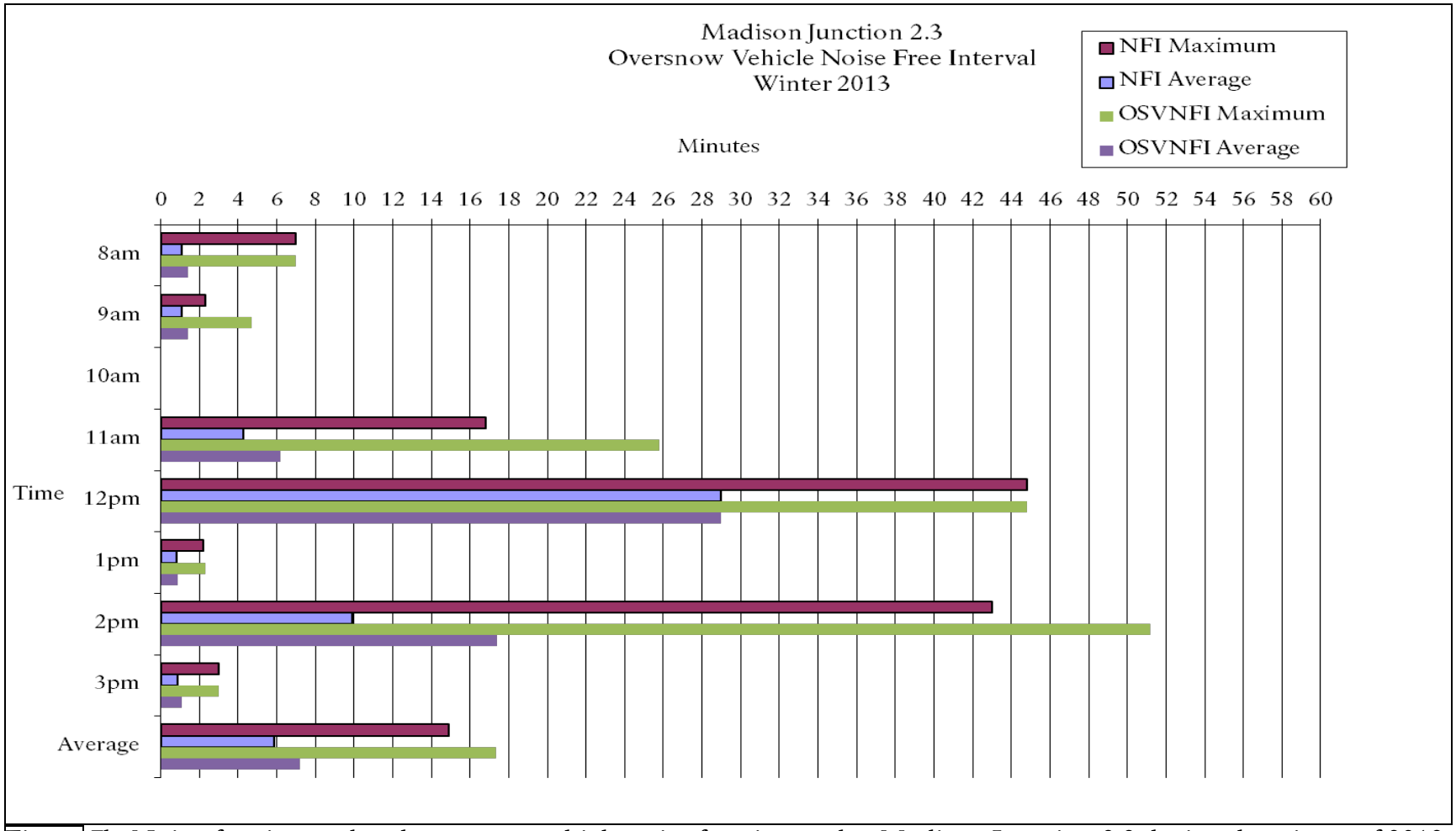

Figure 7b. Noise-free interval and oversnow vehicle noise free-interval at Madison Junction 2.3 during the winter of 2012-2013, YNP. See Table 3 for dates used, and text for more details.

Sylvan Pass 3 Roadside

Winter-long acoustic monitoring data were collected near Sylvan Pass for the first time this winter season. This location was just east of Sylvan Lake, 100 feet (30 m) north of the groomed road. Aircraft (a total of 9 propeller aircraft and 90 jets) were audible for a daily (8 am and 4 pm) average of 3.6% during the winter use season.

There were no guided snowcoaches were used along this section of road (though a few administrative snowcoaches were). Oversnow vehicles, mainly snowmobiles, were audible an average of 5% (*SD* = 3%) of the time between 8 am and 4 pm during the sampling period (Fig. 8).

Only the 8 am hour of the 8-hour day had average OSV audibility over 10% (Fig. 9). In addition to average audibility, Figure 9 shows the range of OSV audibility for each hour of the day for the entire sampling period (labeled high and low OSV). Only the 8 am hour had a maximum audibility of more than 50% on at least one day that was analyzed (Fig. 9). When the wind was not present, this site had very low ambient sound levels (Fig. 23).

The average noise-free interval at Sylvan Pass 3 Roadside is shown in Figure 10. To separate the contribution of only oversnow vehicles to the NFI, Figure 10 also shows the oversnow vehicle noise-free interval (OSVNFI). Additional samples would give a better representation of typical noise-free conditions because only one hour was analyzed for each of these eight hours (Table 3).

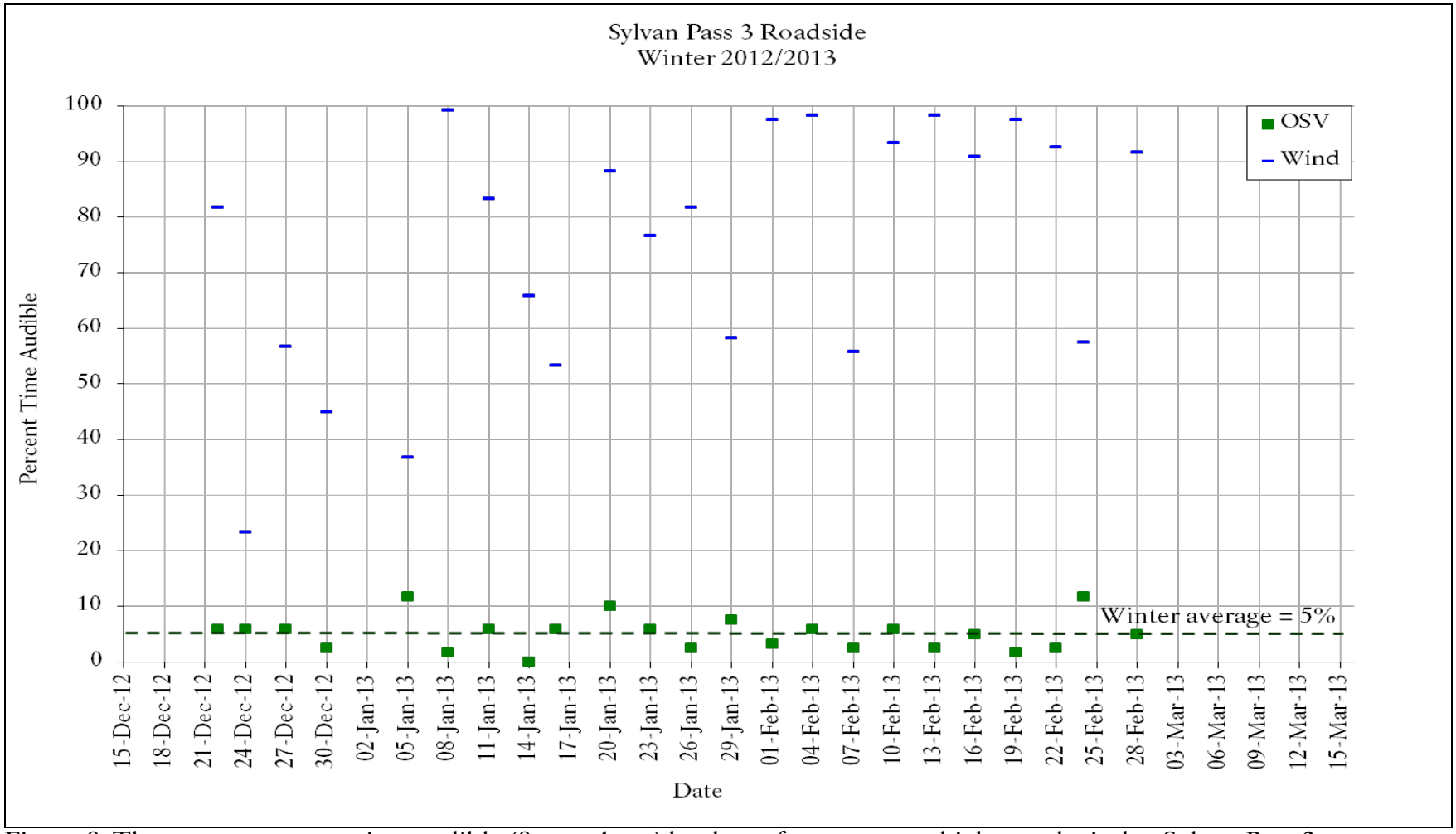

Figure 8. The average percent time audible (8 am - 4 pm) by date of oversnow vehicles, and wind at Sylvan Pass 3 Roadside, YNP, 22 December 2012 - 1 March 2013..

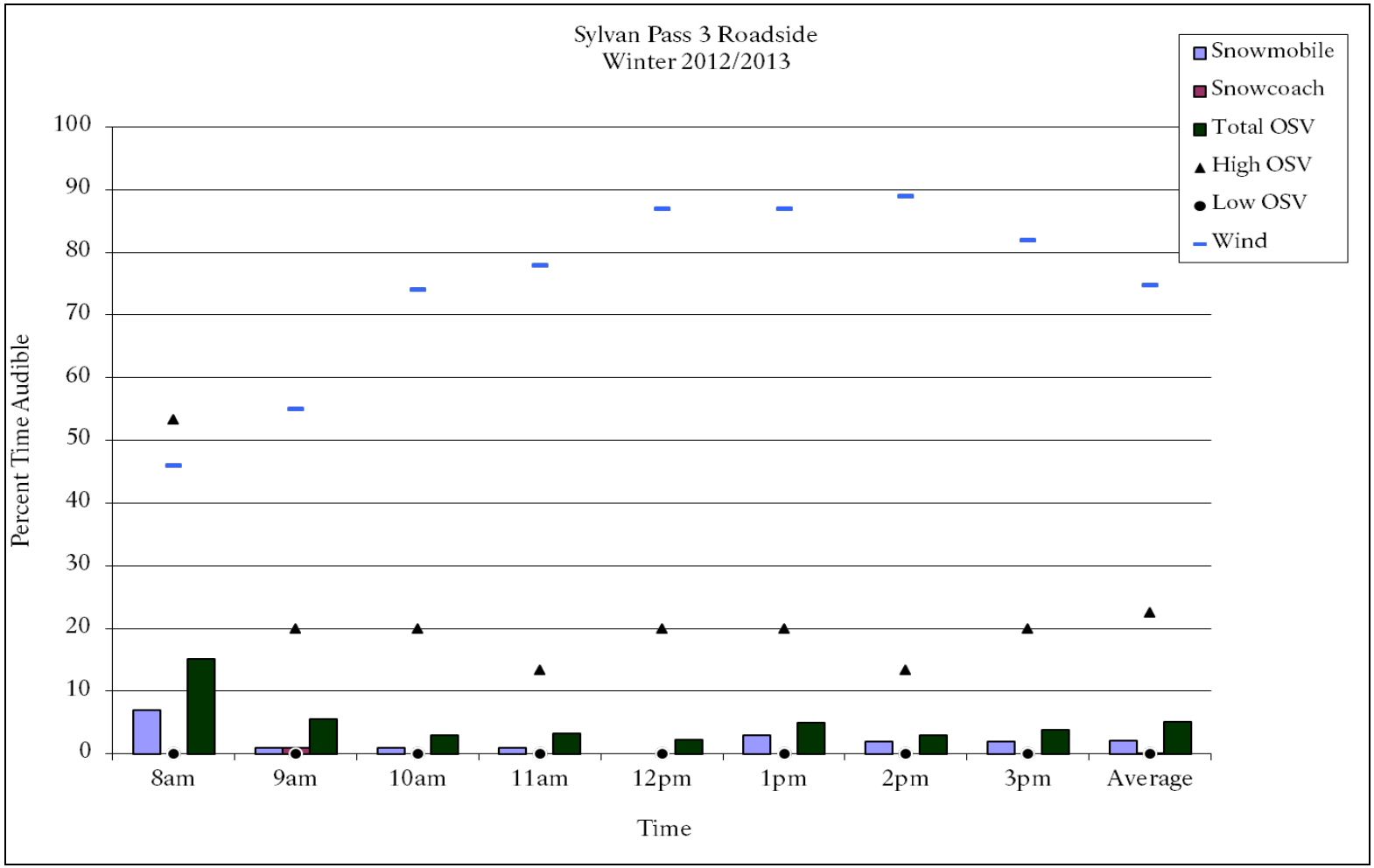

Figure 9. The average percent time audible by hour of snowmobiles and the season's maximum and minimum OSV percent time audible values by hour at Sylvan Pass 3 Roadside, YNP, 22 December 2012 - 1 March 2013.

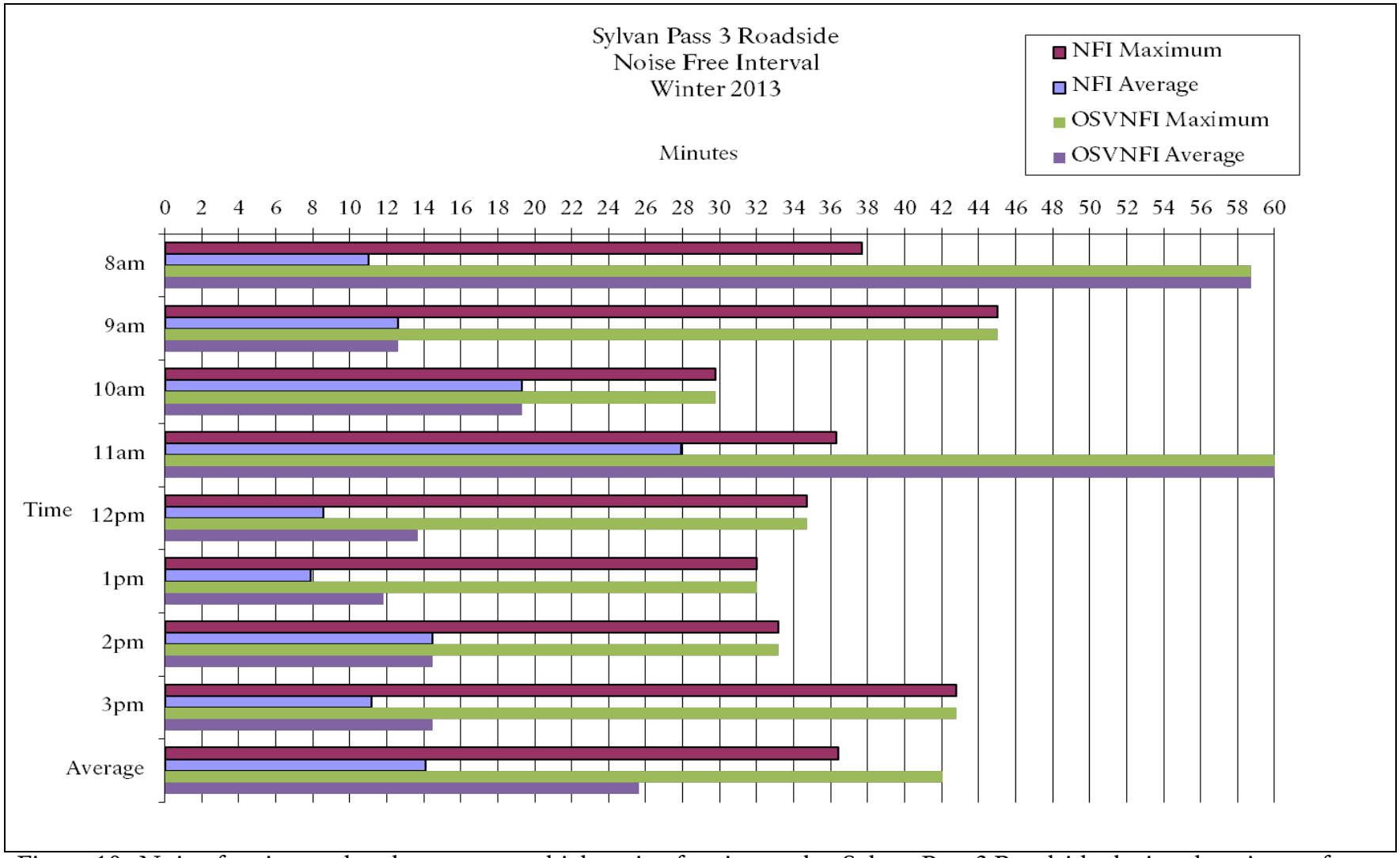

Figure 10. Noise-free interval and oversnow vehicle noise-free interval at Sylvan Pass 3 Roadside during the winter of 2012-2013, YNP. See Table 3 for dates used and text for more details.

Paycheck Pass Backcountry

Oversnow vehicles were audible an average of 8% (*SD* = 10%) of the time between 8 am and 4 pm during the 15 days analyzed in January and February (Fig. 11). Aircraft (a total of one helicopter, 5 propeller aircraft, and 39 jets) were audible for a daily (8 am and 4 pm) average of 2.5% during the winter use season. The effect of wind is apparent. Seven of the eight days with audibility below the average had wind present for over 60% of the day. Eleven of the 15 days analyzed had wind audible for more than 50% of the day.

Although this site was closer to the road corridor than Heart Lake Backcountry it had a slightly lower average OSV percent time audible. This is also likely attributable to the effects of wind speeds on detecting faint OSV sounds. Heart Lake Backcountry was at lower elevation and more protected from wind than was Paycheck Pass.

The hourly average OSV audibility had the bi-modal distribution common on travel corridors near the park entrances. The afternoon peak was much lower than the morning peak, likely due to the increased presence of wind in the afternoon that obscured faint OSV sounds. The peak in average OSV audibility was at 10 am, and the lowest at 1 pm (Fig. 12). In addition to average audibility, Figure 12 shows the range of OSV audibility for each hour of the day for the entire sampling period (labeled high and low OSV).

The average noise-free interval at Paycheck Pass Backcountry was 33 minutes and 41 seconds (Fig. 13). The two hours sampled at 10 am and noon had no non-natural sounds so the noise-free interval for both hours was 60 minutes. To indicate the contribution of aircraft to the NFI Figure 13 compares the noise-free interval including aircraft and the noise-free interval for only oversnow vehicles (OSVNFI). Additional samples would give a better representation of typical noise-free intervals because only one hour was analyzed for each of these eight hours (Table 3).

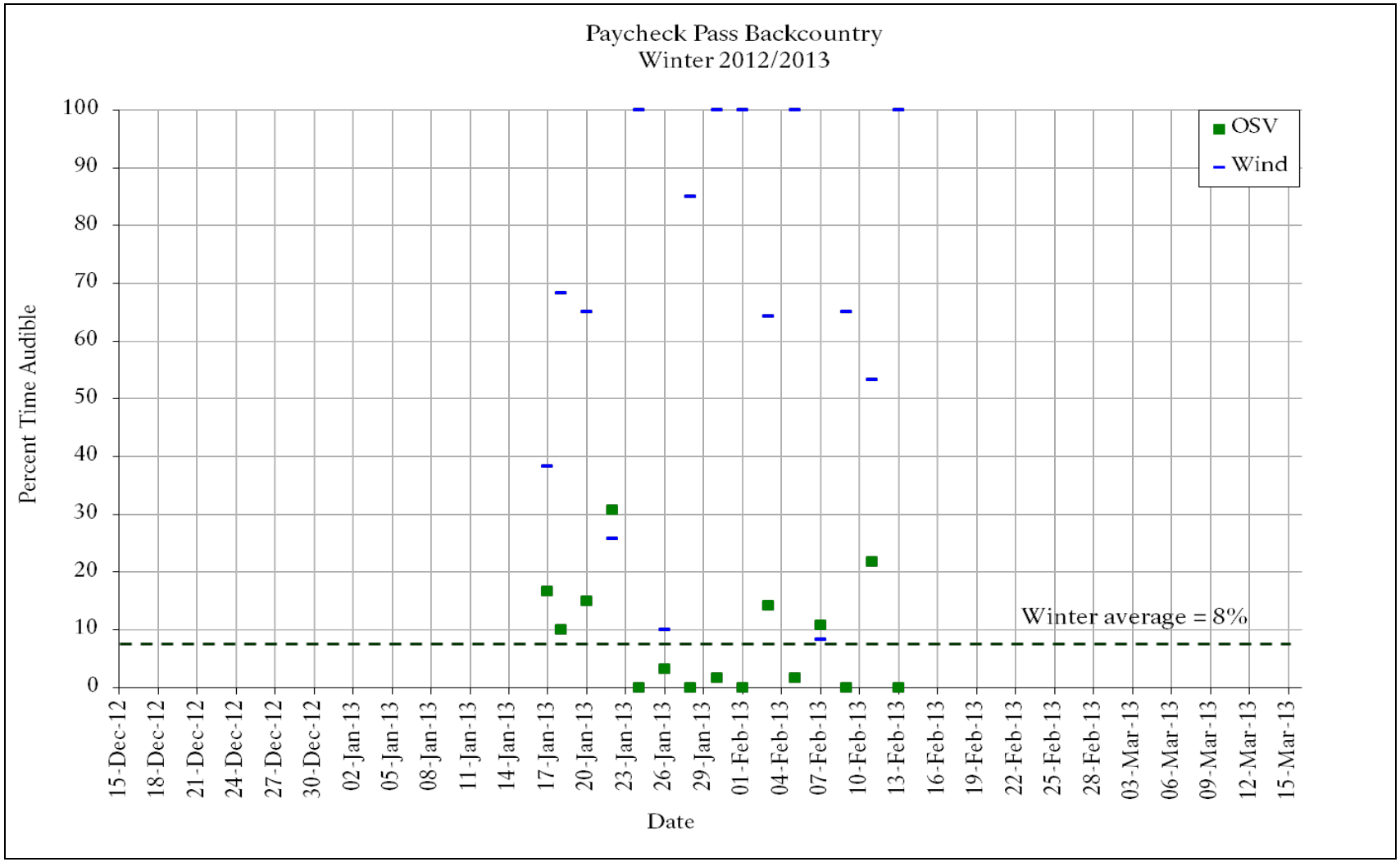

Figure 11. The average percent time audible (8 am - 4 pm) by date of oversnow vehicles, and wind at Paycheck Pass Backcountry, YNP, 17 January – 13 February 2013.

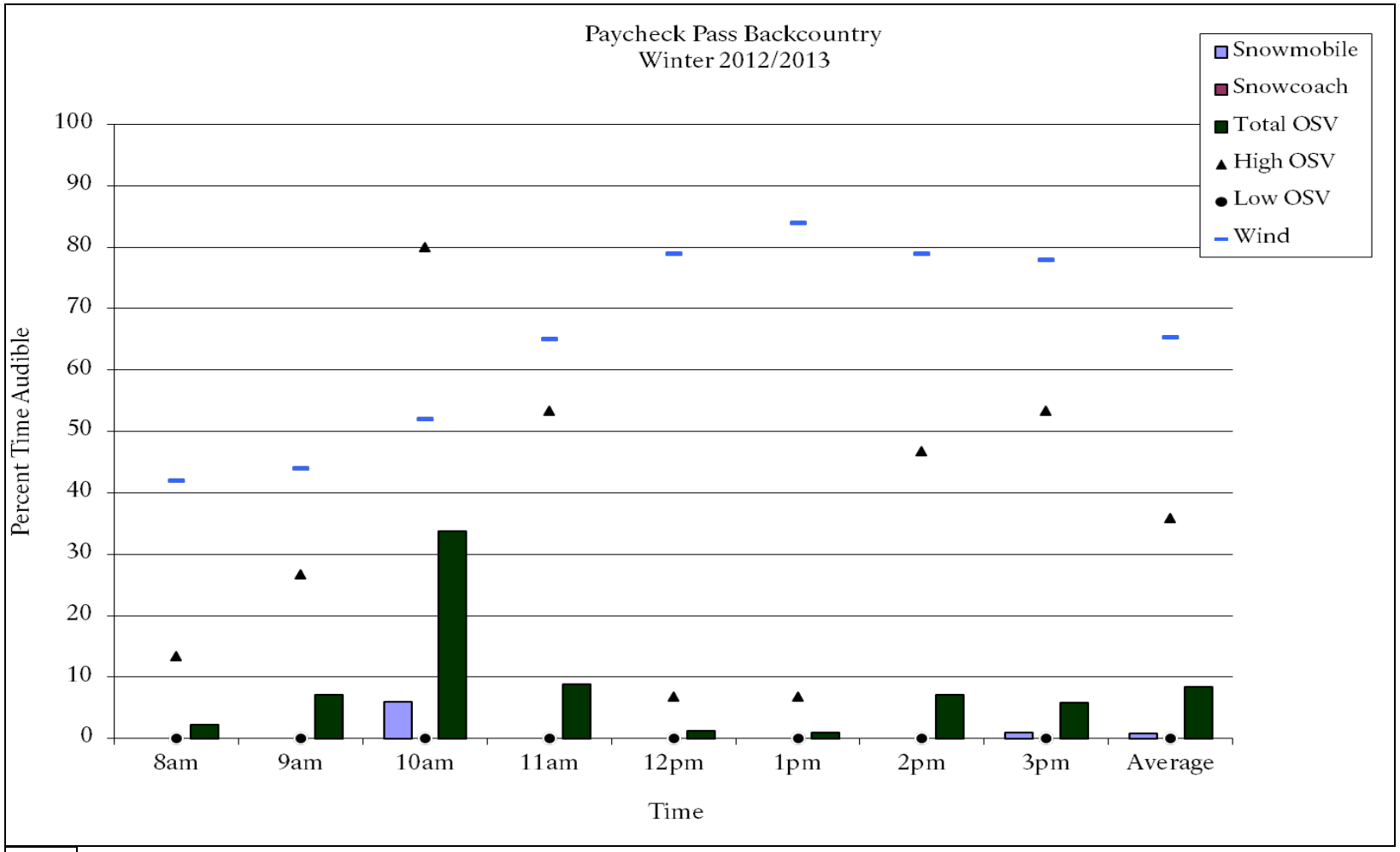

Figure 12. The average percent time audible by hour of snowmobiles, snowcoaches, and total OSVs including unidentified OSVs, and the season's maximum and minimum OSV percent time audible values by hour at Paycheck Pass Backcountry, YNP, 17 January – 13 February 2013.

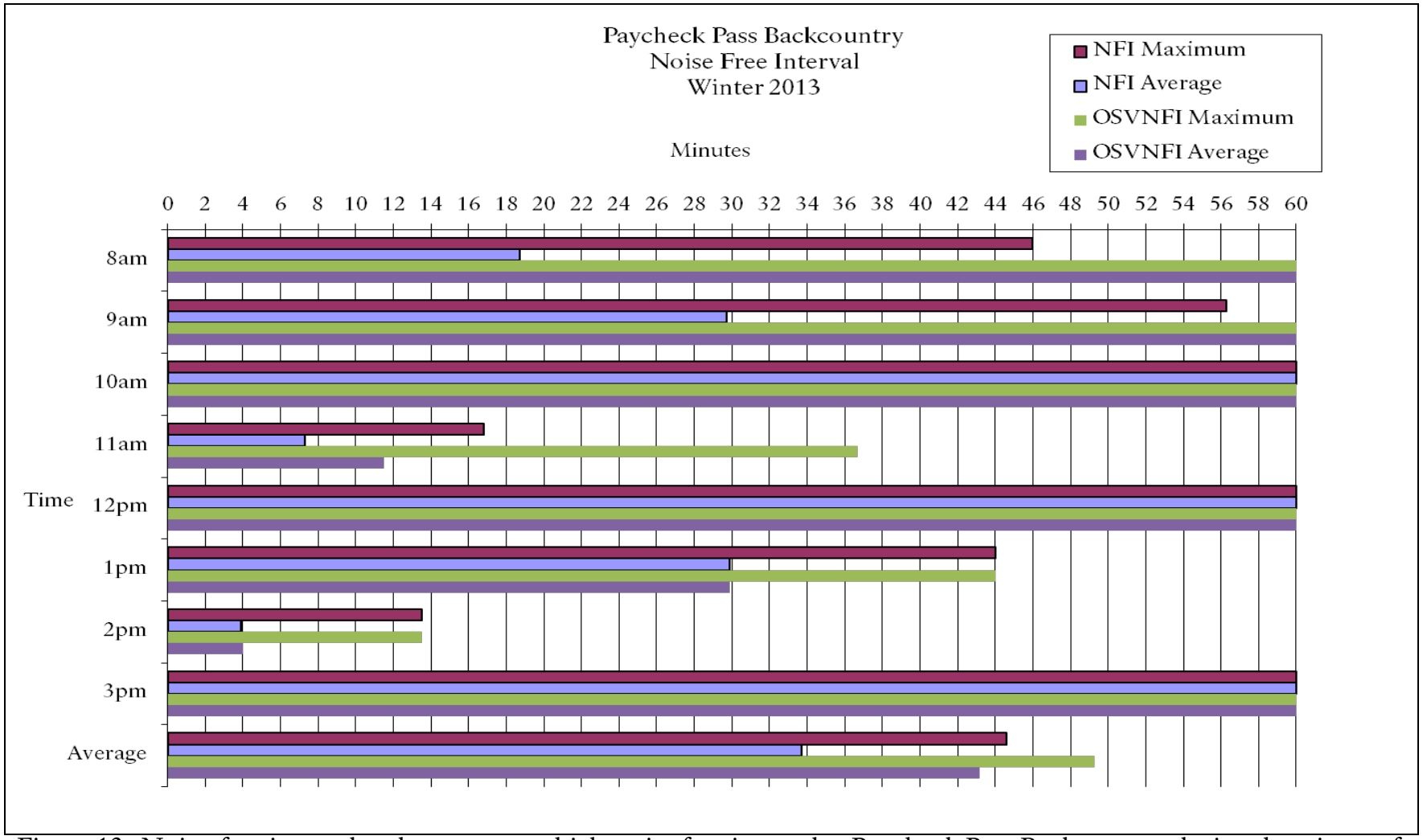

Figure 13. Noise-free interval and oversnow vehicle noise free interval at Paycheck Pass Backcountry during the winter of 2012-2013, YNP. See Table 3 for dates used and text for more details.

Heart Lake Backcountry

Oversnow vehicles were audible an average of 11% (*SD* = 14%) of the time between 8 am and 4 pm during the 16 days analyzed in January and February (Fig. 14). Aircraft (a total of one helicopter, 11 propeller aircraft and 65 jets) were audible for a daily (8 am and 4 pm) average of 4% during the winter use season. Wind was audible for over 50% of the day on eleven of the 16 days analyzed.

Similarly to the nearby Paycheck Pass Backcountry site the hourly average OSV audibility had the bi-modal distribution common on travel corridors near the park entrances. OSV audibility peaked during the 10 am and 3 pm hours (Fig. 15).

The average noise-free interval at Heart Lake Backcountry was 16 minutes and 48 seconds (Figure 16). Although five miles from the OSV travel corridor only the 2 pm hour had no non-natural sounds. To indicate the contribution of oversnow vehicles to the NFI, Figure 16 compares the noise-free interval including aircraft and the noise-free interval for only oversnow vehicles (OSVNFI). Additional samples would give a better representation of typical noise-free intervals because only one hour was analyzed for each of these eight hours (Table 3).

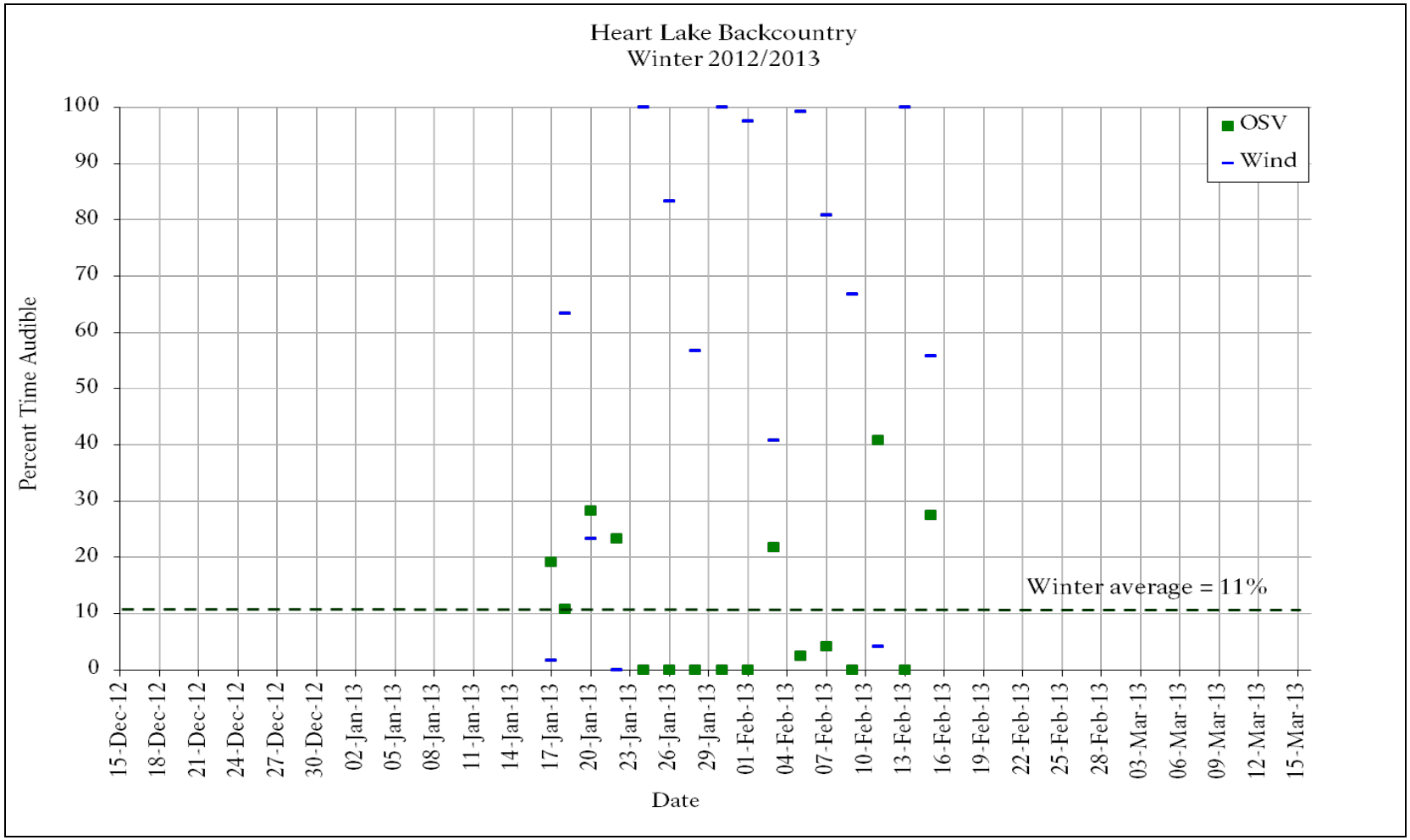

Figure 14. The average percent time audible (8 am - 4 pm) by date of oversnow vehicles, wheeled vehicles, and wind at Heart Lake Backcountry, YNP, 17 January – 15 February 2013.

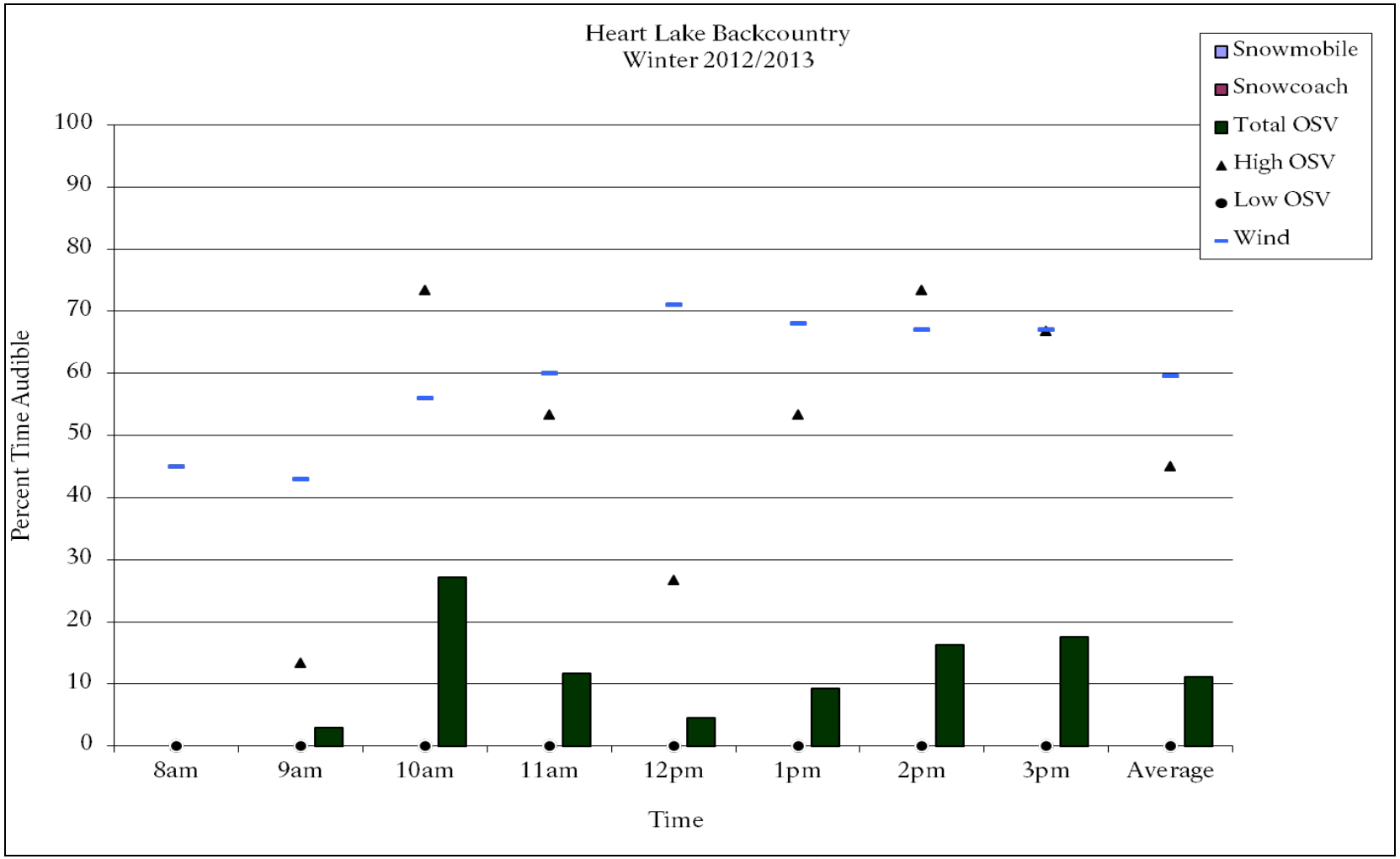

Figure 15. The average percent time audible (8 am - 4 pm) by hour of oversnow vehicles, wheeled vehicles, and wind (bars left to right) at Heart Lake Backcountry, YNP, 17 January – 15 February 2013.

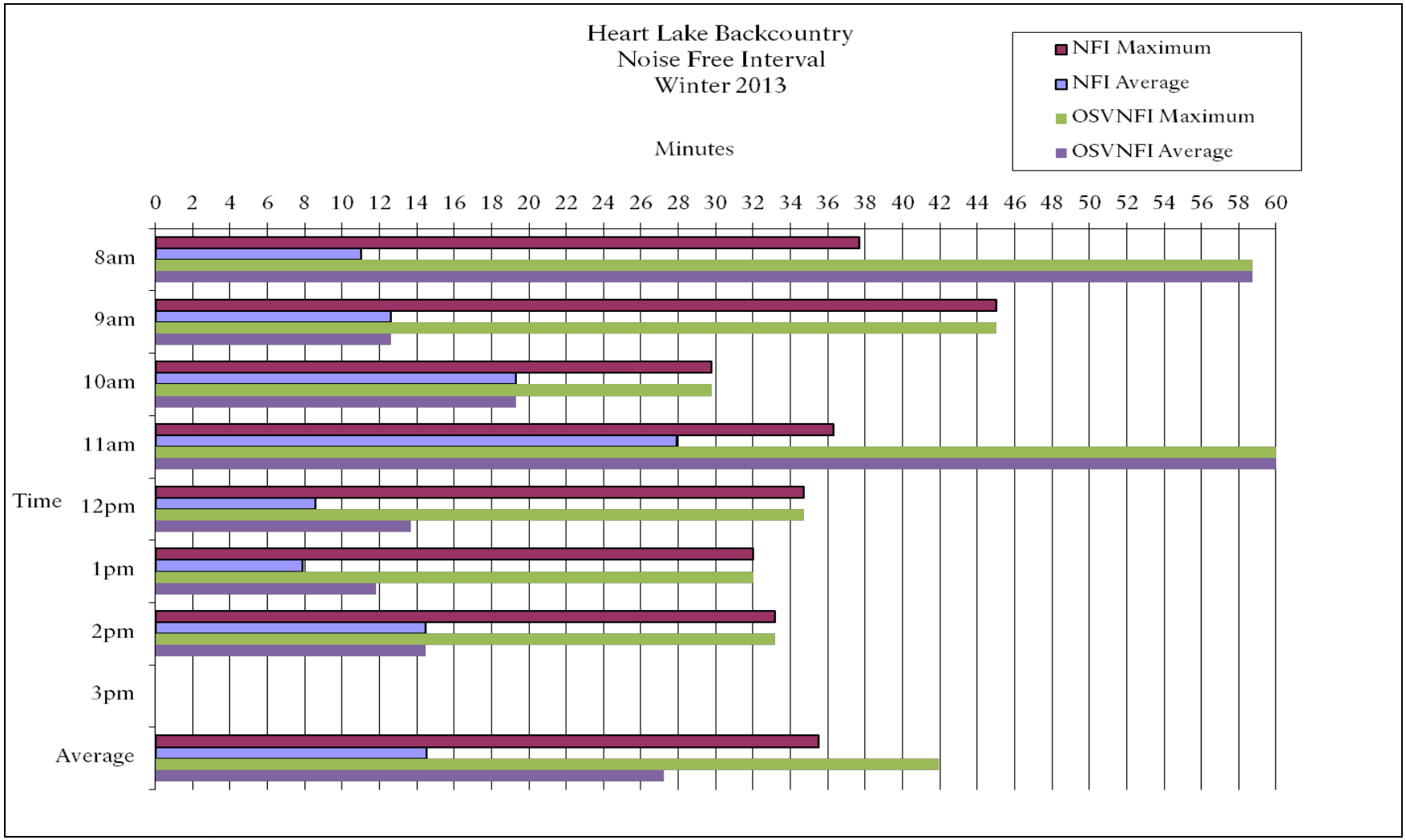

Figure 16. Noise-free interval and oversnow vehicle noise free interval measured at Heart Lake Backcountry during the winter of 2012-2013, YNP. See Table 3 for dates used and text for more details.

Audibility Trends:

Oversnow audibility is summarized for 24 locations in YNP during the past ten winters (Table 5). These locations include the four winter use plan management zones (developed, travel corridors, transition and backcountry). The monitoring sites in Table 5 are ordered left to right from most busy (closer to OSV activity or busier road corridor) to most distant to OSV activity. Interpret sites with small sample sizes, those with seven or fewer days of data, with caution. Acoustic conditions vary widely due to wind and other atmospheric conditions, and depend on the daily number of OSVs; therefore small sample sizes may not represent typical or average acoustic conditions.

The percent time audible values illustrate the expected pattern that sites farthest from OSV activity have the lowest OSV audibility. Based on all monitoring data, the average percent time audible was 52% for developed areas, 33% for travel corridors, 20% for transition zone, and 13% for backcountry areas. Sites that had more than seven days of analysis had relatively consistent audibility values when monitored in multiple years. Sites along the same segment of road (WY31 and MJ23) had similar OSV audibility. OSVs operating outside YNP were often audible at WY31, three miles from the park boundary. Backcountry sites ranged from just over one and a half miles from the busy Old Faithful to West Yellowstone road (MM8K) to eight miles from the less busy East Entrance Road (FLBC). The Shoshone Geyser Basin (SHGB) monitoring site was five miles from the busy Old Faithful to West Thumb road. The two Spring Creek sites (SPCR and SPC2) were 100 feet from this same road. The monitor at Lone Star Geyser (LSGY) was also along this route one mile from the road. Topography and frequent prolonged geyser activity were likely the reasons that OSVs were less audible at Lone Star Geyser than at Shoshone Geyser Basin more than four miles farther from the road.

Table 5. Percent time audible (8 am - 4 pm) of OSV sounds at monitoring sites by management zone during the winters (2003-2013), YNP.

	Management Zone: Sites[1]																							
	Developed[2]			Road Corridor[2]											Transition[3]					Backcountry[3]				
Year	OFWS	CVDA	WETH	MJ23	WY31	SPCR	SPC2	CRPA	GVLL	MUVO	NTLA	CLRS	PPRD	SYL3	MMTR	OFUB	MM4K	DLCR	LSGY	MM8K	PAYP	SHGB	HLBC	FLBC
2003-2004	61%			25%[4]											32%		13%		3%					
2004-2005	69%		47%	61%	55%											29%			4%	26%				
2005-2006	67%		62%	55%		34%										35%								
2006-2007	68%			59%			44%			26%														0%
2007-2008	68%			53%					37%									20%		26%		18%		
2008-2009	55%			47%							24%													
2009-2010	55%			54%																				
2010-2011	61%			51%				44%					22%											
2011-2012	66%	39%		45%								22%												
2012-2013	63%			51%										5%							8%		11%	
Site Average	**63%**	**39%**	**55%**	**53%**	**55%**	**34%**	**44%**	**44%**	**37%**	**26%**	**24%**	**22%**	**22%**	**5%**	**32%**	**32%**	**13%**	**20%**	**4%**	**26%**	**8%**	**18%**	**11%**	**0%**
Management Zone Average			**52%**											**33%**					**20%**					**13%**

	# of Oversnow Vehicles (OSVs) /day		
	Snowmobile	Snowcoach	OSVs incl. OF[5]
2003-2004	254	23	281
2004-2005	206	25	236
2005-2006	267	30	302
2006-2007	299	30	336
2007-2008	290	32	338
2008-2009	196	29	234
2009-2010	181	28	221
2010-2011	214	30	261
2012-2012	162	26	204
2011-2013	185	28	229
Average	**225**	**28**	**264**

1	OFWS-Old Faithful Weather Station; CVDA-Canyon Village Developed Area; WETH-West Thumb Geyser Basin; MJ23-Madison Junction 2.3; WY31-West Yellowstone 3.1; SPRC-Spring Creek; SPC2-Spring Creek 2; CRPA-Caldera Rim Picnic Area; GVLL-Grant Village Lewis Lake; MUVO-Mud Volcano; NTLA-North Twin Lake; CLRS-Cygnet Lake Roadside; PPRD-Pumice Point Roadside; SLY3-Sylvan Pass 3; MMTR-Mary Mountain Trail; OFUB- Old Faithful Upper Basin; MM4K-Mary Mountain 4K; DLCR-Delacy Creek Trail; LSGY-Lone Star Geyser Basin; MM8K-Mary Mountain 8K; SHGB-Shoshone Geyser Basin; PAYP-Paycheck Pass Backcountry; Heart Lake Backcountry; FLBC-Fern Lake
2	Sites ordered from left to right, busiest to less busy
3	Sites ordered from left to right, closest to motorized route to most distant
4	Red underlined indicates 7 or fewer days analyzed; Double red underlined indicates 1 or 2 days only
5	Number of OSVs originating at Old Faithful prior to 2006-2007 and 2012-2013 were estimated

Sound Levels:

The thousands of hours of sound level data collected include all sounds at each of the sampling sites. At times when no motorized or other human-caused sounds were present the data represent the natural conditions. These natural periods were predominant at night and for over 50%of the day at three of the five sites (but not the developed areas of Old Faithful, and only 49% at Madison Junction 2.3). Each site's acoustic metrics, including the L_{10}, L_{eq}, L_{50} (the median) and L_{90}, provide information about the typical sound levels and can be compared among years and across sites.

In conjunction with the audibility analyses, the sound levels of common sound sources can be determined. However, the sound level analysis of OSVs is not as easily understood as OSV audibility analysis. The sound levels for OSVs should be separated from other sounds. Unfortunately there is yet no automated process for separating different sound sources from the sound level data and the manual separation of OSVs sound levels during the millions of seconds of data collected this past winter in this study is practically impossible. Therefore the interpretation of sound levels becomes more difficult. In the developed areas and along travel corridors the loudest sounds during 8 am - 4 pm were almost always from oversnow vehicles, but as distance increased from these motorized areas natural sounds were sometimes louder than OSV sounds. In all areas occasional natural sounds (wind, bird vocalizations, etc.) and other motorized sounds (aircraft, snow groomer, etc.) may be as loud as snowmobile and snowcoach sounds during some periods and in some locations. Sound levels (decibels) of some common sound sources are shown in Table 6.

In addition to maximum (L_{max}) and minimum (L_{min}) sound levels, other common acoustical metrics such as the energy level equivalent or energy average (L_{eq}) and the L_{10}, L_{50}, and L_{90} sound level exceedance metrics are useful to provide a better understanding of the soundscape.

L_{eq} is the level (in decibels) 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, though, is inadequate to fully characterize the intrusiveness of the source. The effects of intrusions in park environments depend not only upon the amplitude of the intrusion, but also upon the natural ambient sound level.

L_{10}, L_{50}, and L_{90} are the sound levels (L), in decibels, exceeded *x* percent of the time. The L_{10} value represents the sound level exceeded 10 percent of the time. Ninety percent of the sound levels would be below this level. L_{50} is the same as the median; the middle value where half the sound levels are above and half below. The L_{50} is also not affected by a few loud sounds as is the L_{eq} and therefore provides another useful measure of the sound environment. The L_{90} value

represents the sound level exceeded 90 percent of the time during the measurement period. L_{90} is a useful estimate of the natural ambient sound level because in park situations, away from developed areas and busy travel corridors, the lowest 10 percent of sound levels 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 90 percent of the time.

By examining these sound level metrics in combination, one can gain an insight into the typical sound level characteristics of a site. For example, very quiet sites will have tightly grouped L_{10}, L_{50}, and L_{90} values. Sites with only occasional loud sounds will have tightly grouped L_{10}, L_{50}, and L_{90} values, but the L_{eq} and L_{max} values will be much higher.

Returning to the challenges of evaluating these sound level results, the L_{90} is the NPS (and other organizations) standard for use as an analog to the natural ambient sound level in locations other than those most heavily impacted from non-natural sounds and when other more site specific calculations are not possible. However, using L_{90} or other L_x metrics as the natural ambient sound level is inappropriate in locations with constant non-natural sounds such as at the Old Faithful Weather Station monitoring site. In very quiet areas the L_{90} may overestimate the true natural ambient sound level because of limitations of the instrument noise floor threshold. The noise floor, the lowest level the acoustic equipment could measure, was approximately 14-16 dBA (see Table 6 for reference levels). The quietest sound levels in YNP are below this noise floor (Burson 2006) so the lowest documented measurements in this report likely overestimate the actual minimum sound levels. While there is no easy solution to these limitations, the disadvantages of any one metric can be reduced by using multiple sound level metrics.

Sound levels depend on the distance from the sound source, the presence of natural sounds, as well as non-sound source variables such as atmospheric conditions, wind speed and direction, topography, snow cover, and vegetative cover. These various factors influenced day to day sound levels measured at each sound monitoring location. No two days were identical, but patterns were regularly observed and differences among monitoring locations are apparent.

Table 6. Approximate decibel levels of commonly known sound sources. Note that decibels are logarithmic and a difference of 10 decibels is sometimes described as a doubling or halving of loudness. The range of audible sound levels for humans is generally considered to be from 0 – 130 dBA. Sound sources in the table below that have no associated distance listed are at typical operational distances.

dBA	Perception	Outdoor Sounds	Indoor Sounds
130	Painful		
120	Intolerable	Jet aircraft at 50 ft	Oxygen torch
110	Uncomfortable	Turbo-prop at 200 ft	Rock Band
100		Jet flyover at 1000 ft	Human scream
90	Very noisy	Lawn mower/Nearby Thunder	Hair dryer
80		Snowcoach at 50 ft	Food blender
70	Noisy	2-stroke snowmobile 30 mph at 50 ft	Vacuum cleaner
60		4-stroke snowmobile 30 mph at 50 ft	Conversation
50	Moderate	Croaking Raven flyover at 100 ft	Office
40		Snake River at 100 ft	Living room
30	Quiet	Summer backcountry	Quiet bedroom
20	Very quiet	Winter backcountry	Recording studio
10	Barely audible	Below standard noise floor	
0	Limit of audibility	Calm winter wilderness	

2012-2013 Sound Metrics by Monitoring Site

A number of sound level metrics at the five sound monitoring sites during the winter season 2012-2013 are compared in Table 7. These sites are individually discussed on the following pages.

Table 7. Sound level metrics (dBA) for five sites and three soundscape management areas in YNP, 8 am - 4 pm, winter 2012-2013. L_{90}, L_{50}, L_{eq} are median values from hourly calculations.

Site	L_{min}	L_{90}	L_{50}	L_{eq}	L_{max}	Hours
Developed Area						
Old Faithful Weather Station	18.0	27.4	33.6	40.6	88.8	697
Travel Corridor						
Madison Junction 2.3	15.2	26.3	30.9	42.6	79.6	721
Sylvan Pass 3 Roadside	13.7	17.3	20.7	29.7	72.1	642
Backcountry						
Heart Lake Backcountry	14.1	18.4	22.4	28.7	79.2	255
Paycheck Pass[1]	*14*[1]	*22*[1]	*27*[1]	*31*[1]	*68*[1]	*241*

[1] Sound levels at Paycheck Pass Backcountry were not collected using a Type 1 sound level meter. Digital recordings were post-processed to derive approximate sound levels. See methods for details.

Old Faithful Weather Station

The median hourly sound levels from the soundscape monitoring site at Old Faithful Weather Station are shown in Figure 19 for the winter 2012-2013. The Old Faithful monitor was 230 feet (70 m) from the entrance/exit road used by oversnow vehicles. In a free-field, sound levels decrease by approximately 6 dBA for every doubling of the distance from a point source to the receiver. Therefore to compensate for the additional distance from the sound monitor using the reasonable assumption that, at least during the day, the maximum sound levels originate from OSVs traveling 230 feet (70 m) from the sound monitor, adding an additional 6 dBA to the maximum sound levels shown in the following figures would approximate the levels at 100 feet (30 m). This assumption is reasonable only for L_{max} because it is likely that lower sound levels commonly originate from areas other than the exit road such as the parking lot, the main road, and other sources near the sound monitor, and thus the source, distance, and therefore the correction factors, are unknown.

Because the loudest sounds have the most influence on L_{eq} values, OSV sounds largely determined the L_{eq} value during the day at Old Faithful. OSVs were often used outside the period covered by the WUP measurement periods, even in the middle of the night (Fig. 4), but other sources of sounds (people shouting, snow grooming, dogs barking, etc.) may have caused the maximum sound levels during the night.

The lowest sound levels (about 20 dBA, Table 7)) and the L_{90} were largely limited by the nearly constant utility sounds (exhaust and heating fans) from the Snow Lodge and Old Faithful Ranger Station (Fig. 19).

In addition to displaying sound levels by hour, winter-long acoustic metric summaries are shown by date in Figure 20. The maximum sound level (Lmax) on 18 January 2013 was caused by a helicopter landing nearby (Fig. 20).

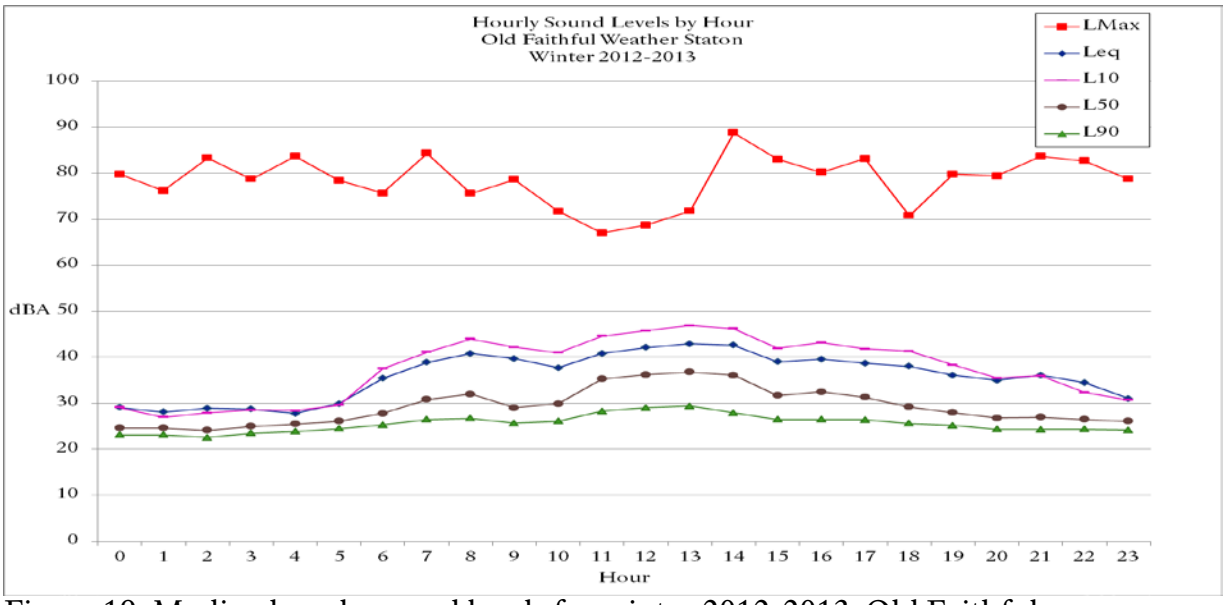

Figure 19. Median hourly sound levels for winter 2012-2013, Old Faithful Weather Station, YNP. These sound levels include all natural and non-natural sounds. L_{max} is the highest sound level measured during each hour of the winter use season. (n=2,101 hours).

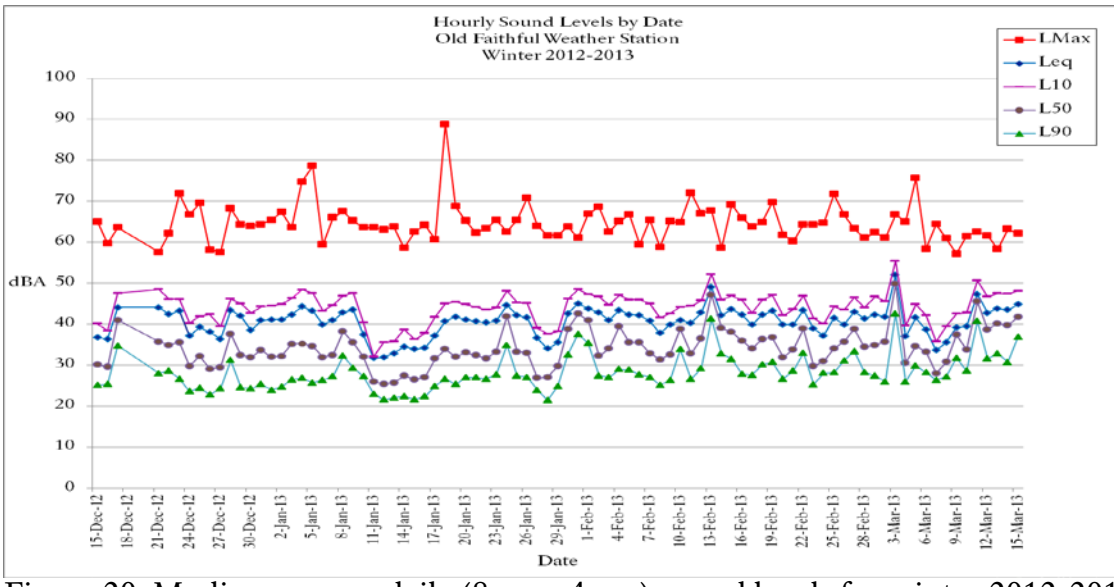

Figure 20. Median average daily (8 am – 4 pm) sound levels for winter 2012-2013, Old Faithful Weather Station, YNP. These sound levels include all natural and non-natural sounds. L_{max} is the highest sound level measured during each hour of the measurement period. (n = 88 days).

Madison Junction 2.3

The median hourly L_{eq} (the average sound energy) roughly follows the predictable bimodal pattern with peaks mid-morning and late afternoon consistent with OSV traffic patterns (Fig. 21). The maximum sound levels (L_{max}) were generally caused by snow groomers at night and snowcoaches during the day. The lowest median hourly L_{90} values are constrained by riffles of the nearby Madison River (Fig. 21). Wind generally increases during the afternoons and is reflected in the median hourly L_{50} and L_{90} values (Fig. 21).

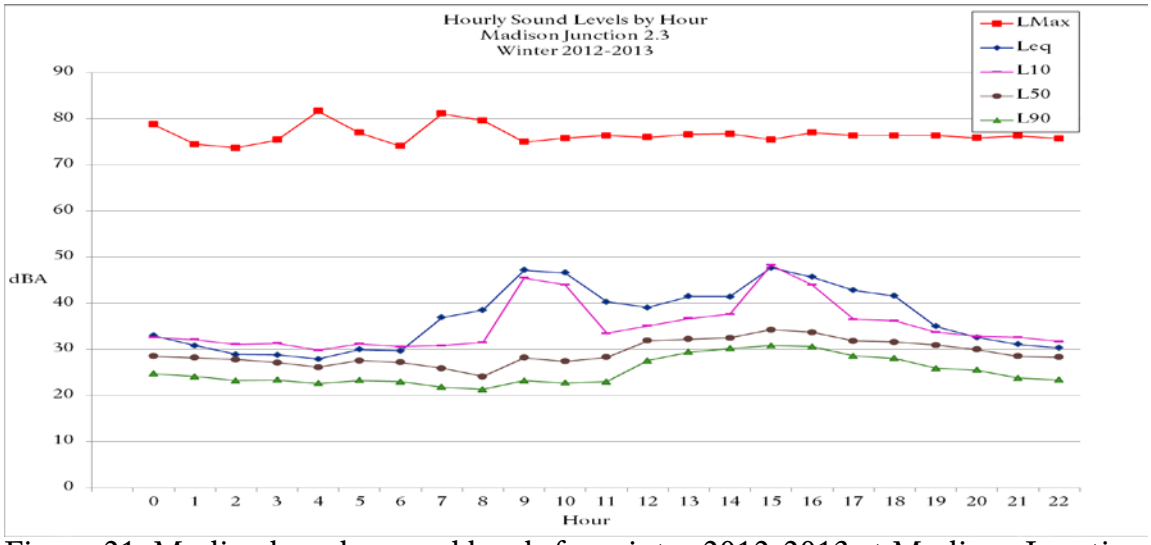

Figure 21. Median hourly sound levels for winter 2012-2013 at Madison Junction 2.3, YNP. See Fig. 19 caption for more details. (n=2,177 hours)

In addition to displaying sound levels by hour, winter-long acoustic metric summaries are shown by date in Figure 22. Especially windy days can be seen in the elevated L90 levels.

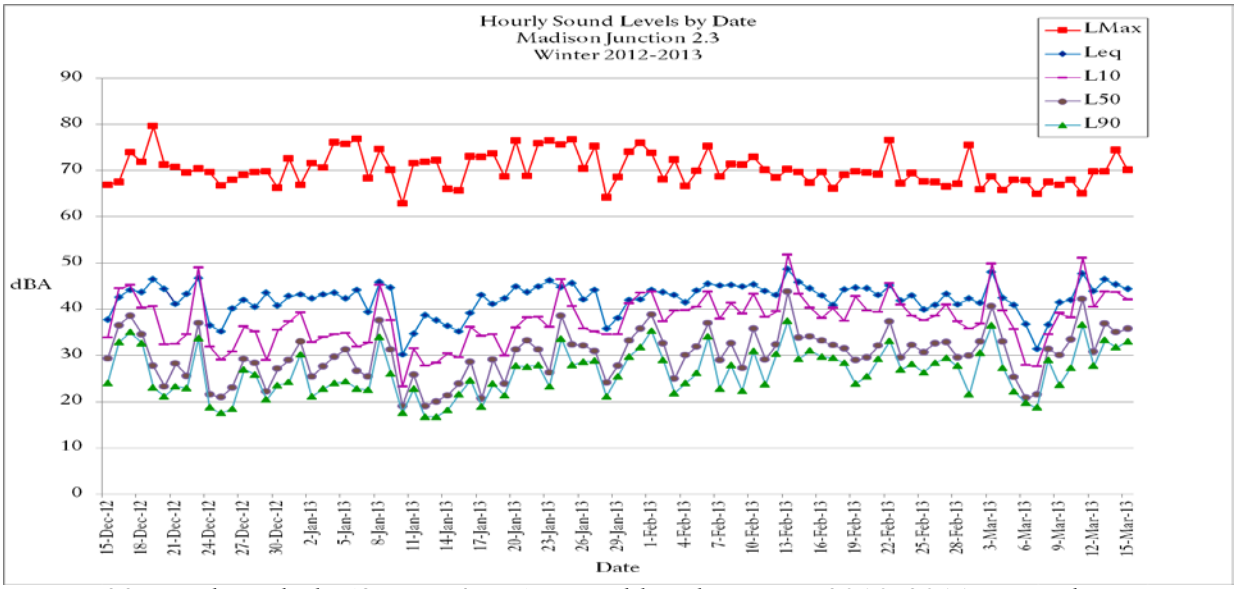

Figure 22. Median daily (8 am – 4 pm) sound levels winter 2010-2011 at Madison Junction 2.3, YNP. See Fig. 19 caption for more details. (n= 91 days)

Sylvan Pass 3 Roadside

This sound monitoring site was 100 feet (30 m) from the groomed road between Fishing Bridge and the East Entrance. This site had the lowest sound levels of all 2012-2013 sites (Table 7). The loudest sounds at this site were OSVs traveling on the road. The peak sound level during the 8 am hour (Fig. 23) was likely the regular administrative snowmobile trip over the pass. Aircraft sounds were sometimes present and at levels above the natural ambient. The very low sound levels were a result of no wind and no nearby streams, rivers, or human development.

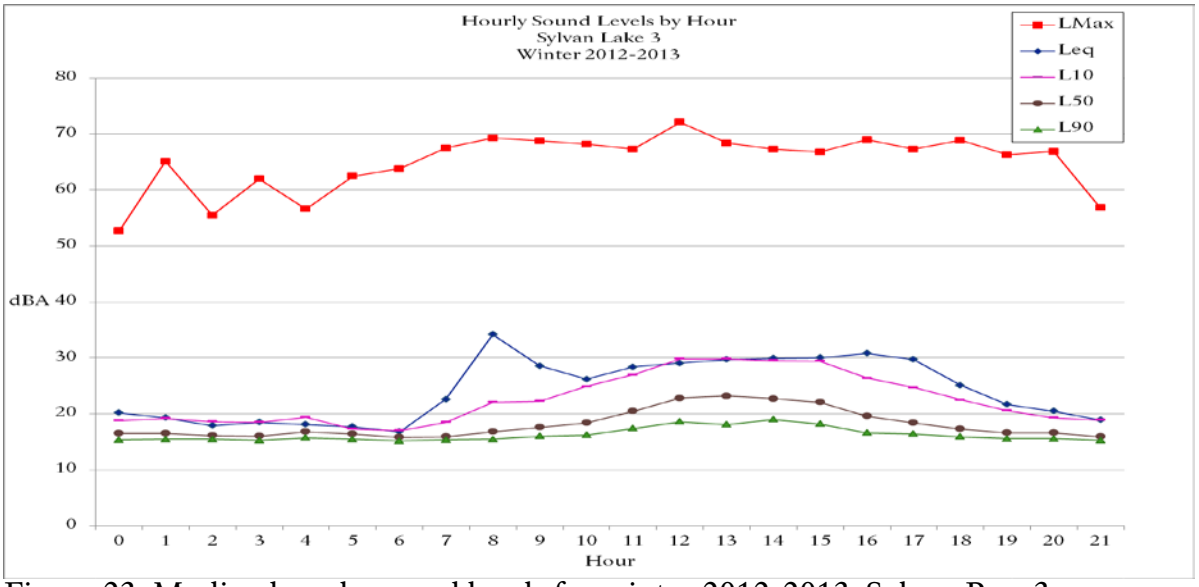

Figure 23. Median hourly sound levels for winter 2012-2013, Sylvan Pass 3 Roadside, YNP. See Fig. 19 caption for more details. (n=1,942 hours)

In addition to displaying sound levels by hour, winter-long acoustic metric summaries are shown by date in Figure 24. The days with high wind speeds, and thus elevated sound levels are shown by increased L90 values (Fig. 24). The two days with the lowest L_{max} were days with no OSV use along that road segment.

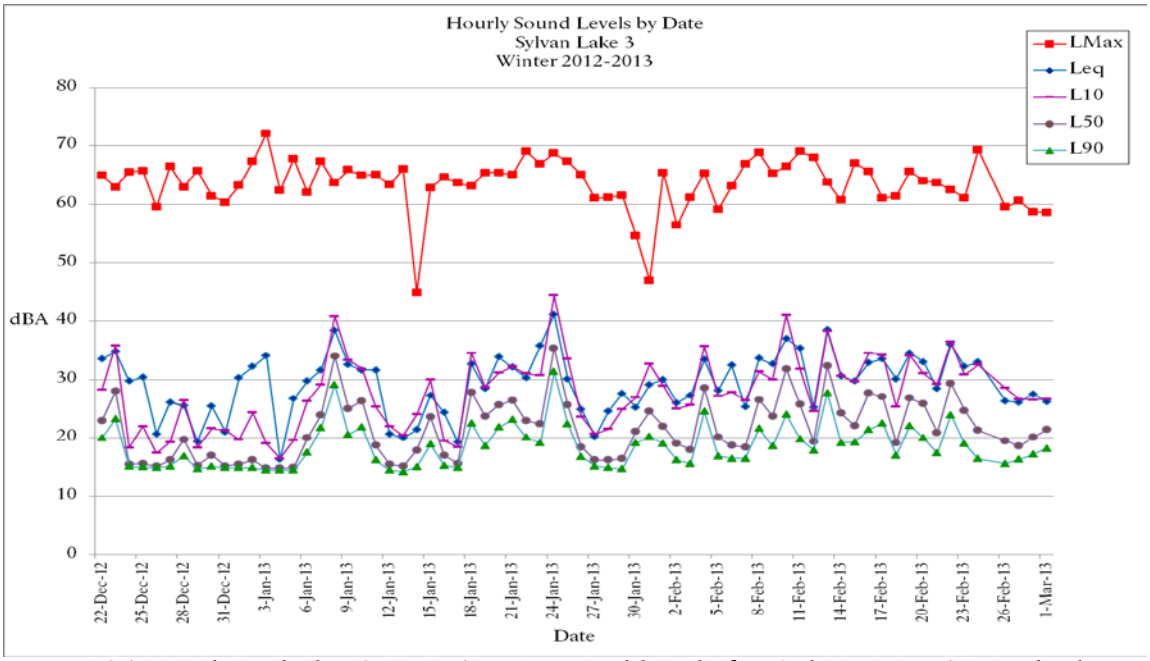

Figure 24. Median daily (8 am – 4 pm) sound levels for Sylvan Pass 3 Roadside, winter 2012-2013, YNP. See Fig. 19 caption for more details. (n=69 days)

Paycheck Pass Backcountry

This site was located three miles (4.8 km) east of the South Entrance Road. This site was very quiet during the night and early morning (Fig. 25). The sounds from wind increased the sound levels in the afternoon.

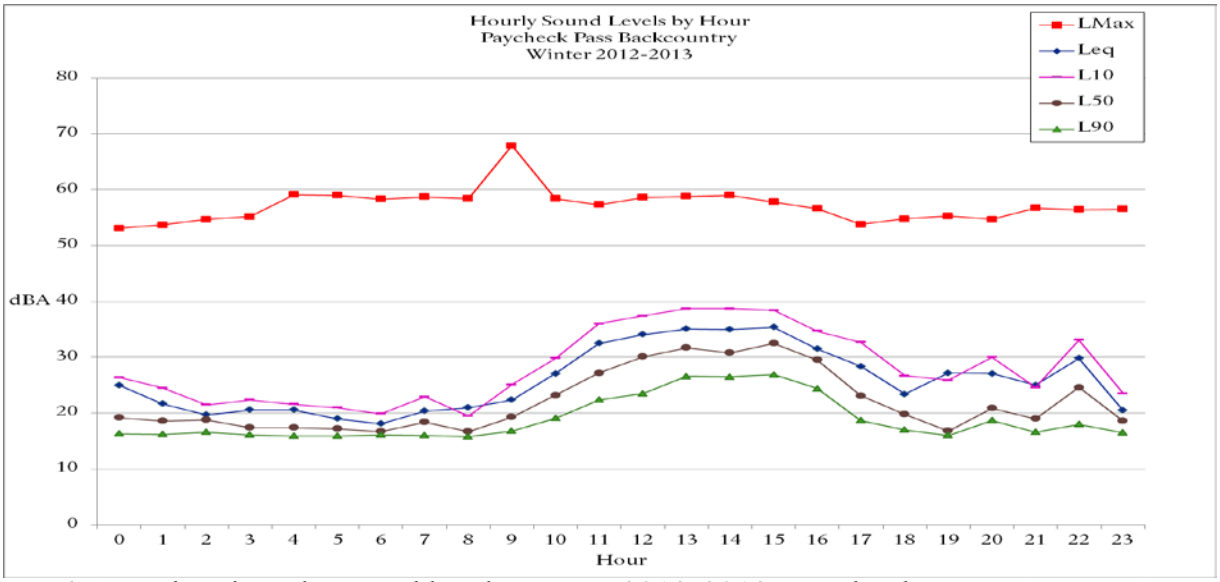

Fig. 25. Median hourly sound levels, winter 2012-2013, Paycheck Pass Backcountry, YNP. See Fig. 19 caption for more details. (n=737 hours).

In addition to displaying sound levels by hour, winter-long acoustic metric summaries are shown by date in Figure 26. The stark difference between windy and calm days is evident as shown by the varied daily sound level values (Fig. 26).

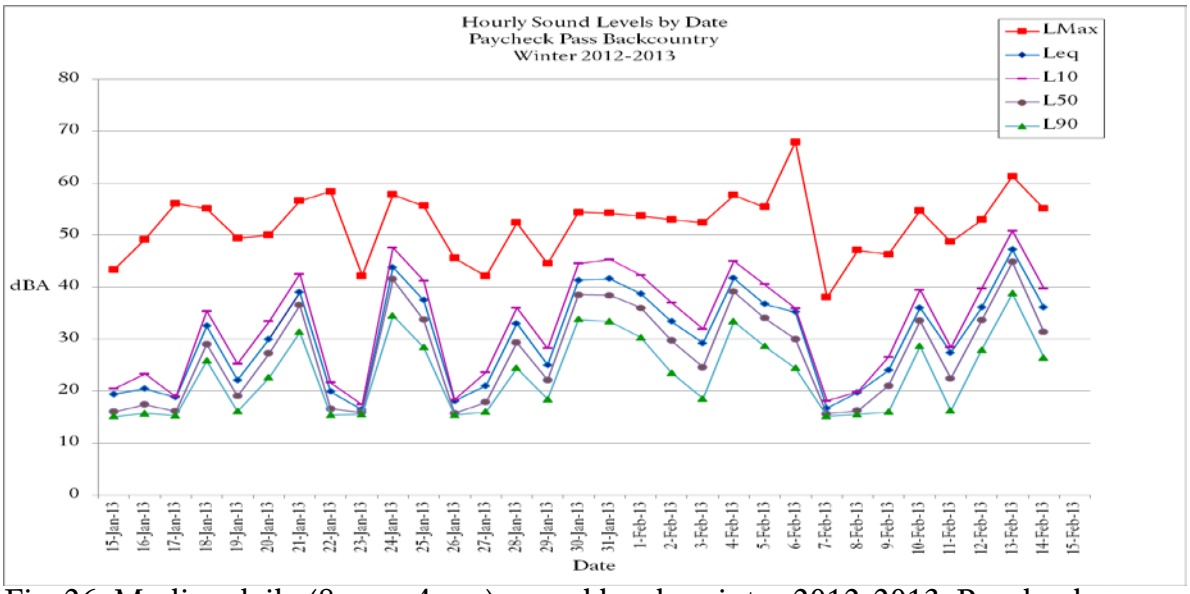

Fig. 26. Median daily (8 am – 4 pm) sound levels, winter 2012-2013, Paycheck Pass Backcountry, YNP. See Fig. 19 caption for more details. (n=31 days).

Heart Lake Backcountry

This site was located 5.4 miles (8.8 km) east of the South Entrance Road. This site was very quiet (Fig. 27.

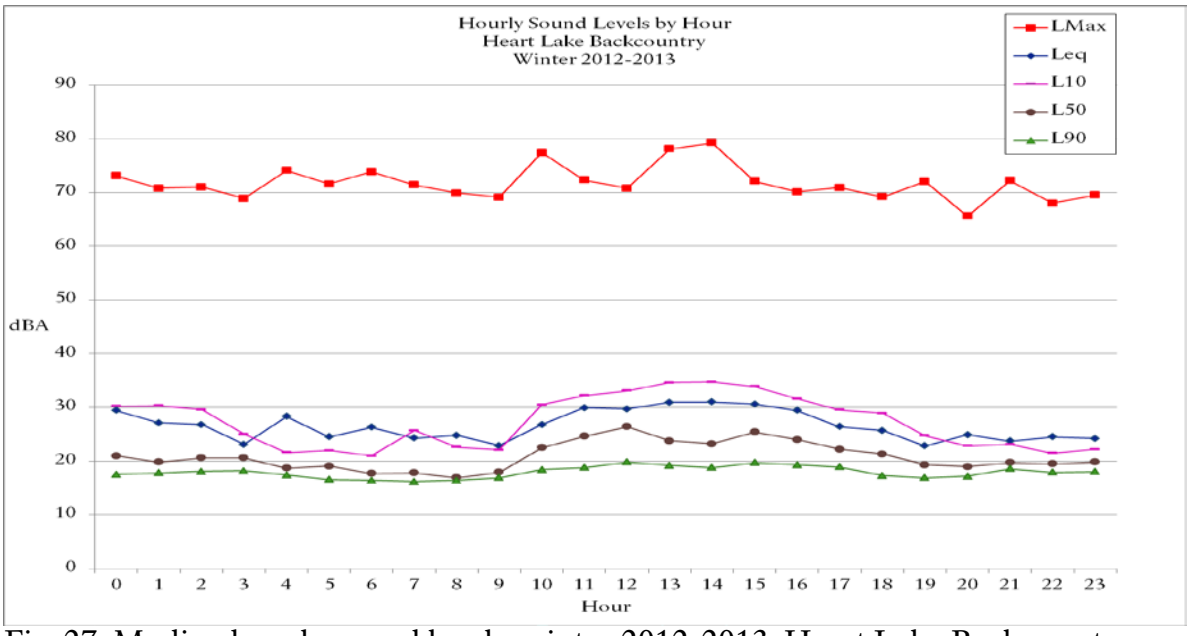

Fig. 27. Median hourly sound levels, winter 2012-2013, Heart Lake Backcountry, YNP. See Fig. 19 caption for more details. (n=752 hours).

In addition to displaying sound levels by hour, winter-long acoustic metric summaries are shown by date in Figure 28. The stark difference between windy and calm days are evident as shown the inconsistent sound level values (Fig. 28).

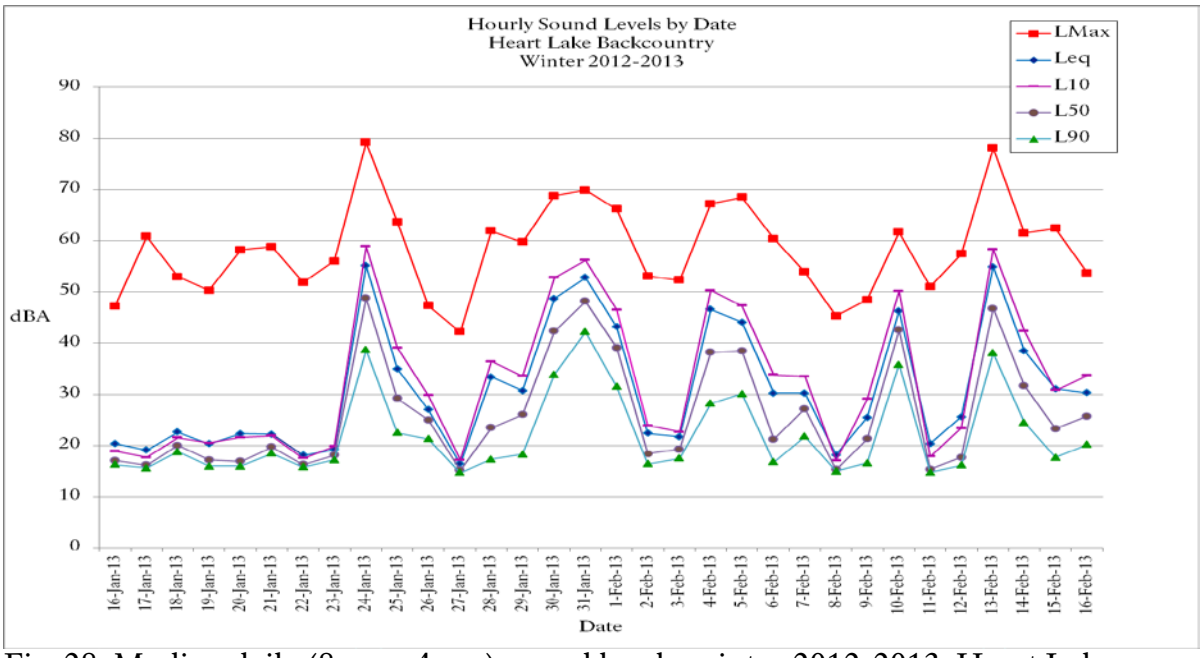

Fig. 28. Median daily (8 am – 4 pm) sound levels, winter 2012-2013, Heart Lake Backcountry, YNP. See Fig. 19 caption for more details. (n=32 days).

Acknowledgements:

Skip Ambrose (NPS Natural Sound Program-retired) developed an initial study plan that led to this project. John Klaptosky collected thirty-one additional hours of OSV logging data over the course of the winter- no small feat. Roy Renkin provided logistical support and encouragement that was helpful. The Old Faithful Maintenance staff also provided logistical help on this project. Robin Long, through the Sandhill Company, expertly coded the digital recordings for the tenth winter season. Her assistance continues to be invaluable. Mike Donaldson and the NPS Natural Sound Program provided computer software. This report heavily relies on previous reports. John Sacklin, Denice Swanke, Mike Yochim, Skip Ambrose, Linda Franklin, Ann Rodman, Dave Hallac, and Robin Long provided valuable editorial comments on previous versions.

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Appendix A: Spectrograms of sound levels

The NPS developed a technique for plotting the 33 one-third octave band frequency decibel levels for each hour of the day (ex. Fig. A-1). The major sources of sound at each monitoring location can be "seen" in these spectrographs. Viewing the pictures in color is preferable. 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 with high frequencies at the top and low frequencies at the bottom of each row. The right, or bottom margin contains the decibel range and associated colors. Brighter colors indicate higher sound levels; deep blue is the quietest. Not only can specific sound sources be identified from these spectrographs, but patterns and the variability in number, timing, and sources of sounds can be seen. These spectrograms were made for every day at every site.

Figures A-1 to A-7 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 or wheeled vehicle signatures are narrow orange-yellow marks that extend from high to low frequency. The louder sounds are brighter yellow as shown in hours 00 (snow groomer) at Madison Junction 2.3 (Fig. A-1). At 0415, a jet appears as a low frequency blob (Fig. A-1). A propeller plane is visible at 1147 (Fig. A-1) The sounds of riffles on the Madison River are shown as diffuse horizontal streaks especially during the early morning and late evening hours (Fig. A-1).

Building utility sounds and wind create the extensive and horizontal light yellow lines at Old Faithful Weather Station along with the sounds from OSVs (Fig. A-2).

Aircraft, wind, and a few OSVs are the main "visible" sounds at Sylvan Pass 3 Roadside on a calm day (Fig. A-3). There were nearly twice as many jets as there were OSVs on this day (Fig. A-3).

Distant oversnow vehicles (not readily seen on the spectrograms) could be heard at Paycheck Pass Backcountry during calm mornings, but this site was often quite windy (Fig. A-4).

23 January 2013 began very cold at Heart Lake Backcountry sound monitoring site. The pops from wood freezing can be seen as sharp vertical lines in the early morning hours (Fig. A-5). Jets starting at 0920 overflew the site and the wind picked up in the evening and continued until midnight (Fig. A-5).

Figures A-6 and A-7 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 2013 (512 snowmobiles during Saturday and Sunday). Although plotted using a different color scheme, 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 A-1 for another example of OSV activity at this site during the most recent winter season.

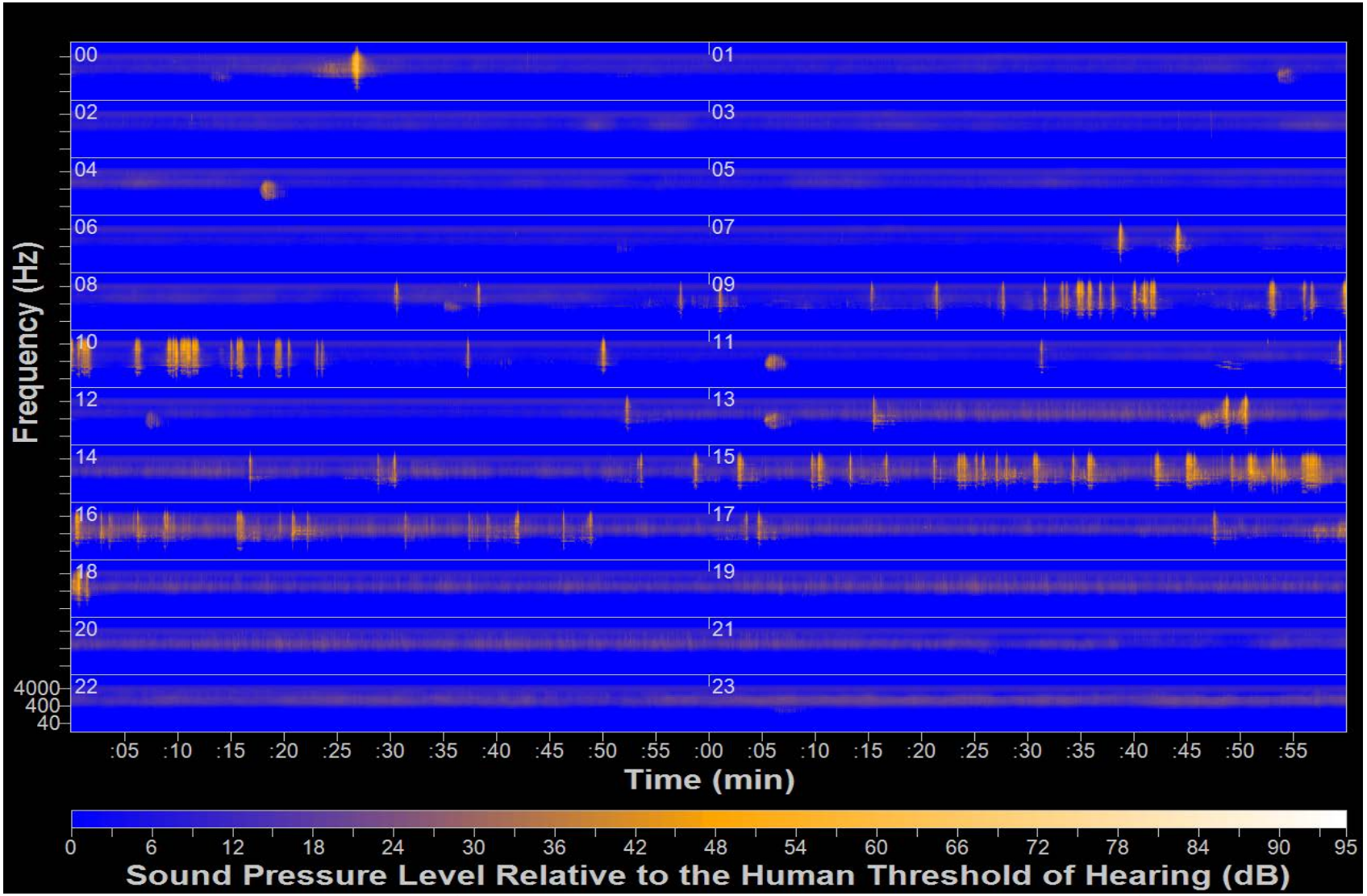

Figure A-1. Sound level spectrograph of 24 December 2012 at Madison Junction 2.3, YNP. See text for explanation.

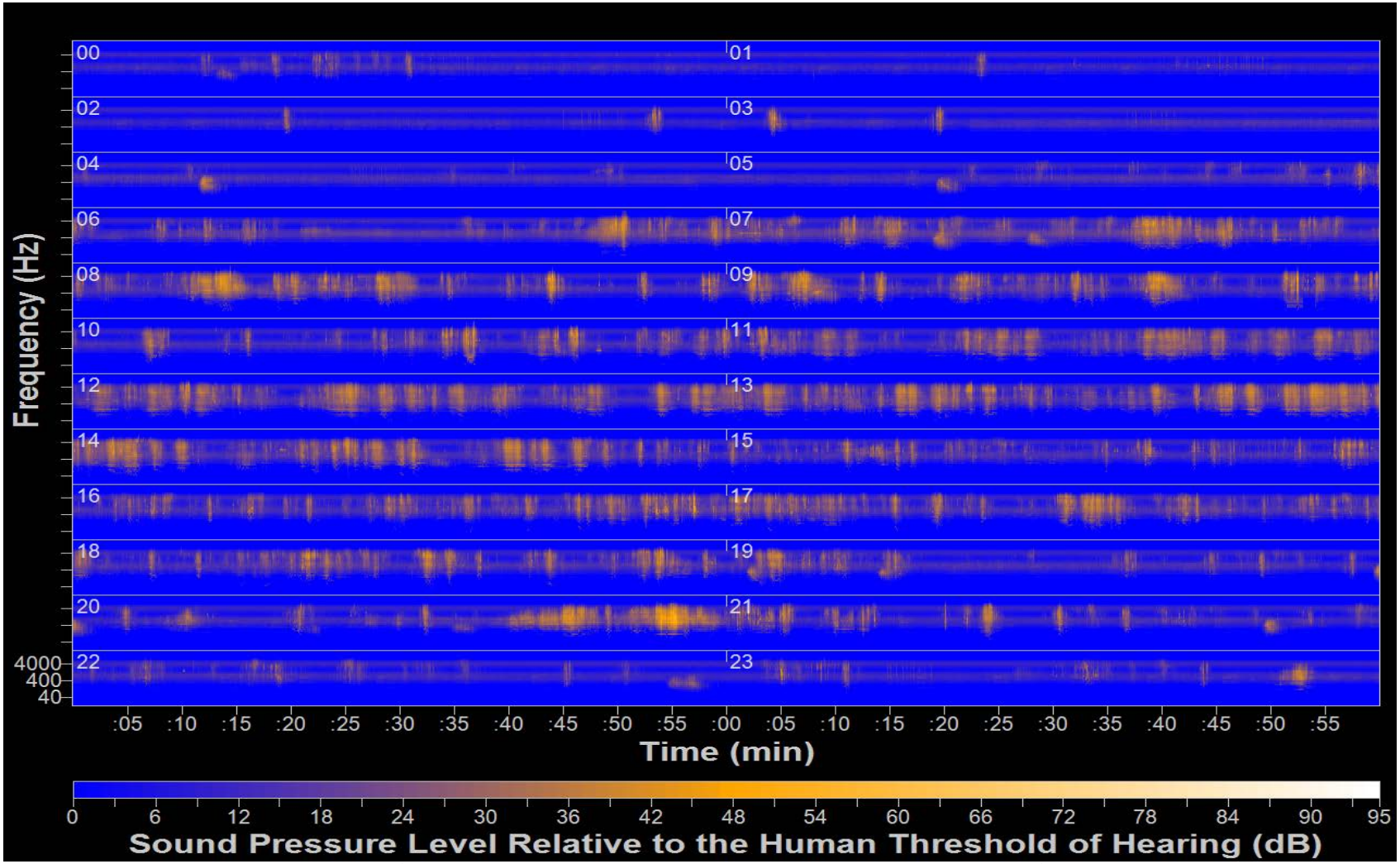

Fig A-2. Sound levels at Old Faithful Weather Station, 26 December 2012, YNP. See text for explanation.

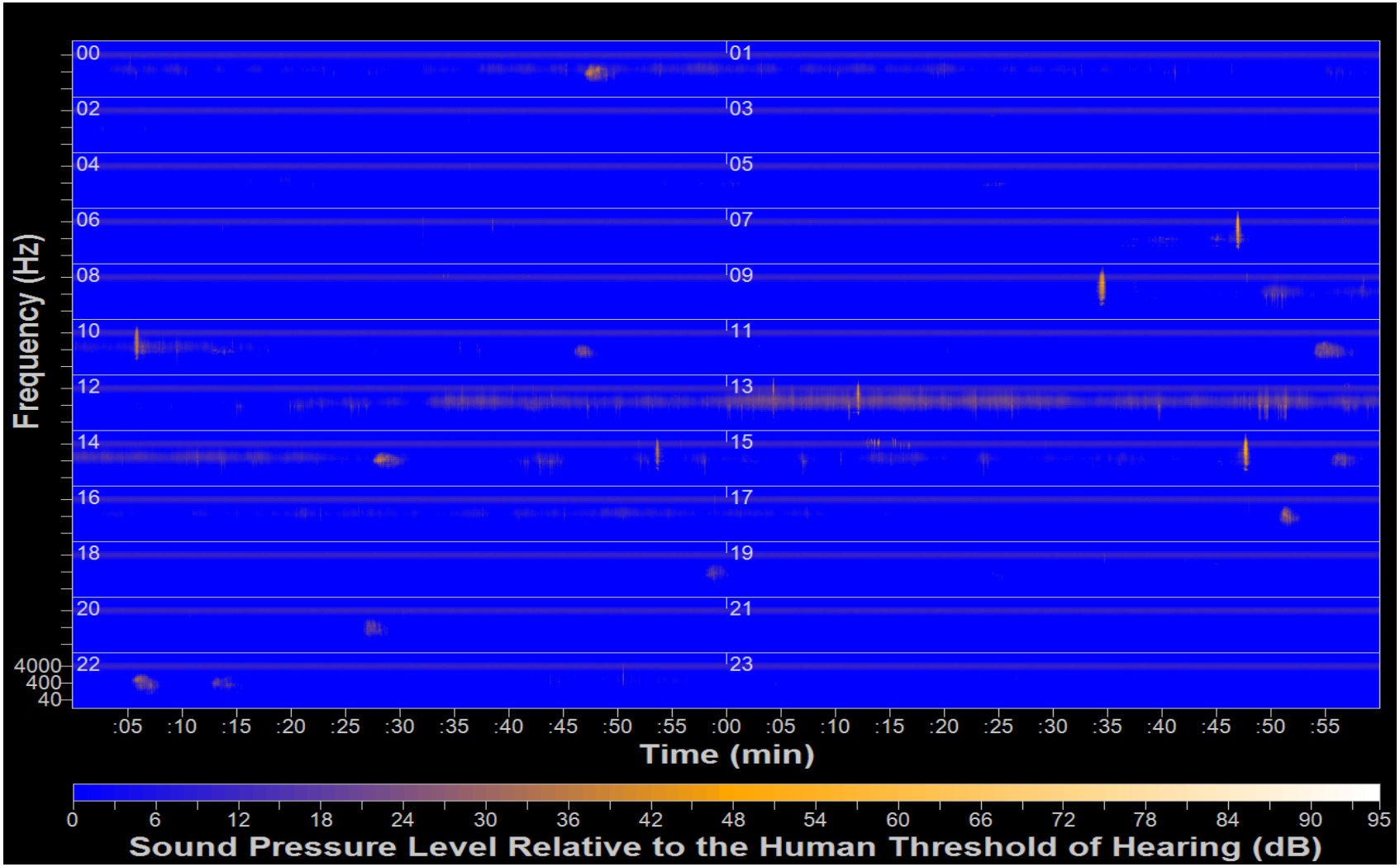

Fig A-3. Sound levels at Sylvan Pass 3 Roadside, 1 January 2013, YNP. See text for explanation.

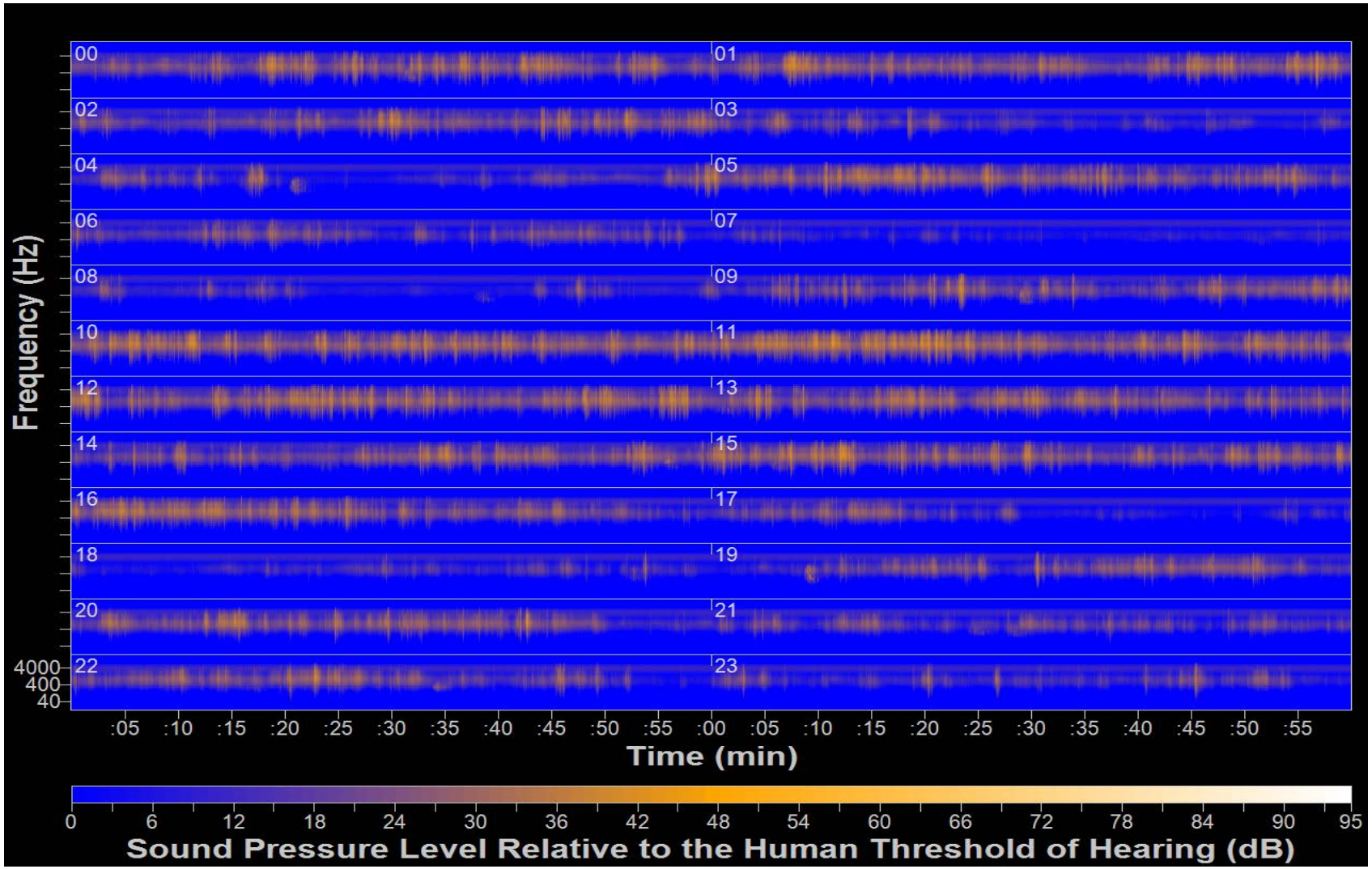

Fig A-4 Sound levels at Paycheck Pass, 25 January 2013, YNP, on a calm day. See text for explanation.

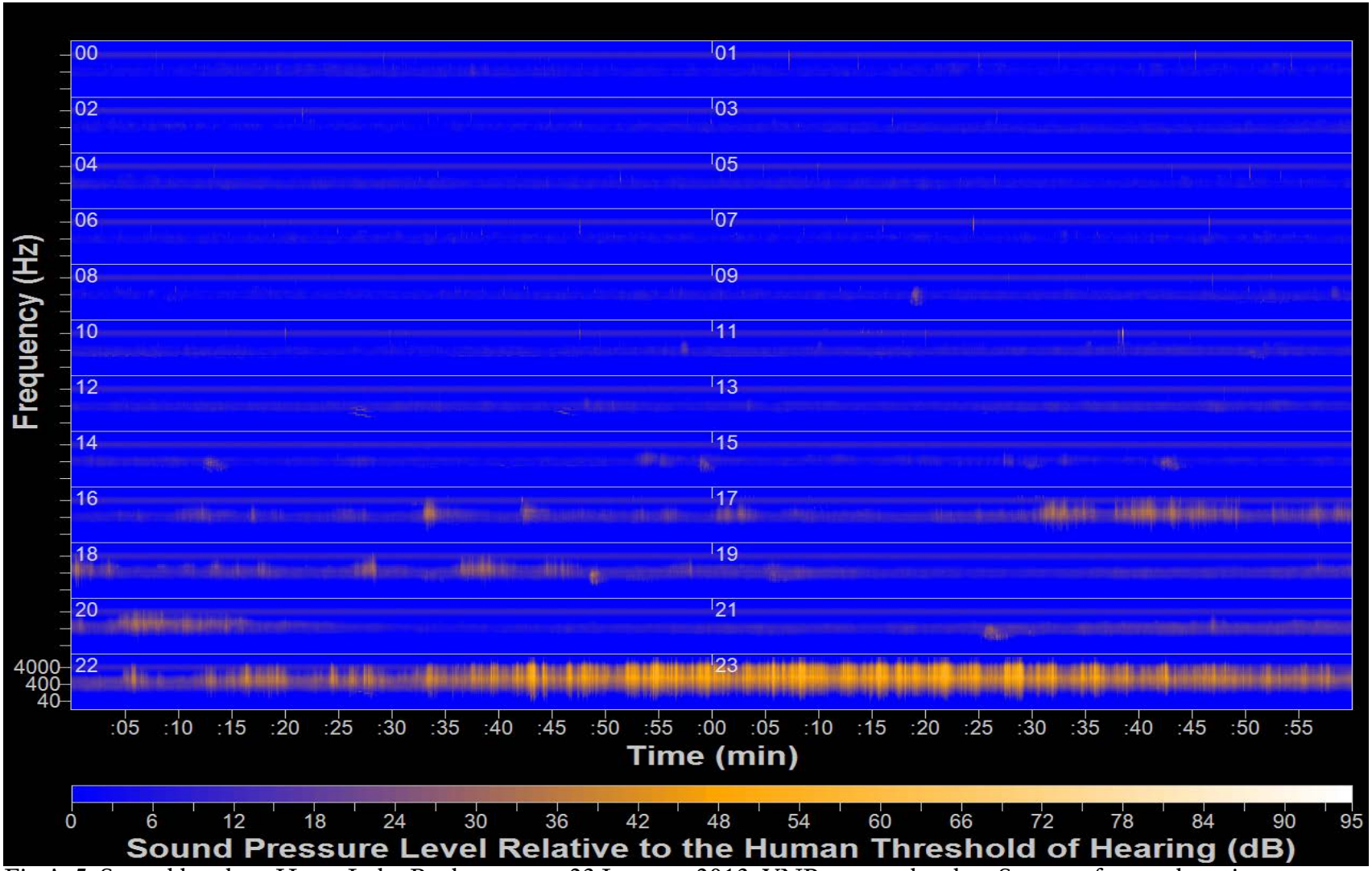

Fig A-5. Sound levels at Heart Lake Backcountry, 23 January 2013, YNP, on a calm day. See text for explanation.

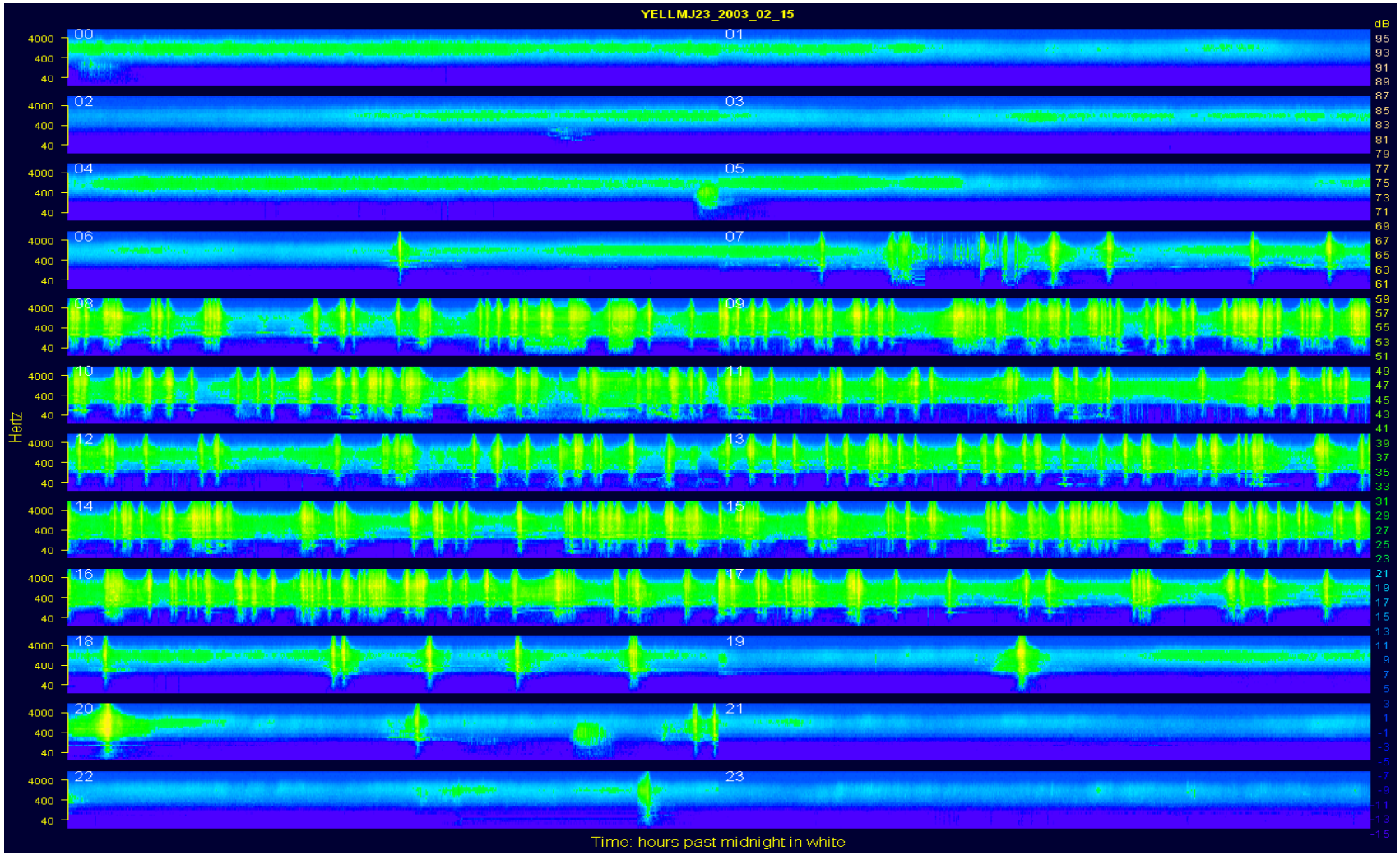

Fig A-6. A-weighted sound levels at Madison Junction 2.3 monitoring site, 15 February 2003, YNP. Compare to Fig. A-6 for number and timing of OSVs. See text for explanation.

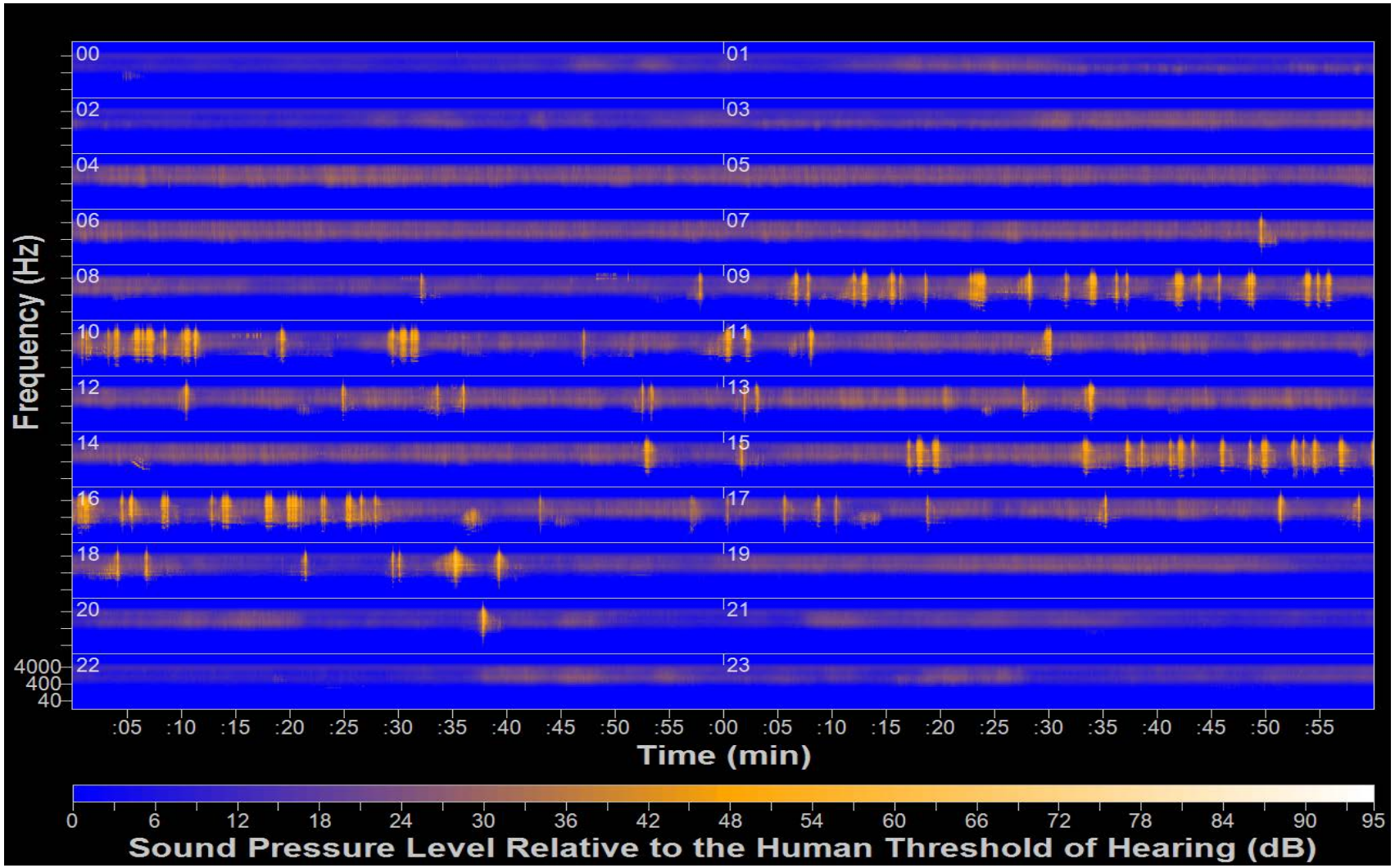

Fig A-7. A-weighted sound levels at Madison Junction 2.3 monitoring site, 16 February 2013, YNP. Compare to Fig. A-7 for number and timing of OSVs. See text for explanation.

Appendix B: 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 OSV usage a separate observational study was conducted during the nine winters of 2005-2013 (Table B-1). Observers were positioned within view of travel routes at key locations and documented the time audible and type of usage for each OSV observed. The data were collected during 289 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 B-2). The total observer logging time was 375 hours 1 minute, and 54 seconds, 7 am to 5 pm, split between morning and afternoon.

Table B-1. Dates of observational study of oversnow usage patterns during winters 2005-2013 in YNP.

17 February-5 March 2005	22 December 2009-11 March 2010
20 January-9 March 2006	5 January-13 March 2011
26 December 2006-5 March 2007	9 January- 22 February 2012
8 January-5 March 2008	26 December 2012- 8 March 2013
12 January-25 February 2009	

Table B-2. Locations used and percent of sampling effort for observational study of oversnow usage type during winters 2005-2013 in YNP.

Developed Area	% Sampling Time	Travel Corridor	% Sampling Time
Old Faithful	12.5	Kepler Cascades Pullout	1.3
Canyon Junction	9.9	Daisy Trailhead	1.9
		Indian Creek	0.8
		Mallard Lake Trailhead	0.5
		Midway Geyser Basin	0.8
		Mary Mountain Trailhead	4.2
		Madison Junction 2.3	9.5
		West Yellowstone 3.1	3.4
		Bridge Bay Area	8.8
		Talus Slopes	0.5
		Tuff Cliff Pullout	7.6
		Cygnet Lake Trailhead	10.7
		Hayden Valley	5.3
		Grant Village Lewis Lake	6.4
		North Twin Lake	7.3
		Spring Creek	7.3
		Caldera Rim Picnic Area	1.2

Oversnow usage types included guided visitors, NPS administrative use, contractors, and Xanterra administrative use, (see sample data sheet Table B-3). These data were then transferred to an MS Access™ database for summary and analysis. Tables B-4 to B-7 present these summary analyses. OSVs that were not seen, but only heard, were not included in Tables B-4 to B-6 because the user group could not be determined.

The number and proportion of snowmobiles was analyzed by group (Table B-4) and by individual machine (Table B-5). The developed area, travel corridor, and combined totals are summarized in both tables. To understand snowmobile usage patterns within YNP it is necessary to assess both group and individual patterns. A total of 3,788 groups of OSVs were documented, including 2,415 groups of snowmobile (Table B-4). Guided group size ranged from 1-31 (the highest counts were presumably from multiple groups that had merged together). Average size for all snowmobile groups was just over four snowmobiles per group; just over seven snowmobiles per guided group; and one snowmobiles per administrative group. A total of 10,791 individual OSVs were tallied, including 9,420 snowmobiles (Tables B-5 and B-6).

Of all individual snowmobiles observed, guided visitors (recreational use) accounted for 91% along travel corridors and 77% in developed areas (Table B-5). Guided visitors comprised 65% of all groups documented along travel corridors and 36% in developed areas (Table B-4). As would be expected, more administrative travel occurred in developed areas than along travel corridors between developed areas (Tables B-4 and B-5). Contractors working on the Old Faithful Inn and the Old Faithful Visitor Center comprised 6% of all groups of snowmobiles documented in developed areas (Table B-4). All administrative travel totaled 58% of the total number of groups observed in developed areas (Table B-4).

The same analysis was done with snowcoach use in developed areas and travel corridors (Table B-6). 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 87% of snowcoaches within developed areas (Table B-6). Of the 1,372 snowcoaches observed, 9 out of 10 were guided (Table B-6).

Guided snowmobiles comprised 55% of all audible snowmobiles and 53% of all audible motorized vehicles were snowmobiles (Table B-7). Guided snowcoaches comprised 29% of all audible motorized vehicles (Table B-7). All OSVs were audible for 48% of the study period and comprised 90% of the motorized sounds audible (Table B-7). Visitor and administrative snowmobiles were audible for 106 hours 14 minute and 2 seconds (29%), and snowcoaches were audible for 58 hours 39 minutes and 0 seconds (16%) of the 375 hours 1 minutes and 54 second

study period (Table B-7). No motorized sounds were audible for 46% of the time during the study period (Table B-7).

Table B-3. Field data sheet for logging oversnow usage type in YNP, during the winters of 2005-2013.

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 B-4. Number and proportion of snowmobile groups by usage type traveling within YNP, winters 2005-2013.

Location	Guided Snowmobiles	Contractor	NPS Maintenance	Ranger	Research	NPS Other/Unknown	Concession Admin	Unknown Admin	Xanterra Admin	Total
Developed Area	406	66	73	118	10	152	18	99	191	1133
	36%	6%	6%	10%	1%	13%	2%	9%	17%	100%
				NPS-All[a]	353					
					31%					
				Admin-All[b]	661					
					58%					
Travel Corridor	837	17	22	75	56	178	17	51	29	1282
	65%	1%	2%	6%	4%	14%	1%	4%	2%	100%
				NPS-All	331					
					26%					
				Admin-All	428					
					33%					
All Areas	1243	83	95	193	66	330	35	150	220	2415
	51%	3%	4%	8%	3%	14%	1%	6%	9%	100%
				NPS-All	684					
					28%					
				Admin-All	1089					
					45%					
[a]NPS-All	Includes maintenance, rangers, research and NPS others/unknown									
[b]Admin-All	Includes all but guided snowmobiles and contractors									

Table B-5. Number and proportion of individual snowmobiles by usage type traveling within YNP, winters 2005-2013.

Location	Guided Snowmobiles	Contractor	NPS Maintenance	Ranger	NPS Research	NPS Other/Unknown	Concession Admin	Unknown Admin	Xanterra Admin	Total
Developed Area	2776	100	85	119	13	167	20	109	199	3588
	77%	3%	2%	3%	0%	5%	1%	3%	6%	100%
				NPS-All[a]	384					
					11%					
				Admin-All[b]	712					
					20%					
Travel Corridor	5895	31	27	82	75	225	26	60	33	6454
	91%	0%	0%	1%	1%	3%	0%	1%	1%	100%
				NPS-All[a]	409					
					6%					
				Admin-All[b]	528					
					8%					
All Areas	8671	131	112	201	88	392	46	169	232	10042
	86%	1%	1%	2%	1%	4%	0%	2%	2%	100%
				NPS-All[a]	793					
					8%					
				Admin-All[b]	1240					
					12%					
[a]NPS-All	Includes maintenance, rangers, research and NPS others/unknown									
[b]Admin-All	Includes all but guided snowmobiles and contractors									

Table B-6. Number and proportion of individual snowcoaches by usage type traveling within YNP, winters 2005-2013.

Location	Guided Snowcoach	Contractor	NPS Maintenance	NPS Ranger	NPS Other/Unknown	Concession Admin	Unknown Admin	Xanterra Admin	Total
Developed Area	574	9	4	3	1	3	4	62	660
	87%	1%	1%	0%	0%	0%	1%	9%	100%
				NPS-All[a]	8				
					1%				
				Admin-All[b]	77				
					12%				
Travel Corridor	666	1	0	1	9	8	7	20	712
	94%	0%	0%	0%	1%	1%	1%	3%	100%
				NPS-All	10				
					1%				
				Admin-All	45				
					6%				
All Areas	1240	10	4	4	10	11	11	82	1372
	90%	1%	0%	0%	1%	1%	1%	6%	100%
				NPS-All	18				
					1%				
				Admin-All	122				
					9%				
[a]NPS-All	Includes maintenance, rangers, research and NPS others/unknown								
[b]Admin-All	Includes all but guided snowmobiles and contractors								

Table B-7. Elapsed time (hours:minutes:seconds) and percentages for motorized vehicles during an observational study, winters 2005-2013, YNP. Percentage totals may not appear correct due to rounding errors.

User Group	Elapsed Time	Percentage	Combined Total
Snowmobiles Only			
Guided Snowmobile	58:03:17	55%	55%
Contractor	1:33:15	1%	1%
NPS-Maintenance	2:49:03	3%	
NPS-Ranger	5:39:57	5%	
NPS-Research	1:56:58	2%	
NPS-Other/Unknown	11:11:39	11%	20%
Admin-Concession	0:40:15	1%	
Administrative-Xanterra	4:31:14	4%	
Administrative-Unknown	4:05:17	4%	9%
Unknown Snowmobile User	15:43:07	15%	15%
	106:14:02		
Snowcoaches Only			
Guided Snowcoach	51:46:07	88%	88%
Contractor	0:04:02	0%	0%
NPS-Maintenance	0:10:56	0%	
NPS-Ranger	0:05:38	0%	
NPS-Research	0:00:00	0%	
NPS-Other/Unknown	0:27:55	1%	1%
Admin-Concession	0:17:37	1%	
Administrative-Xanterra	2:33:27	4%	
Administrative-Unknown	0:13:12	0%	5%
Unknown Snowcoach User	3:00:06	5%	5%
	58:39:00		

Table B-7 continued. Elapsed time (hours:minutes:seconds) and percentages for motorized vehicles during an observational study, winters 2005-2013, YNP. Percentage totals may not appear correct due to rounding errors.

User Group	Elapsed Time	Percentage	Combined Total
All Motorized Sounds			
Jets	10:36:14	5%	
Props	2:58:52	1%	
Helicopters	0:32:43	0%	7%
Snowmobile	106:14:02	53%	
Snowcoach	58:39:00	29%	
Snowmobile or Snowcoach	8:48:20	4%	
Unknown Oversnow Vehicle	6:30:01	3%	90%
Groomer	4:03:59	2%	2%
Unknown/Other Motorized	2:28:07	1%	1%
	200:51:18		
Total Observation Time	375:01:54		
Motorized Sounds	200:51:18	54%	
Oversnow Vehicles	180:11:23	48%	
Snowmobiles	106:14:02	28%	
Snowcoaches	58:39:00	16%	
No Motorized Sounds	174:10:36	46%	

Appendix C: Additional percent time audible considerations

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 several 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, for this study, has been Madison Junction 2.3 along the busiest travel corridor in winter. For the winter season 2012-2013, OSVs were audible 51% 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 visitor OSV use, audibility fell to 42%. Audibility climbed to 87% during the busiest hour of the day, 9 am to 10 am, and was 24% during the noon hour. The average OSV audibility for all days analyzed of all travel corridor monitoring sites was 33% for 8 am to 4 pm. The time period and location of data collection can greatly influence the percent time audible results (Table C-1).

Table C-1: Oversnow audibility as a function of monitoring site and period of analysis, YNP, 15 December 2012-15 March 2013.

Site(s)	Period of Analysis	Audibility
Madison Junction	9 am to 10 am	87%
Madison Junction	noon to 1 pm	24%
Madison Junction	8 am to 4 pm	51%
Madison Junction	7 am to 9 pm	42%
All travel corridor monitoring sites in YNP all years	8 am to 4 pm	33%

In addition to the influence of time period and monitoring site, naturally occurring sounds also affect the percent time OSVs are audible. As would be expected, the percent time OSVs were audible was lower on windy days and was higher during days of higher OSV numbers.