Snowmobile Noise Exposure Monitoring of Yellowstone National Park Employees

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Abstract

In Yellowstone National Park (YNP) the use of snow machines has steadily increased since 1949. Paralleling the rise in snow machine travel were concerns over increases in noise emissions. The concerns resulted in the establishment of winter-use plans for YNP. As periodic iterations of winter-use plans began to appear, input was needed concerning noise exposures received by YNP employees regulating snow machine traffic entering the Park. This study provides noise monitoring results of worker exposure from snow machine traffic at the west entrance to YNP. The study objectives were to characterize noise exposures received by YNP employees and to evaluate these exposures relative to Occupational Safety and Health Administration (OSHA) standards. Concerning area and personal monitoring of YNP employees supervising snow machine traffic, study results suggest compliance with OSHA regulations. This is also true when applying a more conservative approach to estimate daily noise exposure. In contrast, monitoring results estimating noise exposures received by YNP employees operating snowmobiles revealed that 1 of 10 (10%) were not compliant with the OSHA noise standard and 5 of 10 (50%) equaled or exceeded its action level. While the findings associated with snowmobile operators serve to provide awareness of the potential for adverse exposures, limitations concerning these exposure estimates are discussed and point to the need for additional monitoring using more precise methods. Given that winter-use plans for YNP will continue to evolve, it is anticipated that the results of this study will provide information that can better manage occupational noise exposure and the protection of employee health.

Key words: snowmobiles, snow coaches, occupational noise, Yellowstone National Park

Introduction

In Yellowstone National Park (YNP), winter tourism by motorized travel first occurred in 1949 (Haines 1996). These one-to-two passenger vehicles, fitted with three skis and powered by small airplane engines mounted on the rear of an enclosed cab, were deemed snow planes. By 1955, the primary mode of motorized winter tourism in the park had advanced to 15-passenger snow coaches, which are still in use today (Yochim 2003). Yochim explains that the first snowmobiles entered the park in 1963 marking the start of a dramatic rise in motorized winter tourism that would continue over the next several decades into the 1990's where annual counts of snow coaches and snowmobiles entering the park approached seventy thousand.

Paralleling the rise in snow machine travel were concerns over increases in engine exhaust and noise emissions, calling into question the biological value that society was placing on the park (Gourley 2005). As a result, in 1990 YNP began

instituting a winter-use plan (or rule) that, in part, regulated tourism using snow machines (USDI 1990). The plan was based on findings derived from environmental studies and impact statements and was intended to address concerns over ecological impacts caused by mechanized travel at the same time as preserving public access to the park via the use of snow machines. Since approval of the first winter-use plan, YNP has revised and approved subsequent plans using findings from numerous studies performed by environmental professionals (NPS 2011, Olliff et al. 1999).

Along with concerns over biological impacts, further concerns began to mount related to adverse noise exposures received by YNP employees monitoring snow machine traffic entering the Park (Glacier National Park 1975). This study was conducted to characterize occupational noise exposures to provide YNP administrators with information required to establish winter-use plans that not only protect the biological and recreational aspects of the park, but also the occupational health of its employees.

Monitoring of snowmobile and snow coach noise emissions was performed at the west entrance to YNP during two monitoring campaigns in 2005 and one monitoring campaign in 2006. The objectives of these campaigns were to characterize occupational noise exposures received by YNP employees and to evaluate these exposures relative to established Occupational Safety and Health Administration (OSHA) thresholds. The results of this study will add to the limited body of scientific knowledge that has been published regarding the occupational health risk presented by this type of noise exposure.

Methods and Materials

Historical visitation data compiled by YNP shows that holiday weekends associated with Presidents' Day and Martin Luther King Day are typically busy times in terms of the number of snowmobiles and snow coaches entering the national park for wintertime usage (B. Gauthier, personal communication, November 30, 2004). In an effort to characterize peak occupational noise exposures resulting from snow machine traffic, each monitoring campaign coincided with one of these holiday weekends. The specific dates for the three campaigns performed in this study were 15, 16 and 17 January 2005; 19, 20 and 21 February 2005 and; 18, 19 and 20 February 2006. Due to its popularity as a portal and the likelihood of encountering high numbers of snow machines entering the park, noise emission monitoring was performed at YNP's West Entrance, an entry portal adjacent to the city of West Yellowstone, Montana.

Instrumentation

The assessment of exposures received by YNP employees from snow machine noise emissions was based on acquisition and evaluation of personal and area monitoring data using Quest Q-400™ and Quest NoisePro™ dosimeters. These instruments are classified as ANSI Type 2 dosimeters and house omnidirectional, ceramic microphones having an accuracy of ± 2dB, which is the minimum accuracy requirement established by OSHA for the assessment of compliant noise measurements. To ensure that acquired noise measurements were suitable to evaluate compliance with the OSHA noise standard, each dosimeter was configured to record sound using the instrument settings summarized in Table 1. In an effort to maximize the precision and accuracy of acquired sound measurements during a given monitoring period, each dosimeter was pre- and post-calibrated using a Quest Model CA-12B acoustical calibrator emitting a 1000 Hz pure tone at a sound pressure level (SPL) of 114 dB.

Personal Monitoring of Kiosk Attendants

Monitoring of personal noise exposure was performed on YNP employees supervising snow machine traffic passing two 3 m x 3.75 m x 3.75 m buildings (kiosks). Each kiosk, denoted in this study

Table 1. Instrument settings for the Quest Q-400™ and Quest NoisePro™ Dosimeters used during personal and area noise monitoring at YNP during January 2005 and February 2006.

Instrument Setting	Instrument Setting Definition
A-Weighting	The internal weighting filter that reduces sound energy in the lower frequencies (less than 1000 Hz), is based on how humans perceive sound and is designated dBA.
90 dBA Criterion Level	The constant sound level that, if applied for eight hours, would result in a 100 percent sound exposure dose.
5 dB Exchange Rate	The number of decibels required to either halve or double the rate of accumulated sound exposure dose.
Slow Response	A one second averaging time for sound intensities received by the dosimeter.
80 dB and 90 dB Threshold Levels[1]	The decibel level above which sound is accumulated into a dosimeter measurement.

[1] *Both threshold levels are simultaneously applied using separate instrument channels*

as "Kiosk 1" and "Kiosk 2", were identical and adjacent to a snow machine traffic lane. Figure 1 provides a visual depiction of one of these Kiosks. As shown in Figure 2, during the morning hours when traffic flow was at its peak (0700 to 0900), both traffic lanes were simultaneously occupied by snow machines entering YNP. Each traffic lane was configured such that a snow machine would approach and pass the west facing

Figure 1. Kiosk used by employees to supervise snow machine traffic entering YNP through its West Entrance.

Figure 2. Two lanes of snow machine traffic approaching kiosks at the West Entrance to YNP.

wall of a kiosk. In this study, the YNP employee occupying Kiosk 1 is denoted as "Kiosk Attendant 1" and the YNP employee occupying Kiosk 2 is denoted as "Kiosk Attendant 2".

To allow for the appropriate characterization of personal noise exposures received as snowmobiles and snow coaches approached, stopped, idled and departed a given kiosk, dosimeter measurements were collected in the hearing zone of each Kiosk attendant. OSHA defines the hearing zone as a sphere having a 61 cm diameter surrounding a human head (USDL 1999). As shown in Figure 3 hearing zone measurements were performed by clipping the dosimeter microphone to an employee's jacket collar at a point midway between the base of the neck and the tip of the shoulder, which resulted in an approximate linear distance from the ear canal to the tip of the microphone of 20 cm. Each microphone was fitted with a foam screen to reduce the likelihood of recording anomalous noise measurements through contact with wind, clothing, or other surfaces. Care was taken to attach dosimeters to employees in such a manner as not to interfere with their normal job duties.

Monitoring times for the collection of personal exposure measurements were chosen to coincide with the highest levels of daily traffic entering YNP on holiday weekends. After discussions with YNP employees concerning historical traffic patterns on these weekends, it was decided that personal exposure monitoring would begin as close as possible to 0700 and continue until snowmobile and snow coach traffic subsided, typically around 1230.

Area Monitoring at Kiosks

In an effort to extrapolate localized noise emission measurements to human exposures, area monitoring was performed at the opening of a square, 112 cm x 112 cm, sliding glass window centered on the west

facing wall of each kiosk. This window was adjacent to snow machine traffic lanes and was a location where employees spend a majority of time during traffic supervision.

Figure 4 provides visual confirmation of the location where area monitoring was performed. Figure 4 also shows that the dosimeter's microphone was clipped to the

Figure 3. Microphone placement on the collar of a YNP employee during personal noise monitoring.

Figure 4. Microphone placement on the window frame of a kiosk during area monitoring at the West Entrance to YNP.

south side of the window at a point halfway between the window's top and bottom (66 cm). Care was taken to clip the microphone to the outer surface of the window housing such that it would remain parallel to the plane of the window. The microphone cable and dosimeter unit inside the kiosk were carefully placed so they didn't interfere with YNP employee job duties.

Personal Monitoring of YNP Employees While Operating Snowmobiles

Two types of snowmobiles were used to assess personal noise exposures to YNP employees during snowmobile operation. The first type was a 2003 Polaris Frontier snowmobile equipped with 4-cycle, 784 cc, 2-cylinder engine. The second type was a 2004 Arctic Cat T660, housing a 4-cycle, 660 cc, 3-cylinder engine.

During personal monitoring of noise exposures two riders were seated on each snowmobile. The noise dosimeter unit was attached to the belt of the snowmobile passenger and the unit's microphone was held by the passenger as close as possible to the hearing zone of the snowmobile operator. While it is recognized that wind noise is a concern as a potential contributor to hearing loss when operating high speed vehicles, care was taken to shield the microphone from the wind generated by the speed of the snowmobile during operation. Also, each microphone was fitted with a foam screen to provide additional protection against accumulation of measurements resulting from wind and other noise artifacts. These sampling practices were done to enhance the repeatability of each sample given that the microphone was being held and not attached to the lapel of the snowmobile operator.

Quantification of Noise Exposures

The evaluation of compliance with occupational noise exposure limits was based on standards published in the 29 CFR 1910.95 (United States Department of Labor, OSHA, 1970). Under this Federal rule, OSHA has established an eight hour time-weighted-average (TWA) permissible exposure limit (PEL) of 90 dBA with a 90 dBA integration threshold. This PEL, also known as the Engineering Standard, is the sound pressure level (SPL) TWA that, when exceeded, requires employers to implement feasible administrative or engineering controls. If such controls fail, personal protective equipment shall be provided and used to reduce sound levels.

An update to 29 CFR 1910.95 occurred in 1981 known as the Hearing Conservation Amendment (United States Department of Labor, OSHA, 1981). Under the amendment, OSHA established an eight hour TWA with a PEL of 90 dBA with an 80 dBA integration threshold. The amendment requires employers to take specific actions when employee noise exposures meet or exceed an eight hour SPL TWA of 85 dBA (also known as the "action level"). The intent of OSHA's Engineering Standard and Hearing Conservation Amendment is to limit further exposure to noise levels above the established allowable level and, when necessary, require administrative control measures, such as the establishment of a written hearing conservation program and audiometric testing when exposures equal or exceed an 8-hour time-weighted average of 85 dBA.

When evaluating compliance with regulatory threshold limits a common way to document noise exposure is through the conversion of an eight hour SPL TWA to its percent dose equivalent using the following equation:

$$\%\ \text{Dose} = 2^{\left(\frac{\text{SPL}-90}{5}\right)} \times 100 \qquad \text{(eq. 1)}$$

Where,
SPL = TWA sound pressure level averaged over an eight hour time duration.

When using the equation above, SPLs can be applied from OSHA's Engineering Standard and Hearing Conservation Amendment criteria to express eight

hour doses. For the purpose of assessing compliance with these exposure standards, all personal and area monitoring data were reported as percent dose equivalents of acquired SPLs.

During the performance of area and personal monitoring all but one of the monitoring events performed in this study were less than eight hours. For these events, dose equivalents had to be extrapolated over an eight hour time frame to allow for comparison with OSHA's eight hour standards. For these extrapolations, two separate assumptions were made concerning the level of exposure for the remaining portion of the eight hour period when monitoring did not occur.

Exposure Assumption #1–This assumption is intended to provide an indication of the worst case exposure that could be received over an employee's eight hour work shift. Under this assumption it is presumed that the SPL acquired at the end of a monitoring event remains constant for the remainder of the eight hour exposure period where monitoring did not occur. In other words, the monitoring event SPL is equal to the eight hour SPL. This eight hour SPL is then converted to its percent dose equivalent and is reported as the eight hour percent dose exposure for a given monitoring event.

Exposure Assumption #2--Under this assumption it is presumed that there is no further exposure to noise above the instrument's threshold levels (80 dB and 90 dB) after cessation of the monitoring event and extrapolates the acquired TWA over an eight hour time duration using the following equation:

$$TWA_{8-hr} = \frac{TWA_{me}(t)}{8} \qquad \text{(eq. 2)}$$

Where,

$TWA_{8\text{-}hr}$ = The SPL extrapolated over an 8 hour time duration;

TWA_{me} = The SPL acquired at the end of a monitoring event and;

t = Monitoring event duration in hours.

The extrapolated eight hour SPL is then converted to its eight hour percent dose equivalent.

In this study, these two assumptions were used to quantify and report exposure estimates acquired during the performance of personal and area monitoring. Exposure results under each assumption are reported separately for both the 80 dB and 90 dB threshold levels and are used to assess compliance with the Federal standard for occupational noise exposure.

Results

Snow Coach and Snowmobile Populations

The results provided in Table 2 show that over the duration of the study's three monitoring campaigns a total of 1732 snowmobiles and 178 snow coaches entered YNP through its west entrance, yielding a daily average of 192 snowmobiles and 20 snow coaches. Averages for the eight days sampled represent 32 percent and 18 percent higher snowmobile and snow coach traffic when compared with the daily average for all winter use days encompassing the 2005 and 2006 seasons (Ray 2008).

Time Durations for Personal and Area Monitoring

Table 3 summarizes the time durations and standard deviations for personal and area monitoring events performed in this study. All but one of the monitoring events were less than 480 minutes (8 hours). The time durations for the thirteen personal and area monitoring events performed at Kiosks' ranged from 199 minutes to 360 minutes with an average monitoring duration of 291 minutes for personal monitoring events and 230 minutes for area monitoring events. Also provided in Table 3 are the time durations of personal monitoring events associated with snowmobile operation. Because the intent of this personal monitoring was to assess noise exposures received by YNP employees while riding snow machines, monitoring durations were limited to actual riding time and ranged from

Table 2. The number and type of snow machines entering YNP through its West Entrance on the days when noise monitoring was performed during January 2005 and February 2006.

Date	Snowmobiles	Snow Coaches
1/15/05	163	21
1/16/05	142	12
1/17/05	109	19
2/19/05	279	25
2/20/05	227	23
2/21/05	164	15
2/18/06	243	25
2/19/06	231	23
2/20/06	174	15
Total	**1732**	**178**
Per Day Average	**192**	**20**

Table 3. Descriptive Statistics associated with Time Durations for Personal and Area Monitoring Events at the West Entrance to YNP during January 2005 and February 2006.

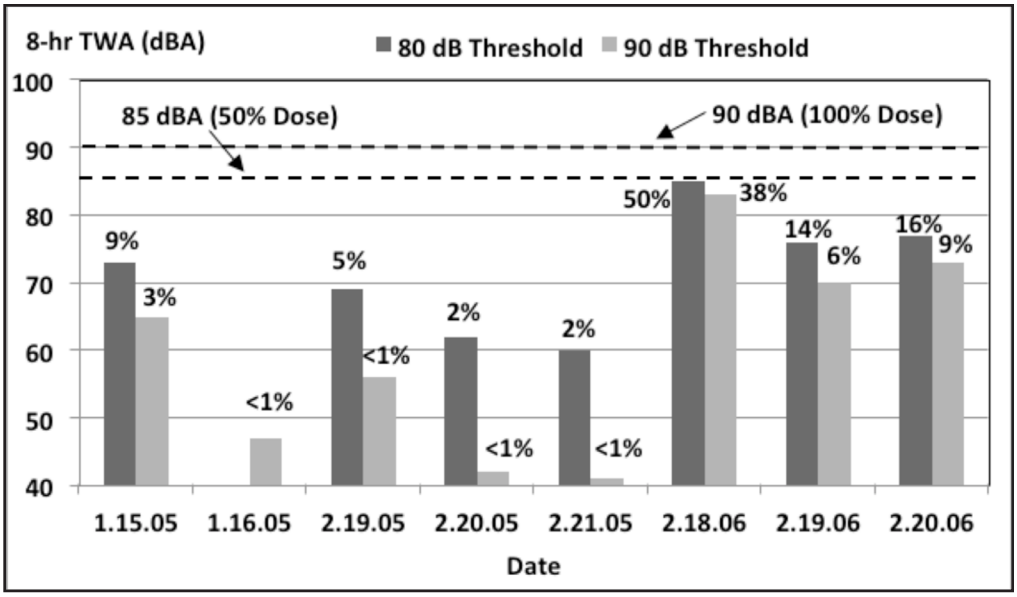
Type of Monitoring	No. of Events	Range) (minutes	Average (minutes)	SD
Personal Monitoring of Kiosk Attendants	8	214 to 360	291	50
Area Monitoring of Kiosks	5	199 to 257	230	32
Personal Monitoring of Snowmobile Operators	7	274 to 480	328	69

274 minutes to 480 minutes, with an average duration of 328 minutes.

Personal Monitoring Results of Kiosk Attendants

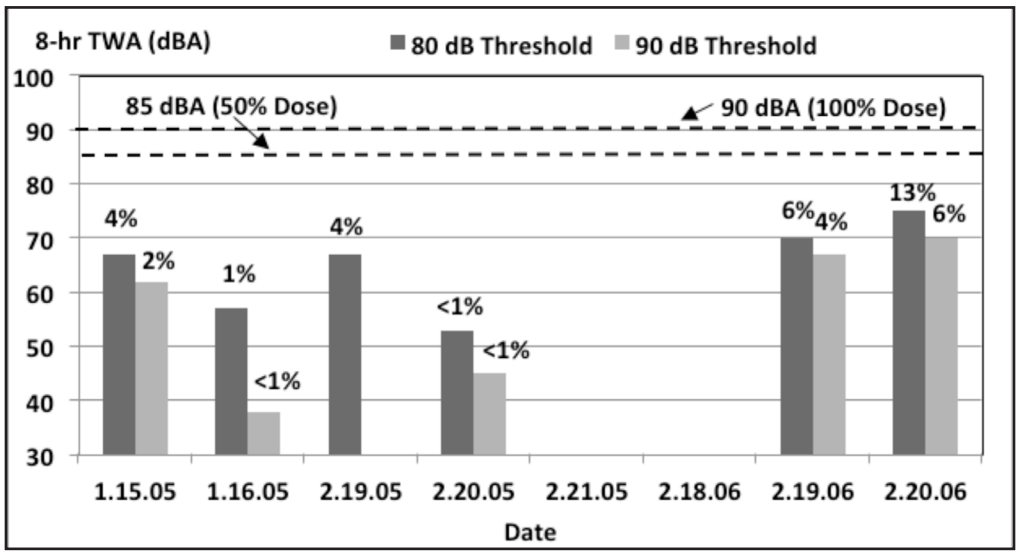
Figures 5 through 8 provide exposure estimates for kiosk attendants supervising snowmobile and snow coach traffic entering YNP. All exposure estimates are expressed as dose equivalents of eight hour SPLs and are differentiated based on the assumption applied to quantify the dose equivalent and on measurements acquired using the instruments' 80 dB or 90 dB threshold level. The dotted lines on each figure identify the 90 dBA (100 percent equivalent dose) and 85 dBA (50 percent equivalent dose) eight hour TWA exposure limits established for OSHA's Engineering Standard and Hearing Conservation Amendment.

Personal Monitoring Results at the 90 dB Threshold Level–As is shown in Figures 5 through 8, consideration of both exposure assumptions at the 90 dB threshold level provide dose equivalents for both kiosk attendants that were less than the non-compliance limit established for OSHA's Engineering Standard (90 dBA



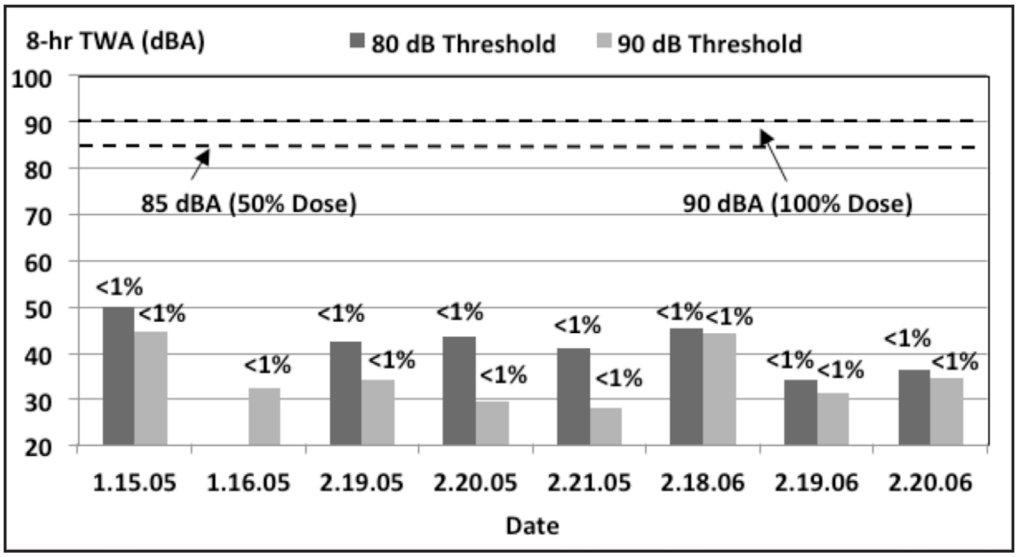
[1] The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume no further accumulation of noise exposure for the remainder of an 8-hr work shift.
[2] No data are available at the 80 dB Threshold for Kiosk attendant 1 on 16 February 2005.

Figure 5. Personal Noise Monitoring of Kiosk Attendant 1 at the West Entrance to YNP during two weekend monitoring campaigns in January 2005 and one in February 2006 **(using Exposure Assumption #1)**.



[1] The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume no further accumulation of noise exposure for the remainder of an 8-hr work shift.
[2] No data are available for Kiosk attendant 2 on 21 February 2005, 18 February 2001 and at the 90 dB Threshold on 19 February 2005.

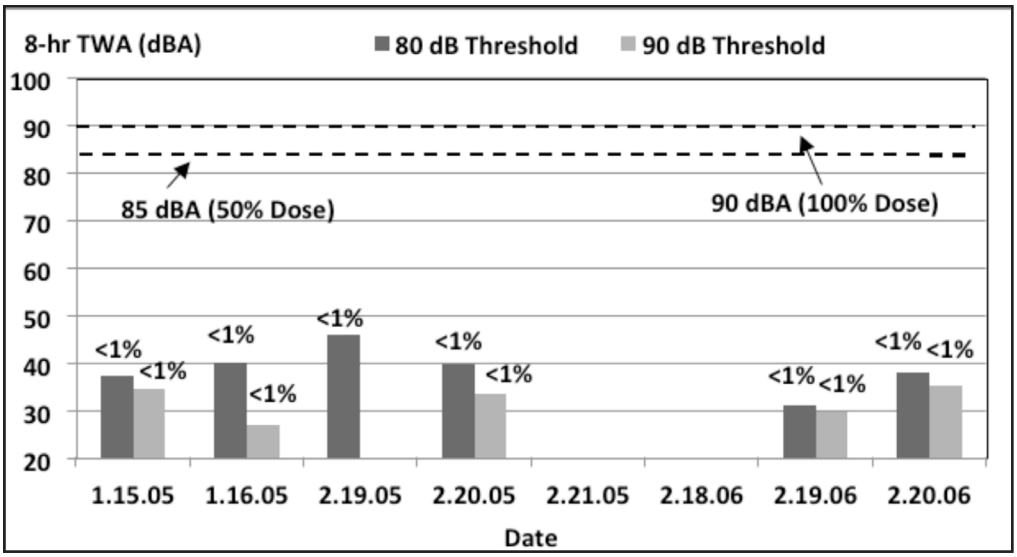
Figure 6. Personal Noise Monitoring of Kiosk Attendant 2 at the West Entrance to YNP during two weekend monitoring campaigns in January 2005 and one in February 2006 **(using Exposure Assumption #1)**.



[1] *The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume that average noise exposures measured at the end of the monitoring period are equivalent to percent dose exposures acquired for an 8-hr work shift.*

[2] *No data are available at the 80 dB Threshold for Kiosk attendant 1 on 16 February 2005.*

Figure 7. Personal Noise Monitoring of Kiosk Attendant 1 at the West Entrance to YNP during two weekend monitoring campaigns in January 2005 and one in February 2006 **(using Exposure Assumption #2)**.



[1] *The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume that the noise exposures measured at the end of the monitoring period are equivalent to percent dose exposures acquired for an 8-hr work shift.*

[2] *No data are available for Kiosk attendant 2 on 21 February 2005, 18 February 2006 and at the 90 dB Threshold level on 19 February 2005.*

Figure 8. Personal Noise Monitoring of Kiosk Attendant 2 at the West Entrance to YNP during two weekend monitoring campaigns in January 2005 and one in February 2006 **(using Exposure Assumption #2)**.

or 100% dose). Further scrutiny using Exposure Assumption #1 at the 90 dB threshold level reveals that of the 13 dose equivalent exposures estimated for both kiosk attendants, six were less than one percent, 12 were less than 10 percent and one was 38 percent. Similar scrutiny of the results reported using Exposure Assumption #2 at the 90 dB threshold level shows that all dose equivalent exposures for both kiosk attendants at this threshold level were less than one percent.

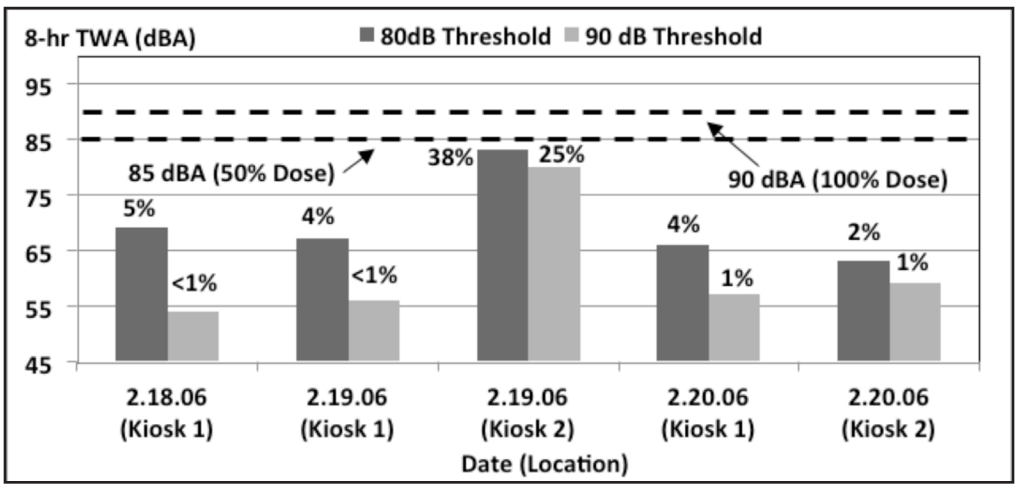
Personal Monitoring Results at the 80 dB Threshold Level–The results provided in Figures 5 through 8 show that for both exposure assumptions at the 80 dB threshold level, all but one of the dose equivalent exposures were less than the 50 percent dose action level that initiates implementation of OSHA's Hearing Conservation Amendment. Consideration of Exposure Assumption #1 in Figures 5 and 6 reveals that of the 13 dose equivalent exposures estimated for both kiosk attendants, nine were less than 10 percent, two were less than 20 percent and one was 50 percent. In Figures 7 and 8, which provide dose equivalent exposures using Exposure Assumption #2, the results show that all 13 dose equivalent exposures estimated for both kiosk attendants were less than one percent.

Area Monitoring at Kiosks

Figures 9 and 10 provide the results of area monitoring at both Kiosk 1 and Kiosk 2. As is shown in these figures, dose equivalent exposure results using both assumptions and at both threshold levels were less than the dose limit imposed by OSHA's Engineering Standard and Hearing Conservation Amendment. Over the five events where area monitoring occurred, all dose equivalent exposure results were less than 10 percent except on 19 February 2006, when area monitoring results showed an equivalent dose exposure of 38 percent at the 80 dB threshold level and 25 percent at the 90 dB threshold level.

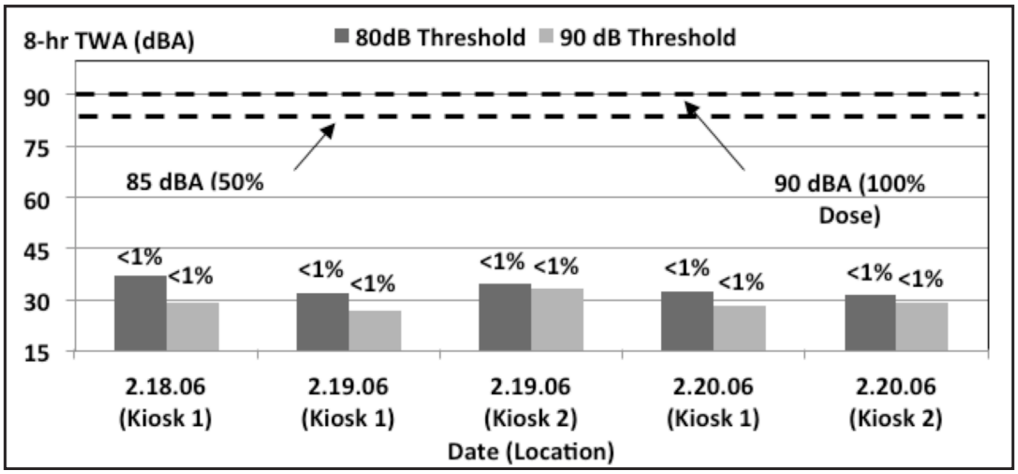
Personal Monitoring of YNP Employees Operating Snowmobiles

Figures 11 and 12 provide results of personal exposure monitoring of YNP employees while operating snowmobiles. In both figures, snowmobile Type 1 refers to the 2003 Polaris Frontier and snowmobile Type 2 refers to the 2004 Arctic Cat T600.



[1] *The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume that the noise exposures measured at the end of the monitoring period are equivalent to percent dose exposures acquired for an 8-hr work shift.*

Figure 9. Area Noise Monitoring at Kiosks Located at the West Entrance to YNP from18 February 2006 through 20 February 2006 **(using Exposure Assumption #1)**.



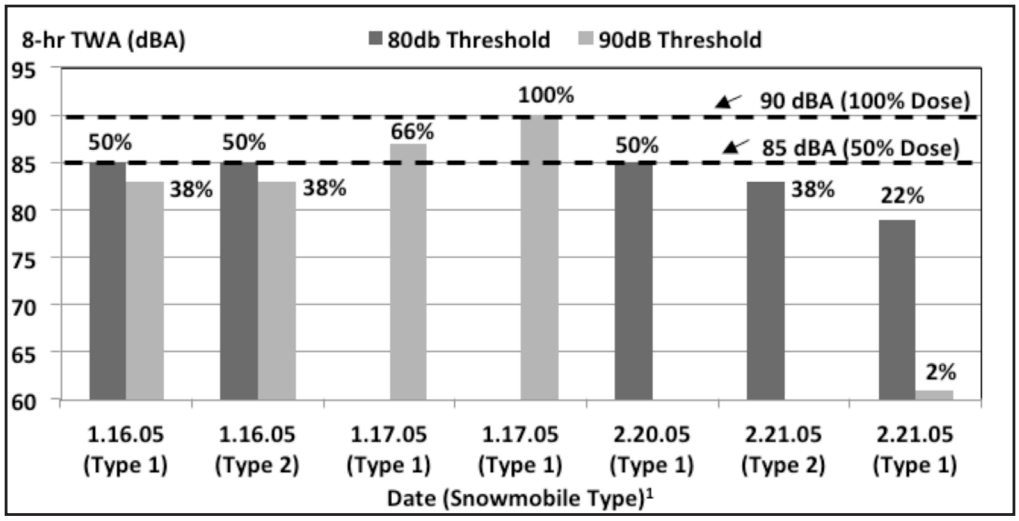
[1] The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume no further accumulation of noise exposure for the remainder of an 8-hr work shift.

Figure 10. Area Noise Monitoring at Kiosks Located at the West Entrance to YNP from 18 February 2006 through 20 February 2006 **(using Exposure Assumption #2)**.

In Figure 11 accumulated exposure doses approached or exceeded OSHA's Hearing Conservation Amendment Threshold (50% dose) on all but two of the monitoring events. Most striking is the result on 17 January 2005 where the accumulated dose exposure equaled OSHA's Engineering Standard (100% dose equivalent), assuming that the 90 dBA TWA achieved after 274 minutes of monitoring remains the same when extrapolated over eight hours (Exposure Assumption #1). Another result of note is the 50 percent dose equivalent observed for the 2003 Polaris Frontier snowmobile when applying either exposure assumption on 20 February 2005 (Fig. 11 and Fig. 12). Most noteworthy concerning exposures received during snowmobile operation is the overall lack of significant dose accumulation when applying Exposure Assumption #2 (Fig. 12). Again, the one exception was on 20 February 2005 where the dose accumulation was 50 percent, which initiates OSHA's Hearing Conservation Amendment.

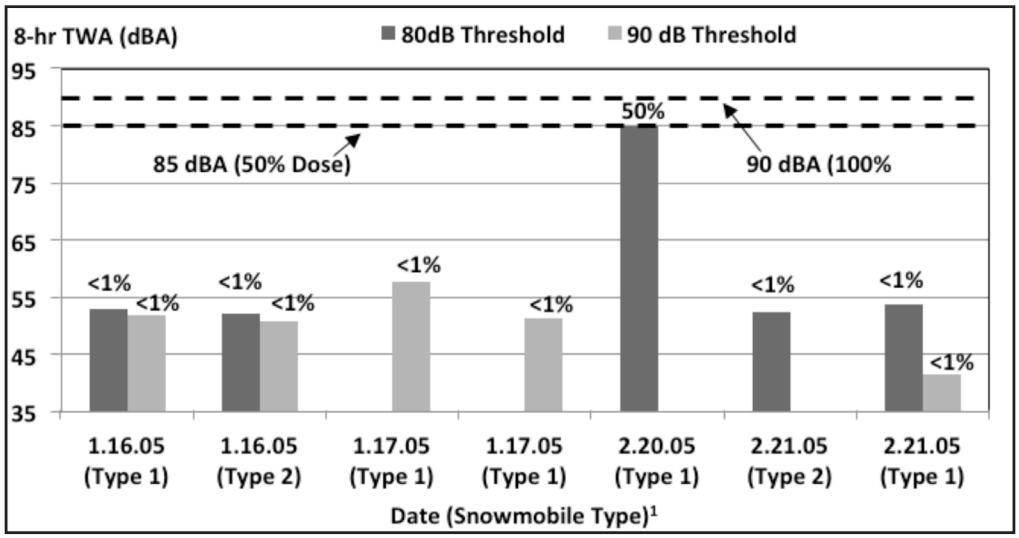
Discussion

In an effort to characterize worst case exposures received by employees supervising snow machine traffic entering YNP, President's Day and Martin Luther King Day holiday weekends were chosen for noise monitoring. The results in Table 2 show increases in snow machine traffic patterns over these chosen time periods, which appear to validate the decision to monitor on these days. Another decision made by the study's researchers was to perform personal and area monitoring for less than 8 hours, which is the typical work duration used by OSHA to establish compliant noise exposures. This decision was based on the daily character of noise exposures received by YNP employees during the performance of their job duties. For YNP employees supervising snow machine traffic, the primary source of exposure during a work shift was from noise generated as snowmobiles and snow coaches approached, stopped and passed a kiosk. Once snowmobile and snow coach traffic subsided, these employees returned to an office environment that contained noise levels below 80 dB. Since 80 dB is the lower threshold at which sound was accumulated into a dosimeter measurement for comparison against the OSHA Hearing Conservation Amendment, the exposures received in the office environment did not contribute additional noise dose to their daily exposure. Thus, for personal and area monitoring, efforts were made to



[1] *Snowmobile Type 1: 2003 Polaris Frontier; Snowmobile Type 2: 2004 Arctic Cat T600.*
[2] *The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume that average noise exposures acquired at the end of the monitoring period are equivalent to percent dose exposures acquired for an 8-hr work shift.*
[3] *On 17 February 2005 personal monitoring was performed twice using snowmobile type 1 and no data are available on this date for snowmobile type 2.*
[4] *No data are available at the 80db Threshold for snowmobile type 1 on 17 February 2005 and at the 90 db Threshold for snowmobile type 1 on 20 February 2005 and 21 February 2005.*

Figure 11. Personal Noise Monitoring of YNP Employees Operating Snowmobiles in YNP on 16-17 January 2005 and 20-21 February 2005 **(Using Exposure Assumption #1)**.



[1] *Snowmobile Type 1: 2003 Polaris Frontier; Snowmobile Type 2: 2004 Arctic Cat T600.*
[2] *The % values above each bar represent dose equivalents for corresponding dBA-TWA values and assume no further accumulation of noise exposure for the remainder of an 8-hr work shift.*
[3] *On 17 February 2005 personal monitoring was performed twice using snowmobile type 1 and no data are available on this date for snowmobile type 2.*
[4] *No data are available at the 80db Threshold for snowmobile type 1 on 17 February 2005 and at the 90 db Threshold for snowmobile type 1 on 20 February 2005 and 21 February 2005.*

Figure 12. Personal Noise Monitoring of YNP Employees Operating Snowmobiles in YNP on 16-17 January 2005 and 20-21 February 2005 **(Using Exposure Assumption #2)**.

coincide the sampling duration with the time when snowmobiles and snow coaches were allowed to enter through YNP's west entrance (0700) and continue until snow machine traffic passing entrance kiosks subsided (between 1200 and 1300 each day).

Overall personal monitoring of kiosk attendants provided exposure results that were well below OSHA's Engineering Standard and Hearing Conservation Amendment. The single outlier in these results is associated with the personal monitoring of Kiosk Attendant 1 on 18 February 2006, who received a 50 percent dose equivalent exposure upon completion of the monitoring event (Fig. 5). While this level of exposure is equal to the threshold that initiates OSHA's Hearing Conservation Amendment, it was noted during monitoring that a portion of the exposure dose was likely caused by noise emissions received from human speech due to the kiosk attendant's loud voice and tendency to speak directly in or proximal to the dosimeter's microphone.

The results in Figures 11 and 12 show that on 20 February 2005 the percent dose received by the operator of the Polaris Frontier snowmobile was the same when using both Exposure Assumptions #1 and #2. The reason the percent dose amounts are equal is because the duration for this monitoring event was exactly 480 minutes (8 hours) negating the need to extrapolate the exposure over a time period not sampled (as is done in Exposure Assumption #2). Thus, in this instance, exposure estimates applying both Exposure Assumptions yield the same percent dose.

Conclusions

Given the volume of snow machines entering the Park on the holiday weekends chosen to perform noise monitoring, it is likely that the results in this study provide a conservative (worst case) estimate of exposures received by YNP employees supervising this traffic. Concerning area and personal monitoring of kiosk attendants, the results suggest compliance with the OSHA Engineering Standard and Hearing Conservation Amendment. This was true when applying an even more conservative approach to estimate daily noise exposure (Exposure Assumption #1). Using this approach it was assumed that the average noise exposure received by an employee over the time period when snow machine traffic and resulting sound intensities were at their peak (0700 to 1300) remained the same for the duration of an eight hour work shift. Through observation and discussion with YNP employees it became clear that once snow machine traffic subsided they would return to an office environment where noise intensities were below those that would contribute to additional daily exposure dose. Thus, it is likely that exposures measured using this approach are overestimated and their compliance with OSHA noise standards provides added confidence of compliance throughout the Park's entire winter-use time frame.

Contrary to the exposure estimates for area and personal monitoring, many of the monitoring results intended to estimate 8-hour TWA noise exposures received by YNP employees operating snowmobiles were close or exceeded the 8-hour TWA that initiates OSHA's Hearing Conservation Amendment (85dBA). Further, it is likely that operation of snowmobiles for durations longer than those monitored in this study, would yield 8-hour TWA exposures that approach or exceed OSHA's Engineering Standard, requiring evaluation of the use of administrative and engineering controls, the mandatory use of hearing protection devices and a Hearing Conservation Program, with all it elements. That said, study limitations concerning the monitoring methods used to estimate operator exposure include, (1) the fact that the snowmobile operator wore a helmet that served to attenuate noise intensity, (2) the variability of microphone placement proximal to the human hearing zone, due to being held by the snowmobile passenger, (3) the contribution of anomalous noise from wind blowing across the microphone's surface. Thus, while these results serve to raise awareness of the potential for adverse occupational

noise exposures received by snowmobile operators, better monitoring methods are needed to provide more precise estimates.

The latest and most recent winter-use plan for YNP, titled the 2012/2013 Winter Use Plan/Supplemental Environmental Impact Statement (Plan/SEIS), was approved by the NPS on 21 August 2013 (NPS 2013). This latest plan focuses on a daily number of "transportation events" in the park, instead of a total number of snow machines allowed in YNP each day. As defined in the 2012/2013 Plan/SEIS, a transportation event is defined as either one snow coach or on average a group of seven snowmobiles. The 2012/2013 Plan/SEIS will allow up to 110 transportation events in YNP each day with no more than 50 being characterized as snowmobile transportation events. Under the 2012/2013 plan, engine performance of snowmobiles and snow coaches will have to meet enhanced best available technology (E-BAT) requirements, which require lower engine exhaust and noise emissions than previous engine performance requirements.

Given that future winter-use plans will continue to evolve, it is anticipated that the results of this study will provide YNP administrators, charged with the development of future winter-use plans, important science-based information regarding noise exposures received by employees supervising snow machine traffic or riding snowmobiles. Having this information will allow for improved management of these types of occupational exposures and better protect employee health.

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