Yellowstone National Park
Winter Use Monitoring 2014-2020
Wyoming, Montana, Idaho

Yellowstone Center for Resources
National Park Service
Department of the Interior

Winter Use Monitoring: Summary of Findings 2014-2020

Prepared by Yellowstone National Park Environmental Quality and Compliance, Yellowstone Center for Resources, October 2021.

Executive Summary

Yellowstone's 2013 Winter Use Plan outlined a phased implementation of the new transportation event concept over several winter seasons. During the phased role out of the Winter Use Plan, National Park Service (NPS) staff conducted monitoring of selected affected resources, specifically wildlife responses to oversnow vehicles (OSV), the acoustic winter environment, and winter air quality. Current monitoring efforts, starting in 2014, are informed by previous monitoring efforts and scientific studies, research design is adjusted to match park capacity or as agreed upon in the adaptive management process.

The 2013 Supplemental Environmental Impact Statement (SEIS) modeled conditions for different alternatives using findings from over a decade of scientific studies (NPS 2011). Since implementation of the Winter Use Plan starting in 2014, the modelling forecasts have largely been proven correct.

- *Wildlife Response to OSVs:* Monitoring data from 2014 to 2019 shows 95% of wildlife in proximity (within 500 feet) to the groomed road corridor demonstrate no response or a "look & resume" response to oversnow vehicles. The sample size during this period of monitoring observed 1,105 groups of wildlife and 6,715 individual animals. Similar monitoring efforts prior to the SEIS in 2013, found roughly 91% of wildlife were observed to demonstrate no response or a "look & resume" response. Given the stability provided by the current winter use plan, the number of transportation events, snowmobile speeds, group sizes, and visitor behavior are unlikely to change, therefore, it is likely that wildlife response to OSVs will continue to follow observed patterns.

- *Air Quality:* Annual air quality data for the following indicators, carbon monoxide (CO) (CO maximum 1-hour, CO maximum 8-hour), particulate matter (PM2.5 maximum 24-hour), and nitrogen oxides (NOx)(1-hour NOx) indicate the park is operating below the from the National Ambient Air Quality Standard regulatory limits and within the stricter impact thresholds defined in the SEIS (Appendix A).

- *Soundscape and Acoustic Environment:* Annual acoustic data indicate that OSV impacts to the winter soundscape remain below levels monitored prior to 2013. Stricter Best Available Technology (BAT) standards implemented in 2015 (snowmobiles) and 2016 (snowcoaches) have reduced the percentage of time OSVs are audible, increased the noise-free-interval, and have been below long-term average sound levels at all monitoring sites. Individual events (helicopters, tracked snowcoach, snow grooming equipment, or mechanical noise) exceed the maximum sound level 75 dBAs, but average maximum levels are below 70 dBAs. Isolated singular sound events that exceed 75 dBAs will likely continue to occur even if incentivized Enhance-BAT (EBAT) OSV standards are met and widely adhered to by all commercial OSV operators.

- *OSV Levels:* Since implementation, transportation events have remained below the established capacity outlined in the Winter Use Plan. For example, the 2019/20 winter transportation event utilization rate was 71%. Although below maximum allowable levels, the number of transportation events and associated impacts from OSVs are likely to remain at current levels until the next round of concession contracts are bid.

Purpose

Since the National Environmental Policy Act (NEPA) planning process on Winter Use in Yellowstone concluded in 2013, and the final rule was implemented, Yellowstone National Park employees have conducted eight years of winter resource monitoring. Data collected through this monitoring effort was designed to inform current and future winter use management decisions, as well as to ensure OSV impacts to the Yellowstone winter environment remain within predicted levels of impact as defined in the Winter Use SEIS (NPS, 2013b). The most recent effort to review winter monitoring data was the Winter Use Adaptive Management Plan (WUAMP) in 2016.

This report summarizes the last eight years of winter use monitoring efforts to gauge the efficacy of the 2013 Winter Use Plan and take stock of current monitoring efforts. For comparison to previous winter use plans, data collection is organized according to pre-2013, and from 2014 onward.

Winter Use Background

The winter landscape of Yellowstone National Park is rugged, harsh and historically difficult to navigate. Access to the interior portions of Yellowstone was limited to traditional means of winter transportation (skis, snowshoes, and limited stock and sled use). Much like the automobile, motorized winter transportation, like snowmobiles and snowcoaches, fundamentally changed park operations and the visitor experience. The use of motorized vehicles in winter provides the public and park employees access to areas that cannot be reached using non-motorized means of transportation.

Commonly referred to as winter use, this motorized access to Yellowstone National Park during winter is historically contentious and has been discussed, argued, and litigated since plowing the park's roads in winter was first considered in the early 1930's. At its core, winter use mirrors the dual mandate outlined in the National Park Service Organic Act (1916). This tenuous balance between preservation and recreation led Yellowstone park managers, regional stakeholders, and the broader American public to consider over 12 separate winter management plans prior to 2013.

National Park Service Regulation 36 CFR 2.18 prohibits snowmobile use in national parks unless promulgated under a special use plan. Without a specific rule allowing their use, oversnow vehicles (OSVs) are prohibited from entering Yellowstone. In October of 2013, the final rule authorizing Yellowstone National Park's Winter Use Plan as outlined in the 2013 Supplemental Environmental Impact Statement (SEIS) and Record of Decision (ROD) was signed and a rule subsequently published in the Federal Register.

This rule replaced the former concept of a fixed maximum number of vehicles allowed in the park each day with a new, more flexible concept of management by transportation events. A maximum level of transportation events was established by type of OSV and allocations were distributed based on historic OSV usage levels by park entrance gate. Within the allowable number of transportation events, commercial tour operators have the flexibility to combine snowcoach and snowmobile trips in a way that protects park resources and responds to fluctuations in visitation demand. The final rule also established a new set of mechanical and manufacturing criteria to reduce noise and vehicle emissions, and incentivize innovation within the OSV industry.

Adaptive Management Framework and Monitoring Requirements

To address the complexity and contentious nature of winter use, the 2013 SEIS embedded elements of adaptive management into the administrative framework of the plan. Loosely, adaptive management can be defined as "the iterative cycle of decision making, monitoring, and assessment, repeated over the course of a project, leads gradually to a better understanding of resource dynamics and an adjusted management strategy based on what is learned" (Williams and Brown 2012). The primary goal of Yellowstone's Winter Use Adaptive Management Program (WUAMP) was to ensure that associated environmental impacts from OSV use did not exceed the impacts predicted in the SEIS.

The SEIS planning process identified and defined the desired conditions for winter use across a spectrum of categories. Monitoring plans and objectives were further detailed in the adaptive management plan to ensure selected indicators remained within the bounds of the predicted impacts. As part of the multi-disciplinary WUAMP, NPS staff led working groups that developed monitoring protocols for potentially affected resource areas identified within the SEIS, which included: wildlife responses to OSVs, soundscape and acoustic qualities, and air quality. These working groups were largely composed of subject matter experts and interested parties that could inform the methodologies to assess the condition or status of the resource of concern. Following the publishing of the final WUAMP in 2016, the adaptive management working groups largely disbanded and now convene infrequently or when specific management actions/adjustments are considered.

Current Winter Use Plan

The final rule for winter use authorized motorized access to Yellowstone under the following oversnow vehicle usage levels and technological restrictions (Table 1):

- Up to 110 daily transportation events.
  - 46 reserved for commercially guided snowmobiles.
  - 4 reserved for non-commercially guided snowmobiles.
  - No less than 60 events reserved for snowcoaches, but no more than 106.

- The snowmobile "best available technology" standards were revised during the SEIS process and implementation was phased in over several winter seasons. New BAT standards, as of 2015, allow up to 10 snowmobiles per transportation event, with group size averaging 7 over the duration of the winter season.
  - Current BAT snowmobile standards are as follows: noise maximum of 67 dBA at cruising speed[1] and tailpipe pollutants: and emissions standard that do not exceed 90 g/kW-hr of CO and 15 g/kW-hr of hydrocarbons.

- Starting in 2016, BAT standards now apply to snowcoaches.
  - Current BAT snowcoach standards are as follows: noise maximum 75 dBA and tailpipe emission compliant with EPA Tier 2 emission standards.

- Voluntary "Enhanced BAT" (E-BAT) certification will allow commercial tour operators to increase the average numbers of snowmobiles per event from 7 to 8 and snowcoaches from 1 to 1.5 across the season. Currently, snowmobiles do not meet E-BAT standards.

- One non-commercially guided group of up to five snowmobiles is permitted to enter through each of the four park entrances every day.

The following adjustments have been made as part of the Adaptive Management framework:

- Use of low-pressure tire (LPT) snowcoaches started in winter of 2017. LPT equipped snowcoaches are more fuel efficient, produce less noise, and reduce overall cost to the commercial outfitter when compared with traditional, track-based snowcoaches. Snow rut monitoring was conducted for a two-year period to evaluate the appropriateness of the LPT snowcoaches and this monitoring was discontinued upon adoption of the adaptive LPT management strategy.

- In 2020, the park authorized extension of the East Entrance winter season to match the rest of the park. Commercial and permitted non-commercial snowmobiles may now use Sylvan pass from December 15 to March 15 as conditions allow.

- Reducing the daily operation period at the South Entrance by 1-hour. This allows NPS personnel time to conduct conditions and safety assessments of the South Entrance road prior to the commercial tour departures from Flagg Ranch.

- One South Entrance concession contract (two transportation events) was awarded but not fulfilled. The transportation events were subsequently split between the West and South Entrances to provide snowcoach shuttle service to the Old Faithful Snowlodge.

Table 1. Allowable OSVs per day by transportation events

	Max # of transportation events	Max # OSVs allowed	Average # OSVs allowed	Max Average # OSVs if E-BAT
Snowcoaches	60	60	60	120
Snowmobiles	46	460	322	368
NCGSAP	4	20	20	20
Sum	110	540	402	488

[1]As measured using the A scale (dB(A)) according to the 1985 version of the Society of Automotive Engineers (SAE) J192 test procedures.

Oversnow Vehicle Usage since Winter of 2013-2014

The final rule fixed the capacity for winter motorized vehicle use within Yellowstone under the transportation event concept. A maximum of 110 transportation events was established and OSV levels cannot exceed the thresholds outlined in the final rule (Table 1). The final rule also included flexibility to meet consumer demand by exchanging snowmobile events for snowcoach events, as long as the total number of transportation events remained below 110[2]. Additionally, the final rule authorized up to 10 snowmobiles per transportation event, with group size averaging 7 over the duration of the winter season.

The SEIS used the maximum numbers (110 events and 540 OSVs, Table 1.) when modeling predicted impacts. Since implementation, transportation events have remained below the maximum established capacity outlined in the Winter Use Plan. The transportation event utilization rate was 71% for the winter of 2019/2020[3]. The primary reason for this low utilization rate is that commercial OSV outfitters intentionally do not use some transportation events in order to balance the averages for the winter (i.e., 1.5 EBAT snowcoaches & 7 snowmobiles per event). Lack of early winter snow pack and low consumer demand at the beginning and end of the winter season also contributed to a lower than maximum utilization rate. Transportation utilization is likely to remain at current levels until the 10-year winter use concessioner contracts expire and are re-bid. Therefore, OSV impacts to the Yellowstone environment have likely stabilized below the maximum predicted levels.

Administrative use of OSVs is included in the total impacts. Yellowstone staff and park concessioners are authorized to operate OSVs for various administrative purposes (grooming operations, law enforcement, emergency medical services, general maintenance, etc.) under the final Winter Use Plan (NPS 2013b). Some administrative OSV (grooming or emergency response) use occurs after daylight hours. However, administrative OSV use was included in the SEIS as part of the cumulative impacts and therefore monitored even though administrative OSVs are not restricted by the transportation event concept like commercial OSVs.

Wildlife Monitoring

A main point of contention during the litigation era of winter use in Yellowstone concerned wildlife responses (direct/indirect) to winter operations, primarily oversnow vehicles. One early, if not initial catalyst for concerns associated with winter use, was a lawsuit filed by the Fund for Animals in 1997 that argued the groomed winter roads facilitated bison migration outside the park boundaries, leading to large scale exodus during excessively harsh winters and greater exposure to hunting and administrative population reductions. Several studies initiated in 1997 and 2003 (Bruggeman 2007a and Bruggeman 2007b) found little evidence to support the hypothesis that bison increasingly used and relied upon the groomed road corridors during winter. Following that law suit, park employees and other researchers initiated a variety of monitoring projects and studies focused on how wildlife respond to motorized oversnow vehicles in Yellowstone.

Summary of Key Findings before 2013

The "Scientific Assessment of Yellowstone National Park Winter Use March 2011," and the "Affected Environment," chapter of the SEIS provide an in-depth review of the scientific understanding of the environmental impacts and conditions central to the final rule (NPS 2011 and NPS 2013b). Scientific studies explored wildlife habituation to OSV use, energetic benefits from using groomed OSV roads, interaction with wildlife from guided groups versus unguided groups, and population and demographic trends compared to OSV usage levels. Principle among those efforts was several monitoring projects aimed at understanding wildlife response (bison, elk, trumpeter swans, bald eagles, etc.) to disturbance along primary over snow transportation routes to motorized winter recreation. By the completion of the SEIS in 2013, the elk population along the Firehole and Madison Rivers was significantly reduced by wolf predation such that monitoring for disturbance from OSVs was no longer relevant. Nevertheless, the SEIS summarized,

"Collectively, all species observed in Yellowstone exhibited non-travel responses (no response, look resume, alert response) to OSV use at least 90 percent of the time. All species demonstrated active responses (travel, flight, defensive) less than 10 percent of the time. Defensive responses (charging) to OSV-related human activities were rare (Borkowski et al. 2006; McClure et al. 2009; White et al. 2009)."

With over a decade of survey data, the SEIS and final rule concluded, "Managing by transportation events would

[2]Snowcoach events cannot be exchanged for snowmobile events. The 50 total snowmobile events are a fixed capacity limit as are the 480 maximum per day if outfitters maximize their snowmobile events.

[3]Winter transportation event records were not collected in a useable form to calculate utilizations rates prior to 2019/2020.

provide for fewer intervals of use and fewer disturbance events for wildlife within the park compared to the other action alternatives" (SEIS, 2013). The cumulative impacts to wildlife would be long-term minor to major adverse, to which the selected alternative in the final rule would contribute minimally (Appendix A). During the initial phase of the WUAMP, wildlife response to OSVs was selected as the primary indicator to monitor and any increase in the rate of active response (greater than 10%) would be notable.

As required under NEPA, the SEIS also examined oversnow vehicle impacts on threatened and endangered species (Lynx, Wolverine, Gray Wolf, Grizzly Bear) and concluded impacts to be minorly adverse. Monitoring objectives were not established for these species of concern but addressed if general winter use conditions changed or management practices were altered through the WUAMP. Most recently, in October of 2020, the winter season dates were extended for the East Entrance Road. As part of the NEPA compliance for this adjustment, the park consulted the United States Fish and Wildlife Service (USFWS) concerning potential impacts to Lynx populations. USFWS concurred with Yellowstone's conclusions, which also aligned with conclusions in the SEIS, that impacts under the current final rule and as amended in 2020 "may affect, but not likely to adversely affect" Canadian Lynx populations (NPS 2020).

Summary of Findings 2014-present

Each winter since the final rule was signed, NPS staff have monitored wildlife responses to OSVs during the winter operating period of December 15 to March 15. Staff conduct an average of 45 surveys each winter. Winter wildlife surveys are conducted in teams of two employees. Employees travel via snowmobile from Mammoth and interior locations to survey sites. Surveys are conducted Monday-Thursday, and up to seven days a week as staffing permits.

Monitoring surveys of wildlife responses to OSV occur along three groomed road segments in areas of both low and high intensity human and wildlife use. NPS employees focused their efforts on monitoring the responses of bison, elk, bald eagles and trumpeter swans owing to the proximity and/or perceived sensitivity of these species to motorized recreation activities during winter. Other, less prevalent species (coyote, fox, bobcat, and wolf) were monitored on an opportunistic basis. Multiple collaborative discussions between the NPS and WUAMP Winter Wildlife Working Group members concluded that distinguishing wildlife responses between snowcoach groups and snowmobile groups is not necessary or feasible and ceased after the winter of 2013/14. All wildlife reactions are calculated as responses to OSVs in general.

Since the winter of 2013/14 YCR staff have observed the responses of 1105 groups of wildlife and 6715 individual animals to the presence of OSVs. Overall, the responses of all wildlife species observed to OSVs and associated humans were as follows: 83% of the observed responses by all groups of wildlife were categorized as no apparent response, 11% look/resume, 3% travel, 1% attention/alarm, and 1% for flight and defense/charge combined[4]. The sample sizes are too low to estimate response percentages each winter for species other than bison and trumpeter swans (Table 2).

Conclusion

Monitoring data since 2014 shows 95% of bison in proximity (within 500 feet) to the groomed road corridor demonstrate no response or a look & resume response to oversnow vehicles. This is based on 7 years of monitoring and a relatively large sample sizes (1105 groups of wildlife and 6715 individual animals between 2014-2019). This

[4]The data in this table was extracted from annual reports prepared by Yellowstone National Park Staff from 2003-2019. Reports available by request.

Table 2. Percentage of bison and swan responses to OSVs pre-2013 and 2014 to present.[4]

Bison Responses	Average 2003-2009	Average 2014-2019	Swan Responses	Average 2003-2009	Average 2014-2019
None	78%	89%	None	64%	67%
Look/ Resume	12%	6%	Look/ Resume	16%	15%
Travel	5%	2%	Travel	10%	15%
Alarm/ Attention	3%	1%	Alarm/ Attention	8%	1%
Flight/ Defense	2%	2%	Flight/ Defense	2%	3%
Sample Size	672	963	Sample Size	265	90
% Active Responses	10%	5%	% Active Responses	20%	19%

% active responses = sum of travel, alarm/attention, and flight/defense categories

percentage is below observed values from previous studies that contributed to the impact analysis in the SEIS (2003-2009), where roughly 90% of bison were observed to have a no response or a look and resume response.

Direct comparison between previous studies and current monitoring efforts proves difficult due to changes in methodology, sample size, and observers. However, under the current Winter Use Plan, the percent of bison and swans that demonstrate an active response to the presence of OSVs is lower than observed percentages from previous studies. One conclusion is that the current Winter Use Plan is as effective or more effective at reducing impacts to wildlife as previous winter use plans. The other conclusion is that the wildlife monitoring strategy carried forward during the Winter Use Adaptive Mangemange Program may not be sensitive enough to detect stress caused by oversnow vehicles, or as the recent monitoring effort demonstrates, there is not a significant percentage of animals that actively respond to the presence OSVs.

Given the stability provided by the current winter use plan, the number of transportation events, snowmobile speeds, group sizes, and visitor behavior are unlikely to change, therefore, it is likely that wildlife response to OSVs will continue to follow observed patterns, even during dates when transportation events are maximized.

Air Quality

Air quality has been a major concern of winter use dating back to at least the 1970s. All internal combustion engines produce air pollutants, such as carbon monoxide (CO), particulate matter with diameters less than or equal to 2.5 micrometers (PM2.5), nitrogen oxides (NOx), hydrocarbons, and volatile organic compounds. Early snowmobiles were two-stroke machines, which produce greater pollutant emissions, namely CO and PM 2.5, when compared to modern four-stroke machines. Snowmobile numbers increased in the years prior to active OSV management (2002/2003), so did the impacts to the park's air quality. Idling snowmobiles at congested areas, such as entrance stations, warming huts, and park attractions caused problematic levels of air pollution.

The park began monitoring winter air quality in 1998 at the West Entrance. In 2008, the State of Montana began using the equipment located at the West Entrance monitoring station for state air quality analysis. Yellowstone later added a second permanent monitoring station at Old Faithful in 2002.

The Clean Air Act (CAA) requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) thresholds for acceptable levels of pollutants that are harmful to human health and the environment (Table 3). The NAAQS thresholds are based on the latest science and are set to reduce the levels of pollutants that are in the air, anywhere in the United States. However, since environmental and health conditions can be impacted at lower levels than the NAAQS, State and park standards may be stricter than the NAAQS, the SEIS used both the NAAQS thresholds as well as a stricter standard. "However, the air quality intensity definitions from the SEIS

reflect the importance of maintaining excellent air quality in parks, not merely complying with the NAAQS." (NPS 2013b)[5].

The SEIS used a series of predictive modeling exercises and concluded that OSVs would contribute minor impacts for most air quality metrics and moderate impacts for NOx. In accordance with the NAAQS and the final rule on winter use, Yellowstone monitors the following indictors at both the West Entrance and Old Faithful sites: CO, (PM2.5), and 1-hr (NO2) Any increasing trends towards NAAQS thresholds would trigger mitigation measures under the adaptive management program.

Summary of Key Findings Before 2013

Air quality monitoring data exhibited a positive difference in the winter CO and PM 2.5 levels when comparing the winters dominated by the presence of 2-stroke snowmobiles versus winters with only 4-stroke BAT snowmobiles (NPS 2021). The requirements of the managed use era and the introduction of 4-stroke BAT snowmobiles in 2003 reduced measured levels of CO and PM 2.5. At the West Entrance Station, the mean second maximum winter CO prior to 2003 was 14.3 ppm (peak 17.4 ppm) which was reduced to a mean value of 3.1 ppm from winter 2003-2004 to 2011; a 78% reduction in CO. The PM 2.5 followed a similar reduction in concentrations at the West Entrance with the PM 2.5 of greater than 16.9 ug/m3 going down to a mean of 7.1 ug/m3; a greater than 57% reduction in PM 2.5 (NPS 2011).

The SEIS utilized the data collected between 2002 to 2011 to conduct a series of modeling exercises and concluded that OSVs would contribute minor impacts for most air quality metrics and moderate impacts for 1-hr nitrogen dioxide (Table 3 – highlighted row "50-79"). Emission of NOx (a measure of nitrogen oxide and nitrogen dioxide) were a particular concern during the SEIS process, even though 4-stroke BAT snowmobiles reduce CO and PM substantially compared to 2-stroke machines, NOx is increased making wintertime emissions of NOx in Yellowstone a greater human health risk as well as contributing to ozone and particulate matter formation. Starting when the NOx analyzer was installed at the West Entrance, NOx emissions were measured in the form of the 1-hr maximum NO2. The NOx monitoring analyzer was only in place for three years prior to the 2013 SEIS. The three-year average of the 2009-2012 winter use seasons for the 98th percentile of the 1-hr maximum NO2 emissions was 36% of the NAAQS standard.

Summary of Key Findings 2014-present

Air quality monitoring data collected at West Yellowstone and Old Faithful indicates the park is operating well below the NAAQS thresholds and at or below predicted impacts in the SEIS (Table 3 & Appendix A). Since 2003, the levels of CO and PM 2.5 have been reduced significantly. This highlights the effectiveness of the 2013 Winter Use Plan where BAT standards were strengthened and applied to all OSVs, speed limits were reduced for all OSVs, and limits on overall OSV number were applied under the transportation event concept.

Carbon Monoxide

From the winter of 2014 to 2020, both the maximum 1-hour CO and maximum 8-hour CO levels have remained below the NAAQS standards and within the predicted impact levels from the 2013 SEIS (Figure 1). This report focuses on the indicators monitored in regard to the NAASQ standard. For CO, the average 1-hour and 8-hour maximum values are reported for each winter since air quality monitoring began in 2003 (Figure 1). Since implementation of the Winter Use Plan, both 1-hour and 8-hour levels of CO have remained below those levels measured between 2003-2013 and also below the NAAQS standard[6].

Particulate Matter 2.5

The maximum of 24-hour PM2.5 value corresponds to the day that had the highest mean concentration out of the 91-day (92-day for leap years) winter use season. The 98th percentile value is calculated in order to compare it to the NAAQS standard, which is the 98th percentile value, averaged over three years (NPS 2021). At both Old Faithful and the West Entrance monitoring locations, the 98th percentile of the 24-hour PM 2.5 has decreased since 2002 (Figure 2). The period from 2014 to 2020 shows this trend continuing.

Nitrogen Dioxide and Nitrogen Oxides

To compare NO2 and NOx levels between locations, an additional NO/NO2/NOx analyzer was added at the Old Faithful air quality monitoring site for the winter of 2019/2020. At the time of this report, there is no discernible trend in NOx emissions from 2009 – 2020 at the West Yellowstone monitoring station. However, one-hour maximum NO2 concentrations measured since 2014 indicate park levels are below the NAAQS threshold (Figure 3). Despite being below NAAQS thresholds, it is important to note that rural and remote locations, such as Yellowstone, would be expected to have much lower NOx

[5]Traffic variability can cuase fluctuations in pollutant concentrations, such as the high values from 2012-2013.

Table 3. Park-specific ranges used to define impact level.[6]

Impact level	1-hr Max Carbon Monoxide (ppm)	Max 8-hr Avg Carbon Monoxide (ppm)	98th percentile of 24-hr PM2.5 (µg /m3)	98th percentile of 1-hr Nitrogen Dioxide (ppb)
Negligible	0 - 0.2	0 - 0.2	0 - 5	0 - 1
Minor	0.3 - 17.5	0.3 - 4.4	6 - 20	2 - 49
Moderate	17.6 - 27.9	4.5 - 7.1	21-28	50 -79
Major	28.0 - 35.0	7.2 - 9	29 -35	79 - 100

Note: Color used to emphasize SEIS impact definitions.

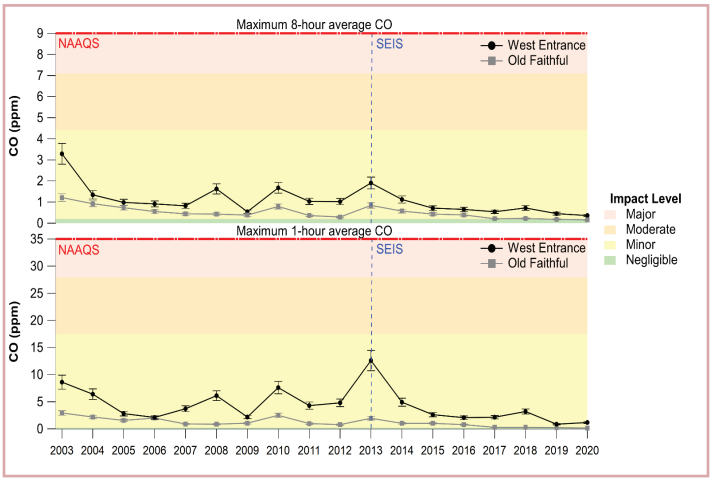


Figure 1. Wintertime Carbon Monoxide levels at West Entrance and Old Faithful locations.

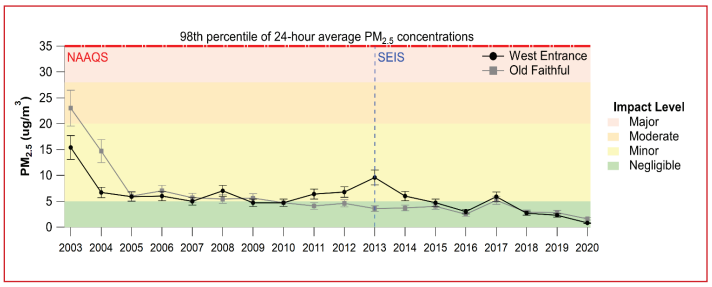


Figure 2. Wintertime Particulate Matter 2.5 levels at West Entrance and Old Faithful locations.

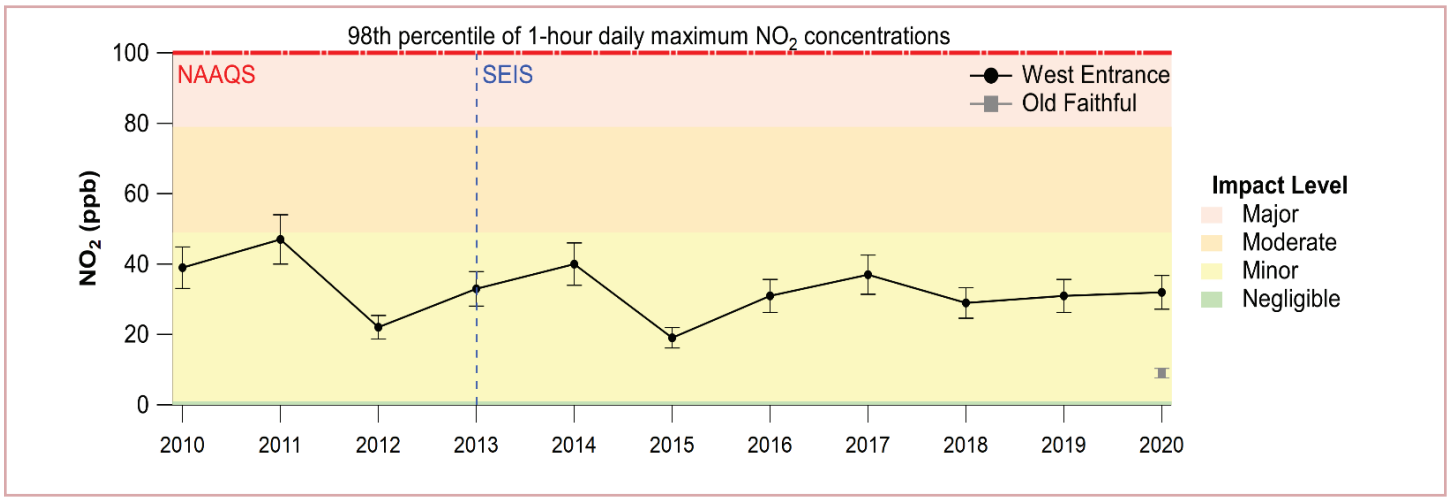


Figure 3. Wintertime NO2 levels at West Entrance and Old Faithful locations.

levels. However, "…the NO, NO2 and NOx levels measured at both Yellowstone sites are more representative of urban areas (i.e., Old Faithful) or highly polluted areas (i.e., West Yellowstone) (NPS 2021)."

Conclusion

Since 2002, the winter air quality in Yellowstone has improved dramatically. Air quality data reported in the 2021 multi-year report indicates the park is operating under the NAAQS and within the impact definition thresholds selected in the SEIS (Appendix A) (NPS 2021).

One potential gap in air quality monitoring is the location of the monitoring sites. Air quality monitoring is conducted at fixed locations. Oversnow vehicle emissions of NOx increase when vehicles speeds increase. The possibility exists for NOx levels to be higher along the OSV travel corridors when OSVS are moving at speed, than the

[6]The magnitude of noise is described by its sound pressure. Because the range of sound pressure varies greatly, the logarithmic scale decibel (dB) is used to relate sound pressure. Sound pressures described in dBs are often defined in terms of frequency-weighted scales. A sound level measurement is usually expressed as an A-weighted average energy value over a specified time interval. (NPS, 2013b)

levels recorded at the West Yellowstone and Old Faithful monitoring locations where vehicles travel slowly or are stopped. Placing temporary air quality monitoring stations along OSV travel corridors would allow the park to monitor NOx emissions where OSVs are moving at speed.

Soundscapes and Acoustic Environment

The natural soundscape is the aggregate of all the natural sounds that occur in parks, together with the physical capacity for transmitting natural sounds. Natural sounds are intrinsic elements of the environment and protected by the NPS Organic Act. Soundscapes in Yellowstone consist of both natural sounds and non-natural noises. Bird and animal calls, running water, wind, and thermal activity (e.g., geysers and hot springs) contribute natural sounds to Yellowstone. Non-natural noises have included those produced by snowmobiles, snowcoaches, snow groomers, aircraft, human voices, wheeled vehicles, and building operations. During public scoping meetings prior to the SEIS, commenters raised concerns about the impact oversnow vehicles had on the winter soundscape.

The 2013 SEIS hypothesized that under the transportation event concept, "…grouping OSVs in discrete groups and proactively limiting the total number of groups allowed entry each day into the park, the park would be able to decrease disturbance to wildlife and *increase the time that natural quiet predominates the wintertime landscape*" (NPS 2013b). Impacts could vary from season to season depending on the distribution of transportation events and whether operators choose to use quieter vehicles to take advantage of an increase in the allowable average group size.

Researcher conducting snowcoach sount testing. - NPS Photo

Human perception of sound is complex and often depends on the setting and environmental conditions present. Soundscapes are highly variable over time. NPS staff have monitored Yellowstone's winter soundscape since the 2003/2004 winter season. The following indicators were selected during the SEIS planning process and carried forward by the WUAMP: percent time audible, the noise free interval, and the sound level recorded at specific locations (maximum noise event and the average for a period of time). Although motorized use is authorized for 14 hours out of the 24-hour day, the period between 8 a.m. and 4 p.m. was selected as the period of analysis to compare impacts across winters.

Since 2003, sound monitoring in Yellowstone has utilized 16 different winter locations. The Old Faithful Weather Station (OFWS) and the Madison Junction 2.3 (MJ23) locations are the only two longitudinal locations where acoustical data has consistently been collected. During the winter of 2014/15, a roadside location south of Grant Village was added along the South Entrance travel corridor. Data is collected in Yellowstone National Park during the three-month winter use season, December 15-March 15.

Summary of Key Findings before 2013

Audibility

The percent time audible for each sound source was calculated using 10-second samples every four minutes as a surrogate for all periods of the day resulting in a total of 120 10-second sample points per day. 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

Lmin —The lowest sound level measured in the analysis period.

Lmax—The maximum sound level measured in the analysis period.

L10 – The L10 values communicate the sound levels exceeded 10% of the time, or 90% of the sound levels below these values.

possible 120 was used to calculate the percent time audible for each sound source.

Prior to the implementation of snowmobile guiding, limits on daily snowmobile numbers, and BAT requirements during winter 2002/2003, the average percent time OSVs were audible at the Old Faithful Weather Station was close to 93 percent. The percent time audible was reduced to an average of 63 percent during the winters from 2003/04 to 2010/11 (NPS, 2013b).

Noise Free Interval

The Noise Free Interval (NFI) is a metric used to measure the uninterrupted periods of time when only silence or natural sounds are audible. The NFI is the silence between discrete OSVs that pass by a single monitoring location. The SEIS examined the NFI of OSVs from 2005 to 2011 across a range of sites. Observers recorded the start time when OSVs were first heard and stop time when they could no longer be heard. A total of 1,012 events were retained for analysis from this time period at ten different locations around Yellowstone. Snowmobile transportation events were heard, on average, for 2 minutes and 36 seconds; whereas, snowcoach transportation events were heard for an average of 2 minutes and 21 seconds (NPS 2013b). NPS winter use planners used the relatively small, 15 second difference in NFI to further justify the transportation event concept.

Sound Level

Maximum sound levels at the Old Faithful Weather Station and Madison Junction 2.3, which are heavily traveled locations, were close to or exceeded 75 dBA indicating this metric should continue to be monitored and the park should evaluate additional BAT methods to reduce these impacts. Snowcoaches contributed most of the loudest events at these locations. The L10 levels at Old Faithful Weather Station and Madison Junction 2.3 monitoring locations were roughly 45 dBA (NPS 2013b) indicating levels should continue to be monitored and the park should evaluate additional BAT methods to reduce these impacts.

Table 4. Summary of notable impact levels prior to 2013.

Indicator	Observed values prior to 2013 SEIS
Percent Time Audible	63 % (8-year average)
Noise Free Interval	2 min 36 sec +/- 15 secs (7-year ave)
Lmax (Maximum Sound Level)	>75 dBA

The 2013 SEIS and Final Rule for Winter Use established maximum sound levels for snowmobiles and snowcoaches. Audibility and noise-free-interval were carried forward as important acoustic indicators from the WUAMP working groups. The values in Table 4 serve as important thresholds, if any acoustic indicator varies from the trends used during the pre-2103 SEIS predictive modeling, then the park could seek alternative management solutions under the WUAMP.

Summary of Key Findings 2014-present

Audibility

Based on all monitoring data since the winter of 2014/2015, the average percent time audible was 53% for developed areas and 43% for travel corridors. The adoption of stricter BAT standards in 2015 (67 dBA snowmobiles) and 2016 (75 dBA snowcoaches), as well as the widespread use of rubber low-pressure tired snowcoaches has contributed to improved audibility (Table 5). The percent time that snowmobiles were audible continues to be more closely associated with the number and distribution of transportation events rather than the total number of individual snowmobiles (Rodman, 2019).

Noise Free Interval

Since 2014, along the busiest oversnow corridor from West Yellowstone to Old Faithful, the average noise free interval (NFI) between 8 am and 4 pm was 2 minutes and 48 seconds. This represents an improvement by an average

Table 5. Comparison of percent time audible of OSVs at Old Faithful Weather Station (OFWS) and Madison Junction (MJ2.3) (Pre 2013 and Post 2013).

	OFWS	MJ 2.3		OFWS	MJ 2.3
2004	61	25	**2014**	60	47
2005	69	61	**2015**	49	30
2006	67	55	**2016**	57	45
2007	68	59	**2017**	50	43
2008	68	53	**2018**	53	47
2009	55	47	**2019**	47	46
2010	55	54	**Average**	53	43
2011	61	51	**SD**	5	7
Average	63	51			
SD	6	11			

increase of 12 seconds of silence during the period of analysis from previous winter use plans.

Although there is an average net increase of 12 seconds of silence, between 8 am and 4 pm, when compared to the years prior to the current winter use plan. The average NFI since the promulgation of the current winter use plan demonstrates a decreasing trend (Figure 4) and potentially indicates a degrading acoustic environmental with fewer periods of silence. This is likely the result of transportation events travelling in close proximity without clear separation from one event to the next, or a wider distribution of transportation events throughout the day, or increases in administrative traffic. Additionally, the average annual NFI at the Grant Village monitoring location has returned erratic results and there is no discernible trend at this time (Figure 4).

Further monitoring and analysis of the Noise Free Interval is warranted to understand recent trends.

Sound Level

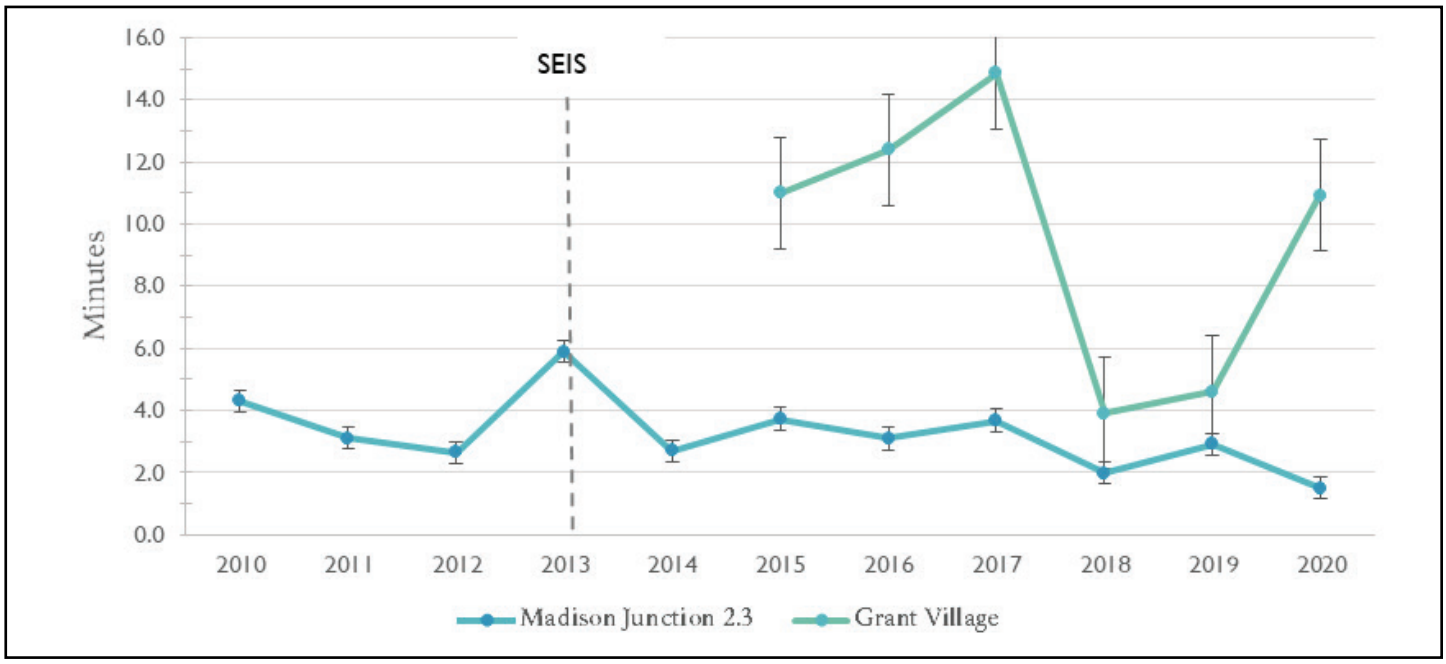
The maximum sound level (Lmax) measured each day includes both natural and non-natural sounds. Under the new Winter Use Plan, BAT standards established a maximum noise rating of 75 dBA for snowcoaches and 67 dBA for snowmobiles. These values can be inferred to be the maximum sound level during winter. The maximum sound levels of oversnow vehicles often exceeded 70 dBA along the groomed travel corridor at the Madison Junction 2.3 monitoring site and the Old Faithful Weather Station site. For example, the highest documented sounds for the 2018/2019 season exceeded 75 dBA (Rodman, 2019). The source for these singular events often occurred outside the 8am to 4pm period of analysis and were isolated events that included a helicopter landing, the snow groomer, people shouting, and mechanical noise in proximity to the instrumentation.

Although not a threshold, the L10 values are an appropriate indicator of the overall sound level trend. The L10 values communicate the sound levels exceeded 10% of the time, or 90% of the sound levels are below these values. Under the current Winter Use Plan, the L10 values would be expected to decrease compared to previous winter use plans due to stricter BAT noise standards for snowmobiles, the implementation of BAT standards to snowcoaches, as well as the incorporation of Low-Pressure Tire snowcoaches. From 2014 to 2019, L10 values were lower or at similar levels than previously observed L10 values prior to 2013 (Figure 5). One notable difference is the L10 values recorded during the winter of 2019/2020. Here the L10 values were more indicative of the acoustic conditions from previous winter use plans. This increase may be an anomaly or indicative of a shift in acoustic impacts from OSVs. Further monitoring and analysis are warranted to understand recent sound levels.

Conclusion

Annual acoustic data indicate that impacts form oversnow vehicles on the winter soundscape remain below levels monitored prior to 2013 and within predicted impacts from the SEIS. Stricter Best Available Technology (BAT)

Figure 4. Average Noise Free Interval.



standards implemented in 2015 (snowmobiles) and 2016 (snowcoaches) have reduced the overall percent time audible, increased the noise-free interval, and been below long-term average sound levels, as communicated by the L10 values. The recent winter soundscape continues to demonstrate the acoustic benefits of the managed use era for Winter Use in Yellowstone.

Previous acoustic studies, as well as current acoustic monitoring efforts, selected 8 am to 4 pm as the period of analysis in order to compare impacts from year to year. This period of analysis may not be sensitive to all sources of sound or acute impacts. The average maximum sound levels are below 70 dBAs. However, individual events (helicopters, tracked snowcoach, grooming machines, or mechanical noise), often outside the period of analysis, exceed the maximum sound level of 75 dBAs. Isolated singular sound events that exceed 75 dBAs will likely continue to occur even if incentivized Enhance-BAT (EBAT) OSV standards are met and widely adhered to by all commercial OSV operators.

Another example where the 8am to 4 pm period of analysis may lack sensitivity to all acoustic impacts is the percent time audible indicator (Appendix B, Rodman, 2019). A person standing at the Madison Junction 2.3 site between 9 am to 10 am will hear noise from OSVs 78% of the time. However, that person would only hear OSV noise 19% of time between noon and 1 pm. This represents the established bimodal pattern of commercial OSV tour routes from West Yellowstone to Old Faithful and back. The impact on the visitor experience and the winter soundscape is drastically different between the two time periods, and not fully captured by the average percent time audible for that location between 8am to 4 pm, which is 46%.

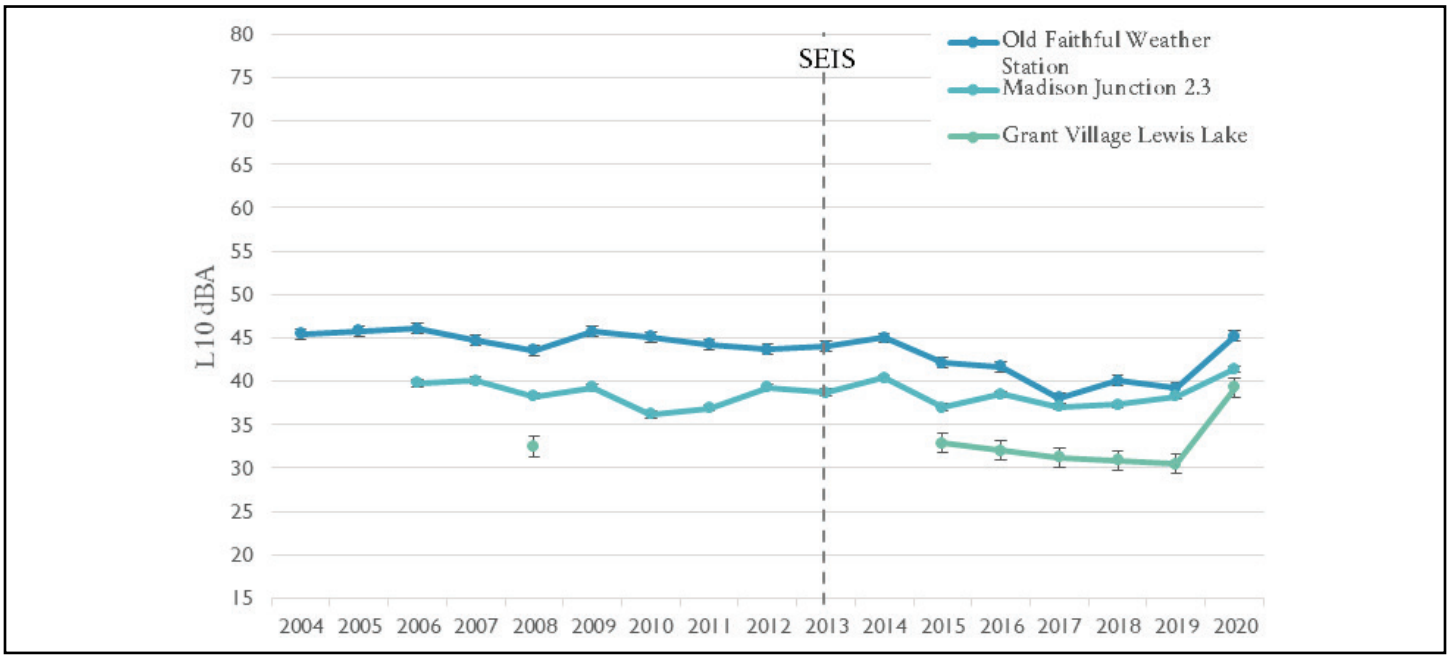
Similar to the planning efforts prior to the 2013 SEIS, the soundscape monitoring program may benefit from revised public scoping or a new qualitative visitor survey to better understand visitor expectations for the Yellowstone winter soundscape.

Discussion

The 2013 SEIS and subsequent final rule for Winter Use represent a seminal moment for winter use in Yellowstone. The inclusion of adaptive management principles and a commitment to monitoring resource impacts result in responsible management and focus our efforts on ensuring we detect changes that result from winter use activities. The 2013 SEIS and final rule on Winter Use did not define thresholds for each resource indicator, relying instead on the use of monitoring to predict trends and identify key deviations from norms. This report was prepared to evaluate the efficacy of the existing monitoring tools in their ability to be sensitive to those trends.

The SEIS used the existing scientific understanding at the time, in conjunction with predictive modeling to assess potential impacts of the transportation event paradigm. Seven years later, monitoring results seemingly validate the predictive modeling used in the SEIS. Broadly stated, indicators across the affected resources of wildlife, air quality, and soundscape and the acoustic environment

Figure 5. L10 values at Madison Junction 2.3. Old Faithful Weather Station, and South Entrance Road.



follow or are below the trend pre-2013. The winter monitoring program has shown that rule is working and is protective of resources consistent with the impacts predicted within the SEIS.

Some measures are not showing a level of sensitivity that would require annual monitoring. For example, wildlife monitoring has consistently shown similar response levels over the years, indicating the methodology is not sufficient to detect subtle responses or that wildlife are not being impacted. Wildlife response to OSVs will likely continue to follow observed patterns from the last 20 plus years of observation. Advances in technology point to using other measures that would detect change with greater sensitivity and will be evaluated as we discontinue the existing wildlife monitoring methods.

Abiotic measures of Air Quality and Soundscape should continue. Definitive thresholds exist for Air Quality and are important to carry forward in order to understand the contributing value of OSVs as a source locally. Soundscape (specifically % time audible, NFI, Lmax, & L10) values continue to provide information relative to impacts associated with number and distribution of transportation events. This information may reveal mechanisms to reduce impacts by changing components of transportation management.

Acknowledgements

Each winter, NPS employees with the Yellowstone Center for Resources brave the cold, harsh winter conditions of Yellowstone's interior, snowmobiling many hundreds of miles, fighting whiteout conditions, dodging bison, and bracing against sub-zero temperatures. These dauntless employees have compiled an extensive dataset that provides a unique opportunity to evaluate a park wide management plan not only in its current form, but against 20 years of proceeding oversnow vehicle use. The park owes Ann Rodman and her physical science team, as well as Brian Teets and the wildlife survey crew a huge measure of gratitude. Without their dedicated efforts, this report would not exist. The NPS Air Resources Division and Mike Tercek and Skip Ambrose provide essential support in analyzing the massive amount of air quality and soundscape data, respectively. Another measure of appreciation is extended to the army of contributors to the original SEIS/ROD, Final Rule and WUAMP.

Appendix A. Impact Level Definitions from SEIS

The SEIS defined levels of impact per each affect environment and assessed that impact based on the existing science at the time.

Affected Resource - Wildlife

Negligible: There would be no observable or measurable impacts of consequence to individual native species, populations, or their habitats.

Minor: Impacts on individual native species, populations, or their habitats would occur but would not be readily apparent. Responses by relatively few individuals could be expected. Some impacts might occur during feeding, reproduction, or other critical periods for a species, but would not result in injury or mortality. Small changes to local population numbers, population structure, and other demographic factors might occur but would be difficult to discern from natural population fluctuations. Sufficient habitat in the park would remain functional to maintain a sustainable population in the park.

Moderate: Impacts on individual native species, populations, or their habitats would be small but readily apparent. Responses by individuals could be expected, with some negative impacts during feeding, reproduction, or other critical periods or in key habitats in the park and result in harassment, injury, or mortality to one or more individuals. However, sufficient population numbers and habitat in the park would remain functional to maintain a sustainable population in the park.

Major: Impacts on individual native species, populations, or their habitats would be largescale and readily apparent. Responses by many individuals would be expected, with negative impacts during feeding, reproduction, or other critical periods or in key habitats in the park. Impacts would occur during critical periods of reproduction or in key habitats in the park and result in direct mortality or loss of habitat. Local population numbers, population structure, and other demographic factors might experience large-scale changes.

Affected Resource – Air Quality

Impact level	1-hr Carbon MoNOx ide (ppm)	8-hr Carbon MoNOx ide (ppm)	24-hr PM10 (ig/m3)	24-hr PM2.5 (ig/m3)	1-hr Nitrogen Dioxide (ppb)
Negligible	0 - 0.2	0 - 0.2	0 - 11	0 - 5	0 - 1
Minor	0.3 - 17.5	0.3 - 4.4	12 - 77	6 - 20	2 - 49
Moderate	17.6 - 27.9	4.5 - 7.1	78 -119	21-28	50 -79
Major	28.0 - 35.0	7.2 - 9	120 - 150	29 -35	79 - 100

Affected Resource – Soundscape and Acoustic Dimension

Impact level	Percent Time Audible	Noise Free Interval	Lmax	8-hour Leq (Average)	1-hr Nitrogen Dioxide (ppb)
Negligible	1 to 20%	NA	1 to 35 dBA	8-hour Leq < 15 dBA	0 - 1
Minor	21 to 50 %	NA	36 to 60 dBA	8-hour Leq ≥ 15 dBA and < 25 dBA	2 - 49
Moderate	51 to 80%	NA	60 to 80 dBA	8-hour Leq ≥ 25 dBA and 8-hour Leq < 35 dBA	50 -79
Major	Over 80%	NA	Over 80 dBA	8-hour Leq ≥ 35 dBA	79 - 100

Appendix B. Indicators, Thresholds, & Predicted SEIS Impact Level

Indicator	Observed Impact pre-2013 or Threshold*	SEIS Impact Level	Observed Impact since 2014
Affected Resource – Wildlife (2018/19 data)			
Bison Response to OSV	Percent Active Response to OSV 10 %	Minor to Moderate	Percent Active Response to OSV 5 %
Swan Response to OSV	Percent Active Response to OSV 20%	Negligible to Minor	Percent Active Response to OSV 19 %
Affected Resource – Air Quality (2019/20 data)			**West / Old Faithful**
1-hr Carbon MoNOx ide (ppm)	0.3 - 17.5 ppm	Minor	1.1 ppm / .17 ppm
8-hr Carbon MoNOx ide (ppm)	0.3 - 4.4 ppm	Minor	.36 ppm / .14 ppm
98th percentile of maximum 24-hr PM2.5 (ig/m3)	6 – 20 µg/m^3	Minor	0.8 µg/m^3 / 1.6 µg/m^3
1-hr Nitrogen Dioxide (ppb)**	50 -79 ppb	Moderate	37.5 ppb /10.8 ppb
Affected Resource -Soundscape and Acoustic Dimension (2018/19 data)			
Percent Time Audible	63 %	Moderate	46%
Lmax	> 75 dBA	Moderate	70 dBA
Noise Free Interval	2 min 36 sec +/ 15 secs (7-year avg)		3 min 24 sec (2019)
Lmax	> 75 dBA	Moderate	70 dBA

% active responses = sum of travel, alarm/attention, and flight/defense categories

*Air Quality is only affected resource with established thresholds

**Values are for West Entrance

Values from the most recent annual reports.

References

Borkowski, J.J., P.J. White, R.A. Garrott, T. Davis, A.R. Hardy, and D.J. Reinhart. 2006. Behavioral responses of bison and elk in Yellowstone to snowmobiles and snowcoaches. Ecological Applications 16:1911–1925.

Burson, S. 2012. Winter acoustic monitoring in Yellowstone National Park December 2011-March 2012. Yellowstone National Park Soundscape Program Report, Moose, Wyoming, USA.

Interagency Visitor Use Management Council (IVUMC). 2017. Visitor use management on federally managed lands and waters: a position paper to guide policy.

McClure, C., D. Reinhart, P.J. White, M. Donovan, and B. Teets. 2009. Wildlife responses to motorized winter recreation in Yellowstone. Draft report. NPS and Yellowstone Center for Resources, Mammoth, Wyoming, USA.

National Park Service (NPS) 2011. Scientific assessment of Yellowstone National Park winter use March 2011. https://www.nps.gov/yell/learn/management/upload/yell_sci_assessment_deis_release_2011.pdf

National Park Service (NPS) 2013a. Yellowstone National Park final winter use rule. U.S. Department of the Interior, National Park Service, Yellowstone National Park, Mammoth, Wyoming, USA. https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=55985

National Park Service (NPS) 2013b. Yellowstone National Park winter use plan/supplemental environmental impact statement. U.S. Department of the Interior, National Park Service, Yellowstone National Park , Mammoth, Wyoming, USA. https://parkplanning.nps.gov/documentsList.cfm?parkID=111&projectID=40806

National Park Service (NPS) 2016. Winter use adaptive management plan. Yellowstone National Park, Mammoth, Wyoming, USA.

National Park Service. 2019. Winter acoustic monitoring in Yellowstone National Park. Draft report. Yellowstone National Park, Mammoth, Wyoming, USA.

National Park Service (NPS) 2020. Winter use adaptive management adjustments; change to East Entrance dates/South Entrance times. Yellowstone National Park, Mammoth, Wyoming, USA.

National Park Service (NPS) 2021. Multi-year winter air quality in Yellowstone National Park through 2020. NPS Air Resources Division, Lakewood, Colorado, USA.

National Park Service (NPS) 2011. Scientific assessment of Yellowstone National Park winter use March 2011. https://www.nps.gov/yell/learn/management/upload/yell_sci_assessment_deis_release_2011.pdf

National Park Service (NPS) 2013a. Yellowstone National Park final winter use rule. U.S. Department of the Interior, National Park Service, Yellowstone National Park, Mammoth, Wyoming, USA. https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=55985

National Park Service (NPS) 2013b. Yellowstone National Park winter use plan/supplemental environmental impact statement. U.S. Department of the Interior, National Park Service, Yellowstone National Park , Mammoth, Wyoming, USA. https://parkplanning.nps.gov/documentsList.cfm?parkID=111&projectID=40806

National Park Service (NPS) 2016. Winter use adaptive management plan. Yellowstone National Park, Mammoth, Wyoming, USA.

National Park Service (NPS) 2020. Winter use adaptive management adjustments; change to East Entrance dates/South Entrance times. Yellowstone National Park, Mammoth, Wyoming, USA.

National Park Service (NPS) 2021. Multi-year winter air quality in Yellowstone National Park through 2020. NPS Air Resources Division, Lakewood, Colorado, USA.

White, P.J., J.J. Borkowski, T. Davis, R.A. Garrott, D.P. Reinhart, and D.C. McClure. 2009. Wildlife responses to park visitors in winter. Pages 581-601 in R.A. Garrott, P.J. White, and F.G.R. Watson, editors. Terrestrial ecology: the ecology of large mammals in central Yellowstone—sixteen years of integrated field studies, volume 3. Elsevier, San Diego, California, USA.

Williams, B.K., and E.D. Brown. 2012. Adaptive management: the U.S. Department of the Interior applications guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, D.C, USA.

For more informations, visit: https://go.nps.gov/yellwinteruse

*All photos are NPS unless noted.